Electric cooking in Tanzania: an actor-network map and analysis of a nascent socio-technical innovation system

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Executive summary

UK Aid wishes to promote modern energy cooking services in the Global South and is investing around GBP 40 million (USD 50.5 million) through a multi-partner programme of activities – the Modern Energy Cooking Services (MECS) Programme – led by Loughborough University in the UK to help achieve its ambitions. The MECS Programme encompasses several modern energy carriers that can be used for cooking, such as liquified petroleum gas, ethanol, biogas and electricity. Of these carriers, historically, electricity has enjoyed little attention in attempts to promote modern energy cooking services in the Global South. But, because of a convergence of several technological advances, cooking with electricity is becoming economically and technically feasible for a much wider group of people in the Global South than has been the case.

Electric cooking (e-cooking) has the potential to realise a number of benefits, including but not limited to cleaner household air, lower cooking costs, shorter cooking times, less deforestation, reduced greenhouse gas emissions, and some improved gender-equity outcomes. Furthermore, there is the potential to nurture local production of e-cooking appliances and related technologies that could contribute to the industrialisation ambitions of Global South countries. In short, e-cooking has the potential to contribute to progress in achieving several of the UN's Sustainable Development Goals (SDGs). None of these benefits is guaranteed. But the chances of success will be raised by fostering what we call *socio-technical innovation systems* that are centred on relevant e-cooking technologies. Fostering these e-cooking socio-technical innovation systems can in part be achieved by bringing together the innovation systems around electricity access and around clean(er) cooking that, to date, have largely been unconnected. But work will also need to be done to nurture the nexus of these two systems, especially in terms of the social practices specific to e-cooking that may be novel in many contexts.

In this paper, we report findings from our project in which we provide a first attempt to map several characteristics of Tanzania's e-cooking socio-technical innovation system. The 'map' consists of visualisations of the actor-networks and actor-relations in the system along with elaborations on who the actors are, the extent and nature of their interactions, sketches of significant projects, and discussion of emerging issues relevant to the further development of the innovation system. It also includes some summary attention to the system's context and enabling environment. Based on this characterisation, we conduct a socio-technical innovation system analysis to determine the system's strengths and weaknesses, and we derive several recommendations we argue the MECS Programme could implement to further its aims more effectively.

Our socio-technical innovation system concept has been developed using insights from several academic literatures that share a common interest in understanding how technology and innovation interact interdependently with society to produce the social and technical systems upon which we rely for meeting human development needs. The concept refers to the complex configuration of several elements including a variety of actors, their capabilities and relationships, core technologies, policy context, and social practices (especially those involving the core technologies). Within this complex of interacting and interdependent elements, we see the diffusion of technologies and other innovations. And, depending on

the nature of the interactions among the elements, we can also see further technological development and new innovations emerge.

A strong and well-functioning socio-technical innovation system can help a country enjoy more of the economic added value of technologies and innovations, as well as use its mastery of a technology to gain more control over its own development direction. Insights from the broad field of innovation studies show that new technologies, innovations, markets, and their associated systems need to be protected while they are developed and nurtured; they are likely to fail if exposed too quickly to 'market forces' and will face resistance or hostility from those interests that stand to lose if they succeed. A significant set of ideas in the innovation studies field has given rise to the strategic niche management approach or 'niche theory'. Developed in tandem with numerous historical studies of how new technologies have become widely adopted and adapted, niche theory points to the imperative of protection (as we noted above) and the development and growth of diverse networks of actors around a specific technology, among other evolutionary dynamics. Translated into policy-relevant terms, niche theory tells us that active public interventions are crucial for the eventual success of innovations, especially where they must disrupt a dominant technology. A specific example closely relevant to the promotion of modern energy cooking services is the development of the solar PV markets in East Africa. These markets have become successful through deliberate and active long-term public interventions. The combination of these insights forms our socio-technical innovation system concept.

Applying this concept to e-cooking in Tanzania, we find there is a large number of relevant and interested players who could form the actor-network in Tanzania's e-cooking socio-technical innovation system, but there is only a small core who are active at present. TaTEDO, a long-standing player in the Tanzanian cooking domain, is clearly the central actor in this small core. Together with a few other players, including the MECS Programme, TaTEDO have been involved in several e-cooking projects, experimenting mainly with electric pressure cookers (EPCs) in mini-grid installations. Evidence emerging from these experiments is encouraging that EPCs are attractive to ordinary Tanzanians for various reasons, including some that could contribute to positive 'developmental' outcomes such as savings in energy costs and cooking times, improved cooking safety and reduced health problems. But other characteristics of EPC-based cooking are also attractive to cooks, especially their cleanliness compared with biomass-based cooking: i.e. cooking with an EPC results in much less sweat and grime. At a deeper level, the experiments conducted so far suggest, albeit with only weak evidence for now, that EPCs can resonate with meanings and values such as welfare, prestige, modernity and empowerment, amongst others. These technical and social findings are helpful for constructing narratives designed to communicate the benefits of e-cooking to ordinary Tanzanian women and men. And, together with the small core of active players, there is a useful basis upon which to start building in earnest an e-cooking socio-technical innovation system. However, the policy environment is clearly weak in its support for clean cooking and so effort is needed to work with policymakers, among others, to raise the status of clean and e-cooking on policy agendas and to develop policy instruments that will help nurture the long-term building of the innovation system.

To this end, we offer here some recommendations for the MECS Programme to consider in its efforts to contribute to the building of a Tanzanian e-cooking socio-technical innovation system. Readers should take

note, however, that we will be conducting further research to understand how the current nascent innovation system has evolved in Tanzania and, based on this further work, we will likely be able to say more about how MECS can support the development of the system. In this sense, the recommendations given below are somewhat tentative. It may also be the case that the MECS Programme is already implementing or planning to implement the recommendations given here. We offer our recommendations even if this is the case.

1. **Increase the number and variety of multi-stakeholder projects conducted in diverse settings across Tanzania**

   Much more learning about the full range of socio-technical innovation system dimensions is needed. These dimensions include, but are not limited to, technology development. They also include the 'breadth' of the actor-network, and the nature and strength of relations between the network's actors. Alongside these, the system includes social practices, the policy environment, supply chains, business models, actors' capabilities, and more. To achieve learning across these dimensions, MECS should seek to implement an increase in the number and variety of e-cooking projects across a diversity of settings in Tanzania. Moreover, these projects need to involve multiple stakeholders. This will increase the chances of learning and facilitate the circulation of that learning through the resulting expansion of the innovation system's actor-network. Multiple stakeholders working together in a range of projects will also likely build trust and deepen actor-relations.

2. **Conduct more research that specifically investigates cooking and related social practices**

   The research conducted so far in Tanzania has revealed some promising aspects of experimenting with e-cooking that connect with potentially important social meanings and values. But more evidence – gathered across diverse settings – is needed before developing strong and clear e-cooking narratives that will resonate with ordinary Tanzanians. Meanings and values evoked through the e-cooking experiments to date include welfare, safety, prestige, modernity, empowerment and cleanliness. But the evidence for this is weak at present. Research targeted specifically at cooking and related practices will help reveal the extent to which e-cooking is disruptive of biomass-based cooking practices and the ways in which e-cooking can evolve with new practices through which ordinary Tanzanians can express meanings and values that are powerful for them. The results will not only be useful for persuading Tanzanians of the benefits of e-cooking but could also be useful for evolving technology designs to align more closely with the preferences of Tanzanians.

3. **Help policymakers to widen their conception of the clean cooking challenge beyond promoting improved cookstoves and alternative fuels**

   The policy environment for clean cooking is currently weak in Tanzania, and policymakers do not seem to take the issue seriously, despite policy statements committing to SE4All and the SDG on energy access. The MECS Programme can work with others such as TaTEDO, who already have good connections with policymakers and policy-influencing actors, to help policymakers widen their conception of the clean cooking challenge and its opportunities. This includes not only persuading policymakers to think of the issue beyond technology and alternative fuels but also to understand the

systemic nature of meeting the clean and e-cooking challenge. By systemic nature of the challenge, we mean the interlinkages between cooking practices and various pressures policymakers need to relieve such as climate change, deforestation, and air pollution, among others. These interlinkages are only weakly articulated in the Government's policies and actions. Tanzania's electrification strategy is one positive example of where these issues are connected. But more opportunities exist in e-cooking's potential that could be used to further Tanzania's development goals. Among these opportunities is the possibility to develop local manufacture of e-cooking appliances and so further Tanzania's industrialisation ambitions. We will return to this below. However, policymakers will need to be persuaded to take clean cooking more seriously and they will need to understand the interconnections e-cooking can help articulate. To do this, it would be useful for MECS to work with local partners to construct policy-focussed narratives that join the various issues and opportunities together coherently. Evidence from the increased number of projects, recommended above, would go some way to providing the pieces from which to construct such narratives.

4. **Understand the broader forces at work that may hinder, either passively or actively, the building of a strong e-cooking socio-technical innovation system**

   It is important to understand the other factors that may impede progress with e-cooking, beyond policymakers' narrow conception of the challenges and beyond the specific challenges of making e-cooking appliances work in Tanzanian contexts. The biomass sector generates significant revenues for its supply-side actors, and biomass cooking practices are deeply embedded in Tanzanian life. These are two signals that suggest there is a powerful and rigid 'dirty' cooking socio-technical regime in place in Tanzania (to use the conceptual language of socio-technical transitions). The nascent e-cooking niche must compete with this regime yet does not have the same powerful resources at its disposal as the regime. Research to understand the dirty cooking regime would be useful for characterising the nature of the challenge facing the e-cooking niche and may even identify ways in which to 'destabilise' it in favour of the niche practice. Alternatively, or in addition to understanding the regime, political economy analysis of dirty cooking could be helpful.

5. **Investigate the potential for local production of e-cooking appliances**

   At present in Tanzania, there is production of biomass cookstoves. But this is taking place mainly in the informal sector and is said to be of poor quality. E-cooking appliances must be imported. As part of building the e-cooking socio-technical innovation system, MECS could support the investigation of local production of e-cooking appliances. Establishing full-scale manufacture is likely to be a long-term effort but there may be short-term potential to begin assembly of products. As shown elsewhere – e.g. with the electronics industry in East Asia and with solar PV in Kenya, amongst many others – the establishment of new industrial sectors can begin with local assembly and over time move up the value chain to original equipment manufacture. Tanzania has ambitions to industrialise and the e-cooking industry could be a candidate to help realise this ambition. Generating the evidence for how this could happen would be helpful in persuading policymakers to take clean cooking more seriously. Investigation could begin with feasibility studies including, perhaps, the involvement of those who

currently produce cookstoves as well as EPC manufacturers such as BURN in Kenya. This should lead to an understanding of what needs to be in place for appliance manufacturers to invest in Tanzanian production. But the process to develop local manufacturing will be a long-term endeavour so it will need risk-tolerant funding, which likely means funding from public sources such as donors, and strategic implementation.

6. **Make the argument for more active public intervention to help build the e-cooking socio-technical innovation system**

   The MECS Programme can make the argument for more active public interventions to build the socio-technical innovation system. The money to fund interventions can come from the Tanzanian government but, as we noted above, the bulk of it will likely be needed from donors and other development partners. This is because it will be a long-term effort with perhaps only small short-term wins and so will need risk-tolerant funders prepared to stay for the long-term. Without active publicly supported interventions, of the kind discussed in the recommendations above, the socio-technical innovation system will emerge extremely slowly and is unlikely to evolve beyond importing products and business models designed and developed elsewhere. As a result, Tanzanians may get access to e-cooking appliances but there will be few, if any, economic gains and perhaps even economic losses, where profits are extracted by companies based outside the country.

7. **Establish a local dedicated actor to strategically coordinate socio-technical innovation system building**

   The recommendations given above imply a range of complicated and long-term efforts are needed to build the e-cooking socio-technical innovation system in Tanzania. The MECS Programme can spearhead some of these for the time-being, working with key local actors. However, it is unlikely that MECS can perform this role for long, especially if the number of projects proliferates – as it needs to do – and the number of actors in the innovation system's network expands substantially. It would therefore be wise to begin establishing a well-resourced local actor who can focus efforts on analysing the state of the innovation system, and on designing and implementing the kinds of projects mentioned above. Such an actor can also convene forums for e-cooking stakeholders, manage actor-relations, advocate for policy interventions, and more. In effect, the actor will be a socio-technical innovation system builder for e-cooking in Tanzania, much the same as system builders played important roles in the solar PV innovation systems in both Tanzania and Kenya.

Contents

Abbreviations and acronyms

A2EI	Access to Energy Institute
AC	Alternating Current
ACTS	African Centre for Technology Studies
AMDA	African Mini-Grid Developers Association
BEST	Biomass Energy Strategy
CAMARTEC	Centre for Agricultural Mechanization and Rural Technology
CCA	Clean Cooking Alliance
CCFAT	Clean Cooking and Fuels Alliance for Tanzania
CLASP	Collaborative Labelling and Appliance Standards Program
COET	College of Engineering and Technology
COSTECH	Tanzania Commission for Science and Technology
DC	Direct Current
DFID	UK Department for International Development
DGIS	Netherlands Directorate for Development Cooperation
EDPG	Energy Development Partners Group
EPC	Electric Pressure Cooker
EPSRC	Engineering and Physical Sciences Research Council
EWURA	Energy and Water Utilities Regulatory Authority
FCC	Fair Competition Commission
FMO	Financierings-Maatschappij voor Ontwikkelingslanden (Dutch development bank)
GCRF	Global Challenges Research Fund
GIZ	Gesellschaft für Internationale Zusammenarbeit
ICS	Improved Cookstove
IIED	International Institute for Environment and Development
IRENA	International Renewable Energy Agency
ISH	Innovation System History
ISM	Innovation System Map

LEAP	Global Lighting and Energy Access Partnership
LPG	Liquified Petroleum Gas
MECS	Modern Energy Cooking Services Programme
MEM	Ministry of Energy and Minerals
MFI	Microfinance Institution
MOE	Ministry of Energy
NGO	Non-Governmental Organisation
OECD	Organization for Economic Co-operation and Development
PAYGO	Pay-as-you-go
Pinnsmap	Participatroy innovation system map
PIPA	Participatory Impact Pathways Analysis
PV	Photovoltaic
RBF	Results-Based Finance
REA	Rural Energy Agency
SDG	Sustainable Development Goal
SE4All	Sustainable Energy for All
SESCOM	Sustainable Energy Services Company Limited
Sida	Swedish International Development Cooperation
SIDO	Small Industries Development Organization
SNV	Netherlands Development Organisation
STIPRO	Science, Technology and Innovation Policy Research Organisation
TAMISEMI	President's Office: Regional Administration and Local Government
TANESCO	Tanzania Electricity Supply Company
TANGSEN	Tanzania Gender and Sustainable Energy Network
TAREA	Tanzania Renewable Energy Association
TaTEDO	Tanzania Traditional Energy Development Organisation
TBS	Tanzania Bureau of Standards
TDBP	Tanzania Domestic Biogas Programme
TDC	Technology Development Group
TICS	Tanzania Improved Cookstoves Programme

TIRDO	Tanzania Industrial Research and Development Organisation
TPDC	Tanzanian Petroleum Development Corporation
TVET	Technical and Vocational Education and Training
UNDP	UN Development Programme
UNEP	UN Environment Programme
UNIDO	UN Industrial Development Organization
VAT	Value-Added Tax
VETA	Vocational Education and Training Authority
VPO	Vice President's Office

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1 Introduction

UK Aid wishes to promote modern energy cooking services in the Global South, and is investing around GBP 40 million (USD 50.5 million) through a multi-partner programme of activities – the Modern Energy Cooking Services (MECS) Programme[1] – led by Loughborough University in the UK to help achieve its ambitions. The MECS Programme, as a whole, encompasses several modern energy carriers that can be used for cooking, such as liquified petroleum gas (LPG), ethanol, biogas and electricity. Of these carriers, historically, electricity has enjoyed little attention in attempts to promote modern energy cooking services in the Global South and so the MECS Programme is something of a pioneer in this respect. Because of a convergence of several technological advances in, amongst others, energy storage, ICT-enabled payment systems, and cost and efficiency improvements in generating technologies such as solar photovoltaics (solar PV), cooking with electricity is becoming economically and technically feasible for a much wider group of people in the Global South than has been the case (Batchelor, Brown, et al., 2018).

Electric cooking (e-cooking) has the potential to realise a number of benefits, including but not limited to cleaner household air, lower cooking costs, shorter cooking times, less deforestation, reduced greenhouse gas emissions (if the electricity is generated from renewable energies) and some improved gender-equity outcomes. Furthermore, there is the potential to nurture local production of e-cooking appliances and related technologies that could contribute to the industrialisation ambitions of Global South countries. In short, e-cooking has the potential to contribute to progress in achieving several of the UN's Sustainable Development Goals (SDGs). None of these benefits is guaranteed. But the chances of success will be raised, we would argue, by fostering what we call socio-technical innovation systems (defined below) that are centred on relevant e-cooking technologies. Fostering these e-cooking socio-technical innovation systems can in part be achieved by bringing together the socio-technical innovation systems that currently exist around electricity access (e.g. in solar PV in Tanzania) and around clean(er) cooking that, to date, have largely been unconnected. But work will also need to be done to nurture the nexus of these two systems, especially in terms of the social practices specific to e-cooking that may be, to varying degrees, novel in many contexts at present.

In this paper, we report findings from the first stage of our project, funded by the MECS Programme, in which we characterise the socio-technical innovation system around e-cooking in Tanzania. A sibling paper reports our findings for the e-cooking socio-technical innovation system in Kenya. We mention both papers at this point because they share some common text. Consequently, those who have read the sibling paper may prefer to skip Section 2 in its entirety, as the presentation of the analytical foundations and methodology is practically identical to the text in the other paper, apart from a few details. Otherwise, the text here is mostly specific to e-cooking in Tanzania. In the rest of this introduction, we explain the nature and purpose of our e-cooking socio-technical innovation system characterisation (or 'map'), define briefly what we mean by the term *socio-technical innovation system*, argue why it is important to develop a socio-

[1] See the MECS website for more information https://mecs.org.uk/about/ (accessed 12 July 2020)

technical innovation system understanding of e-cooking in Tanzania, and preview our main findings. We finish the introduction with an outline description of the paper.

This paper provides a first attempt to map several characteristics of Tanzania's e-cooking socio-technical innovation system. The 'map' consists of visualisations of the actor-networks and actor-relations in the system along with elaborations on who the actors are, the extent and nature of their interactions, sketches of significant projects, and discussion of emerging issues relevant to the further development of the innovation system. It also includes some summary attention to the context and enabling environment of the e-cooking socio-technical innovation system. Based on this characterisation, we conduct a socio-technical innovation system analysis to determine the system's strengths and weaknesses and, building on this analysis, derive several recommendations we argue the MECS Programme could implement to further its aims more effectively. Readers should take note, however, that the characterisation is only a snapshot of the current system and so the recommendations should be seen as open to further refinement as we continue our research. More specifically, the next stage of our research involves constructing a historical account of how the current system has evolved, something we will also be doing in respect of the Kenyan e-cooking socio-technical innovation system. Once we have these historical accounts, we will be able to conduct a comparative analysis that will likely yield new insights with which to develop more robust recommendations for the MECS Programme and others wishing to promote clean cooking services in the Global South.

Before arguing why it is important to understand a socio-technical innovation system, we should define what we mean by this term. More detailed discussion of the concept is given in Section 2.1, but we can provide a brief definition here. It has been developed using insights from several academic literatures that share a common interest in understanding how technology and innovation interact interdependently with society to produce the social and technical systems upon which we rely for meeting human development needs. The concept refers to the complex configuration of several elements including a variety of actors, their capabilities and relationships, core technologies, policy context, and social practices (especially those involving the core technologies). Within this complex of interacting and interdependent elements, we see the diffusion of technologies and other innovations. And, depending on the nature of the interactions among the elements, we can also see further technological development and new innovations emerge. Beyond this, it is possible and often desirable to attend to the broader context of competing or dominant technologies and practices, environmental pressures and the politics of change (from the micro-politics of changing practices to the 'higher' politics around national and international interests). The next phase of our research will include attention to these broader dynamics, as understanding them is best done through historical analysis. The current paper focusses only on a snapshot characterisation of the e-cooking socio-technical innovation system in Tanzania and so is concerned with the actors, their capabilities and relations, the core technologies, policies and social practices.

It is important to understand the complex configuration we are calling a socio-technical innovation system because such a system is essential for helping a country direct and achieve its self-defined development goals. These goals include economic growth and development as well as more socially oriented goals such as equality and justice along with environmental integrity. In short, a well-functioning socio-technical

innovation system can contribute positively to achieving a wide range of SDGs. A narrower analytical focus, such as on economics and engineering – which is often the case in the literature on energy access (e.g. see Watson et al., 2012) – can only take us so far. Analysing the economics of a specific technology, for example, is of limited value in showing us how to foster the conditions for the widespread adoption of that technology, and is unable to provide recommendations for how to develop the capabilities needed to further develop the technology or, indeed, how to innovate completely new solutions. An economics focus is also unable to consider the complex interactions across the many dimensions of social and technical systems that enable those systems to endure, despite the availability of what might be 'superior' technologies or innovations (e.g. sustainable energy technologies, gender-equal practices, healthy work environments).

We need more complex analyses from which we are then able to nurture the socio-technical innovation systems required for successful adoption and diffusion of new or unfamiliar technologies and innovations, which are often in need themselves of adapting to new environments, and for building the actor-networks and capabilities needed to move beyond simply using existing technologies. A strong and well-functioning innovation system can help a country to enjoy more of the economic added value of technologies and innovations, as well as use its mastery of a technology to gain more control over its own development direction. Left to free markets, technology design and production, for example, will take place wherever there are already well-functioning appropriate socio-technical innovation systems, which are generally in the most industrially advanced countries, even if the technology is adopted widely in poorer countries. Contrary to free market orthodoxy, new technologies, innovations, markets, and their associated systems need to be protected while they are developed and nurtured; they are likely to fail if exposed too quickly to 'market forces' and will face resistance or hostility from those interests that stand to lose if they succeed.

These general insights have arisen over many decades from the broad field of innovation studies, a field initially developed to understand why more traditional economics approaches could not explain a nation's economic growth. Early work in the innovation studies field generated the basic notion of a national system of innovation (e.g. see Freeman, 1987, 1997; Lundvall, 1988). But other work over the past two decades has widened the scope of analysis to include sociological insights (e.g. Geels, 2002) and ideas centred on knowledge politics (e.g. Leach et al., 2010), among many other influences. A significant set of ideas, inspired by evolutionary theory and the kinds of sources just mentioned, has given rise to strategic niche management or 'niche theory'. Developed in tandem with numerous historical studies of how new technologies have become widely adopted and adapted, niche theory points to the imperative of protection (as we noted above) and the development and growth of diverse networks of actors around a specific technology, among other evolutionary dynamics. Translated into policy-relevant terms, niche theory tells us that active public interventions are crucial for the eventual success of new technologies, especially where they must disrupt a dominant technology. A specific example closely relevant to the promotion of modern energy cooking services is the development and growth of the solar PV markets in East Africa (Byrne, 2011; Ockwell et al., 2019; Ockwell & Byrne, 2017). These markets have become successful not through free market orthodoxy but through deliberate and active long-term public

interventions, an approach that continues. The combination of these insights forms our socio-technical innovation system concept, the specifics of which are further explained in Section 2.1.

Applying this concept to e-cooking in Tanzania, we find there are some positive signs the socio-technical innovation system is emerging, with a large number of actors who might be recruited to its actor-network. However, only a small core of these players is active in the e-cooking space at present, with the Tanzanian organisation TaTEDO (Tanzania Traditional Energy Development Organisation) central to this core. We find that there are no capabilities in Tanzania to manufacture high quality e-cooking appliances, such as electric pressure cookers (EPCs), and it is unclear whether capabilities exist in other aspects of the system: e.g. in repair, waste management and recycling. The policy context is weak in its support for e-cooking (or clean cooking more generally). E-cooking appliances are receiving the bulk of attention from those active in the space; few are actively involved in nurturing the broader socio-technical innovation system. Among a number of recommendations, we argue there is a need for a well-resourced coordinating actor to help foster the building of the wider socio-technical innovation system, a role we doubt could be played by MECS in the long-term, even though it can spearhead activities at present while working with key local actors. As such, we recommend that the MECS Programme identify such a coordinating actor or begin developing one so that the complex and intensive work of implementing the expanded and systematic range of projects needed can continue for many years.

The paper continues with Section 2, which briefly explains the socio-technical innovation system concept and analytical framework we use as well as describing the study's methodology. Section 3 provides a summary of the policy context. In Section 4, we report the findings from our primary research, characterising the various elements of the e-cooking socio-technical innovation system in Tanzania as it currently stands. We analyse the system in Section 5 and finish the paper by giving our recommendations for the MECS Programme in Section 6.

2 Analytical foundations and methodology

2.1 Socio-technical innovation system analysis

The objective of the discussion in this section is less about exploring and critiquing the conceptual basis for the analytical framework we use in this paper and more about describing the elements of the framework. This is because the paper is primarily concerned with assessing the state of play in the current e-cooking socio-technical innovation system in Tanzania with a view to offering thoughts on how it can be nurtured, strengthened and evolved so as to better achieve transformations in clean cooking that work in the interests of poor and marginalised groups in the country. As such, the paper is intended to be most useful to practitioners working on e-cooking in general and the broader MECS Programme in particular. Our analytical framework is therefore constructed instrumentally from the theoretical work done elsewhere, although we provide here a brief review of the conceptual underpinnings of the theory as this may be useful to readers in their understandings of what we present in this paper. The conceptual underpinnings for the socio-technical innovation system approach originate from various streams of theory including, most notably, the STEPS pathways approach (e.g. Leach et al., 2010), transitions theory (e.g. Geels, 2002, 2004), strategic niche management (Byrne, 2011; Raven, 2005) and innovation systems (e.g. Chaminade et al., 2009; Freeman, 1997; Lundvall, 1992). And a fuller exposition of the socio-technical innovation systems approach can be found in Ockwell and Byrne (2016, 2017).

We define a socio-technical innovation system in terms that go beyond the more traditional understanding of "innovation system", an understanding that refers to the "network of actors, and the strength and nature of the relationships between them, from which both innovation and technological change emerge" (Ockwell & Byrne, 2017, p. 25). Our extended concept draws from the socio-technical literatures mentioned above (pathways, transitions and niche theory) to incorporate the socio-technical nature of innovation and technological change. That is, our concept includes attention to the co-productive interactions between innovations and the social practices of actors (policymakers, firms, non-governmental organisations, ordinary citizens, and so on), as well as the politics of socio-technical change.

The traditional concept of an innovation system, defined in the preceding paragraph, remains important in our enhanced socio-technical innovation system concept, although our enhanced concept expands the range of actors involved. In the traditional version, the actors of interest are firms and policymakers. Firms each have specific capabilities (skills and knowledge) they use to innovate, which can include creating and developing technologies and production processes, evolving the management of stakeholder relations, and implementing new marketing strategies (OECD/Eurostat, 2019). Policymakers set the policy environment in which firms operate, conditioning what kinds of innovation are possible, what is illegal, and so on, and setting and enforcing the regulatory regime for, amongst other issues, private property protection. Relationships between these various actors are also important because, for example, individual firms are unlikely to be able to perform all the activities necessary to produce a specific technological product or service. They will buy components from other firms, assemble these components, manufacture others, and sell to customers who may be other firms or so-called final users. In some cases, firms will collaborate with other firms to produce technologies or services. The network of actors is therefore a key characteristic of

any specific innovation system, including how actors are connected to each other and the nature of their interactions.

Although this traditional innovation system concept is useful for certain kinds of analysis, it is entirely technical in its focus and so is blind to the social, cultural, political and ecological dynamics that co-evolve with technical change (Ockwell & Byrne, 2017). Understanding how these other co-evolutionary dynamics work interdependently with technical change to produce the systems that service human needs is important because they influence the direction any system takes as it develops. For example, in response to climate change, we need systems to develop in directions that rely on renewable energy sources. But steering systems away from fossil fuel-based reliance is difficult because of the interdependent relationships between, amongst others, powerful political and economic interests, social practices such as car-based mobility linked with cultural values such as freedom and independence, and established infrastructures of energy generation, storage and distribution. Socio-technical perspectives incorporate these different dimensions into analysis, seeking to generate insights useful for guiding our social systems (socio-technical systems) in more sustainable directions. We adopt these socio-technical ambitions in our enhanced concept: hence the use of the term *socio-technical innovation systems*.

Table 1: Socio-technical innovation system analytical categories

Category	Description
Central technologies	The main technologies towards which actors in the system will focus their innovation efforts
Actors	Who is involved in the innovation efforts in the system: potentially, the full range of actors, not just firms and policymakers but also NGOs, communities, households, private individuals
Actor-network	The ways in which the actors interrelate: what connections they have with each other, the nature of those connections
Policy environment	The range of policies (and regulations, laws, etc.) that can influence the system, including beyond the national level
System directionality	The trajectory of system change: e.g. growing or shrinking use of electric pressure cookers; mainstreaming or marginalising electric cooking
Social practices	The social practices of relevance, especially how these are understood by 'supply-side' actors
Broader dynamics	Various forces that can influence what is possible, desirable, and so on in system development: e.g. climate change translates to pressure to reduce emissions
Narratives	The narratives at work in the system, used to mobilise, motivate, persuade, argue, contest, etc., on issues relevant to system change

In sum, we use several categories to analyse what is happening in any socio-technical innovation system. We need to know which technologies are centrally involved in the system, which actors are involved, how these actors relate to each other (actor-networks), details of the policy environment, what 'supply-side' actors understand about 'demand-side' social practices, what direction the system is taking, and what broader dynamics are at work. We also need to understand something about what actors envisage the system will be and why, which links strongly with the direction the system is taking or could take. This brings us to the role of discourse and, more specifically, narratives in shaping a system's directionality. Narratives are important in several respects. They can justify and motivate specific kinds of action, they can mobilise others to join in with these specific actions, they can persuade others to act in particular ways – e.g. policymakers to provide resources for action, customers to buy particular products or services rather than others – and can shape identities around which groups of actors can coalesce (e.g. Byrne et al., 2018; Hudson & Leftwich, 2014; Leach et al., 2010). In short, narratives do essential political work. For analysis, we can also use narratives to infer what actors understand about the system in which they are working or the system they are trying to create. Table 1 summarises these analytical categories. Characterising the specifics of each of these categories to the extent possible provides the basis for an integrated analysis of a socio-technical innovation system, its strengths and weaknesses, and ways in which it could be improved. In turn, this provides the basis for recommendations, whether for policy or practice.

2.2 Methodology

Initial information gathering took place during an Innovation System History workshop held in Dar es Salaam on 5 February 2020. We conducted two kinds of participatory exercises during this one-day workshop from which we produced two outputs: an Innovation System Map (ISM) of e-cooking in Tanzania, and a skeleton Innovation System History (ISH). The ISH was focussed on recording various events, processes and projects that have contributed to the development of the current e-cooking socio-technical innovation system and this will be used as the basis for the second phase of our research. As such, the ISH produced in the workshop is not relevant to the focus of this current paper and so will not be discussed further here. It is the ISM or, more precisely, the Participatory Innovation System Map (Pinnsmap, and see below for explanation of this output) that is relevant to the current paper and this formed the basis for follow-up interviews and desk-based secondary research upon which the reporting and analysis in this paper is built. Our Pinnsmapping method is an adaptation of the STEPS Centre tool *Participatory Impact Pathways Analysis* (PIPA) (Ely & Oxley, 2014), itself an adaptation of a process developed by Boru Douthwaite and colleagues (e.g. see Douthwaite et al., 2009).

Planning for the ISH workshop included identifying and selecting participants from a range of stakeholder groups who would have some interest in, and knowledge about, e-cooking in Tanzania. The process of identifying participants involved reference to the database of contacts held by ACTS[2], Science, Technology

[2] ACTS were a research partner in project work foundational to the MECS Programme – Low cost energy-efficient products for the bottom of the pyramid, see http://www.sussex.ac.uk/spru/research/projects/lct (accessed 22 June 2020) – and so already had relevant contacts with knowledge about clean cooking in Tanzania.

and Innovation Policy Research Organisation (STIPRO, the workshop organisers), and consultations with Jon Leary[3], Anna Clements[4] and Tanzania Traditional Energy Development Organisation[5] (TaTEDO) as well as some snowballing through those identified from these sources. Selection was based on maximising the depth and range of knowledge and perspectives available to us in the workshop. Including members of the project team and organisers, 28 people took part in the workshop.

In outline terms, the Pinnsmapping exercise aimed to enable the participants to co-produce a 'map' of the actors involved or interested in e-cooking in Tanzania, to represent how these actors are connected to each other, and to characterise their relationships (e.g. funding, collaboration, and so on). The exercise was conducted over about two hours, with the Pinnsmap produced in a structured process involving all the workshop participants.

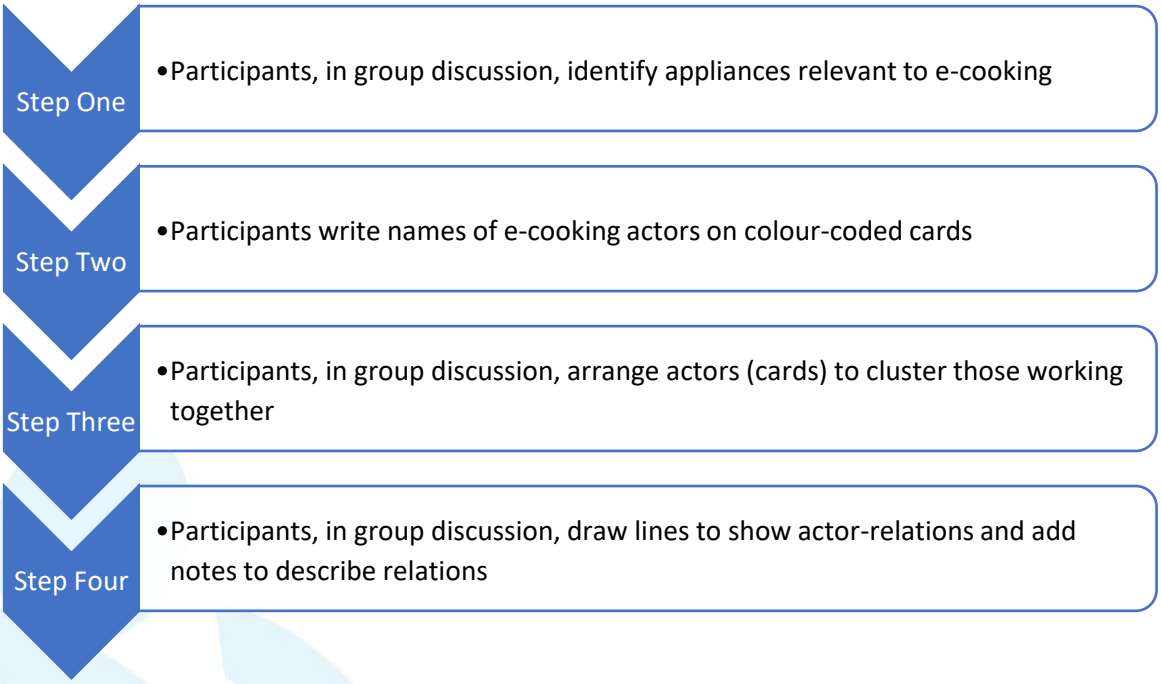

Figure 1: Pinnsmapping steps

[3] Jon Leary, a researcher in the broader MECS Programme, has spent extended periods of time working in e-cooking in Kenya and Tanzania.

[4] Anna Clements is a consultant and Tanzania Anchor Researcher for the broader MECS Programme.

[5] TaTEDO is a Tanzanian organisation with a long history of involvement with cooking. See https://tatedo.or.tz/who-we-are/about-tatedo# for more (accessed 19 July 2020)

Step one in the process involved the participants identifying the appliances they thought relevant to electric cooking (i.e. not just electric pressure cookers but also, for example, electric kettles, rice cookers, and many others). For step two, the participants were asked to write on cards the names of actors in Tanzania they thought were working in some way relevant to e-cooking (bearing in mind the list of appliances). One actor was named per card, with the cards colour-coded according to broad stakeholder groups (i.e. government, academic institutions, private sector, financing organisations, civil society, non-governmental organisations and multi-stakeholder projects). Step three involved arranging the actors (cards) so that those working closely together were clustered on the map (to the extent possible), achieved through a process of group discussion during which more actor names were added and the nature of various actor-relations began to emerge. Step four involved drawing lines on the map to show the connections between actors and marking these lines with small Post-it notes to indicate the nature of the connections and relationships. Figure 1 summarises the four steps in the Pinnsmapping exercise and Figure 2 provides a snapshot of the exercise in process. The 'final' map was then photographed as a record of the output and this was used to produce an electronic version of the map.

Figure 2: Some participants in the Dar es Salaam ISH Workshop constructing the Pinnsmap

Source: Photograph courtesy of Jacob Fodio Todd

In the months following the workshop, semi-structured interviews with 9 individuals from 5 organisations were conducted (see the Annex I for the generic version of the questionnaire and Annex II for a list of those interviewed). Because of the Covid-19 epidemic response, interviews had to be conducted virtually via telephone or video communication platforms such as Zoom and Skype. During the interviews, respondents described their organisation and its projects or initiatives in clean cooking and e-cooking, the partnerships or collaborations it was involved in, the cooking technologies and fuels it focussed on and its evaluation of the e-cooking innovation system as a whole. The interviews included a section devoted to the Pinnsmap, during which respondents were shown the draft ISM and asked to comment on its accuracy. Based on these comments, the draft ISM was adjusted to produce the version shown in Section 4 below. The interviews also included a question on policy and this, together with analysis of secondary sources, formed the basis for the context discussion in Section 3. The interviews were audio recorded and transcribed verbatim to facilitate narrative analysis.

We analysed the information in a series of project-team virtual 'write-shops', in between which we drafted various sections of the text, with designated team members leading specific sections. We used the analytical framework discussed in Section 2.1 above and summarised in Table 1. Triangulation of the evidence involved cross-reference between the workshop material, follow-up interviews and, where available, secondary sources. For the final complete draft of the text, one author copy-edited the entire paper.

3 The context of e-cooking in Tanzania

Before describing the details of Tanzania's e-cooking socio-technical innovation system (in Section 4), as revealed through the ISH workshop, follow-up interviews and further desk-based research, we review the innovation system's context. Following some general comments on Tanzania's e-cooking context, we briefly review the country's state of electricity access and e-cooking. We then offer a brief overview of the policy context at both the international and national levels, and summarise the national policies relevant to e-cooking in Tanzania. Section 4.4.1 provides a more specific discussion on Tanzania's regulatory context. We then describe the key national actors who we suggest are associated with clean and e-cooking, and we finish this section with a discussion of the national development trajectory for e-cooking, highlighting some of the barriers and opportunities the Tanzanian context presents for e-cooking's promotion.

3.1 General comments on the Tanzanian e-cooking context

Tanzania, in the eCook Global Market Assessment report (Leary et al., 2018), is regarded as having enormous potential for e-cooking – despite a low rate of electricity access – due to its already well-developed solar home systems market and mini-grid sector, an abundance of renewable resources and, perhaps counterintuitively, one of the world's largest charcoal markets. Widespread electricity access is key to e-cooking, and Tanzania has a high and largely untapped potential for renewable energy generation. One somewhat successful example is the harnessing of Tanzania's abundant solar resources underpinning its thriving off-grid solar market. Many donor organisations such as DFID, Sida and the World Bank have financed large energy access projects in Tanzania, and it is regarded as a favourable environment for setting up renewable energy projects (Mokveld & von Eije, 2018).

Established mobile money services and pay-as-you-go (PAYGO) financing schemes offer opportunities to develop novel business models around cooking, both on- and off-grid, as electricity access improves. The Tanzanian government is supportive of renewable energy enterprises such as mini-grid development and small power projects, and have offered incentives like VAT and tariff exemptions for small solar products. The government, meanwhile, seeks to address high deforestation rates and have implemented measures such as charcoal bans, albeit to limited success and considerable public opposition. This creates demand for alternative fuels and efficient cooking (Leary et al., 2018), although the alternatives are not currently affordable or accessible compared with charcoal.

In urban and rural areas, charcoal or wood are the dominant fuels; the use of electricity as a primary cooking energy source is rare. Nonetheless, electrical appliances are available in urban areas. Some of the most commonly used include microwave ovens, electric kettles and other fabricated coil water heaters, induction stoves, hot plates, mixed liquified petroleum gas (LPG)-electric stand-alone cookers and thermal pots. Of the newer generation of energy-efficient electrical appliances, rice cookers have become increasingly popular, whereas electric pressure cookers (EPCs) are relatively new entrants to the Tanzanian market and are not widely available. However, recent research has demonstrated that cooking some Tanzanian staple foods such as beans, stews and rice is compatible with energy-efficient appliances such as EPCs, and time, cost and energy savings have been identified (Sawe & Aloyce, 2020). But the social and

cultural implications of transitioning to new appliances and modern cooking energies are less well understood, and so are in need of further research and greater understanding.

3.2 State of electricity access and e-cooking

Only 36% of the Tanzanian population has access to electricity[6], although this is a significant rise from the 15% who had access in 2010. Within this overall access rate, there are significant disparities between urban and rural areas: average urban access is at 68% while rural access is just 19%. The Tanzania Electricity Supply Company (TANESCO) generates, transmits and distributes the bulk of the electricity in Tanzania, which is mainly generated from gas and hydropower sources. Electricity supply is unreliable, with poor transmission infrastructure and hydropower generation susceptible to environmental factors such as drought (IRENA, 2017).

Modern sources of energy for cooking – sources such as liquified petroleum gas (LPG), biogas and electricity – are used by few households in Tanzania. The World Bank reports that, in 2016, as little as 2% of the population had access to clean cooking fuels[7]. The vast majority of the population – approximately 90% – rely on firewood and charcoal as the primary cooking energy source, with charcoal especially dominant as a fuel in urban areas.

3.3 E-cooking policy context: international and national overview

Prominent international organisations spearheading global and national engagement with e-cooking include the Clean Cooking Alliance (CCA) and Sustainable Energy for All (SE4All), both positioning their efforts within the SDG framework. The CCA, for example, seeks to elevate clean cooking to address 10 of the 17 SDGs, among them, climate action (SDG13) and affordable and clean energy (SDG7). The CCA, formerly the Global Alliance for Clean Cookstoves, prioritises focus countries – among them Kenya, Uganda, Ghana, Nigeria, India, Bangladesh and China – who receive extensive in-country engagement. The CCA also works with partner countries who have made a national commitment to support cleaner cookstoves and fuels and ascribe to the principles of the Alliance. Tanzania is one of these partner countries. The CCA also supports national and regional alliances.

SE4All focusses on SDG7, which targets universal access to affordable, reliable and modern energy services by 2030 and doubling the global rate of improvement in energy efficiency. SE4All advances a clean cooking programme that undertakes strategic activities around electric and clean cooking, including research and development, technical and partnership support, and advocacy. Another prominent international actor around e-cooking in Tanzania is the UK government, primarily through the MECS Programme. Among other activities, the MECS Programme intends to develop new technologies that make electric and gas cooking appliances more efficient, practical, desirable and affordable for poorer households. The Programme works

[6] See the database from the SE4All Global Tracking Framework, shown on the World Bank's website at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=TZ (accessed 4 August 2020)

[7] See https://databank.worldbank.org/reports.aspx?source=sustainable-energy-for-all (accessed 4 August 2020)

closely with the private and third sector to develop business models and financing methods that will help get electric and gas cooking appliances into the market.

On a national level, given the dominance of biomass energy as the primary cooking fuel in Tanzania (Rajabu et al., 2014), the policy focus around clean cooking in the country has traditionally been geared towards supporting improved biomass cookstoves, and it cuts across a range of sectors including health, forestry, environment and climate change. In Tanzania, in common with neighbouring countries, e-cooking currently plays a negligible part in each of the discourses on clean cooking and energy access (which is often equated with electricity access). Nonetheless, the current regulatory framework for energy shapes the nascent e-cooking landscape, setting the 'rules of the game'.

Tanzania's contemporary energy sector comprises governmental institutions (e.g. Ministry of Energy), private sector operators (e.g. Power Corner), NGOs (e.g. TaTEDO), civil society actors (e.g. the Africa Mini-Grid Developers Association, AMDA), and parastatals (e.g. TANESCO). The first National Energy Policy was introduced in 1992, but revised in 2003 and again in 2015. The 2003 policy laid the foundation for promoting renewable energy sources and encouraging private sector participation in the energy sector. The 2015 policy focussed on ensuring the provision of reliable and affordable energy by facilitating an efficient and sustainable energy value chain (EEG, 2016).

3.4 Summary of national policies relevant to e-cooking in Tanzania

Despite limited references to the use of electricity as a source of cooking energy in energy policy documents, the latest National Energy Policy (2015) features e-cooking[8]. Framed around health and environmental drivers, it includes an objective to improve the quality of life through the use of modern fuels. This objective is accompanied by two policy statements: (i) enhance fuel switching from woodfuel to modern energy; and (ii) facilitate adoption of appropriate cooking appliances to promote alternatives to woodfuel (URT, 2015a).

Numerous other initiatives since the first National Energy Policy in 1992 have notably altered the energy landscape in Tanzania. These include the establishment of the Energy and Water Utilities Regulatory Authority (EWURA) with the EWURA Act in 2001 (revised in 2006) and the Rural Energy Agency (REA) with the REA Act in 2005. These two institutions are key actors in the e-cooking landscape. EWURA, for instance, regulates tariffs for electricity trade in the country, and promotes the availability of regulated services to all, including low-income, rural and disadvantaged consumers. This includes lifeline tariff allowances, which are targeted subsidised tariffs based on consumption and are a potential enabler for e-cooking in low-income households. In 2018, the regular electricity tariff of 0.13 USD/kWh was reduced to 0.06 USD/kWh for the first 75kWh (Leary et al., 2018).

REA supports multiple mini-grid systems and solar PV programmes. A few mini-grid projects currently host e-cooking pilot projects (Avila et al., 2019), with mini-grid developers eager to drive electricity demand

[8] See section 3.1.6 Alternative Fuel to Biomass, in the Electricity subsector.

through the use of e-cooking appliances[9]. Indeed, the Tanzania mini-grid sector is illustrative of strategic policy reform. The sector, which is leading in the region, was enabled by what Odarno et al. (2017) describe as an adaptive and responsive policy approach that has created better market conditions for renewable energy and encouraged developers to invest in mini-grids.

Table 2: Summary of Tanzanian energy policies, regulations and acts relevant to e-cooking

Year	Policy/Regulation/Act	Details
1992	National Energy Policy	Tanzania instituted its first National Energy Policy to "provide an input in the development process by establishing an efficient energy production, procurement, transportation, distribution, and end-user systems".
2001	Energy and Water Utilities Regulatory Authority (EWURA) Act	Established the Energy and Water Utilities Regulatory Authority (EWURA) to regulate tariffs for electricity trade in the country, and promote the availability of regulated services to all, including low-income, rural and disadvantaged consumers.
2003	National Energy Policy	The 2003 policy laid the foundation for promoting renewable energy sources and encouraging private sector participation in Tanzania. Superseded by the National Energy Policy 2015.
2005	Rural Energy Agency (REA) Act	Established the Rural Energy Agency in order to enhance energy access in rural areas.
2006	EWURA Act	Further mandated the autonomous multi-sectoral regulatory authority in charge of technical and economic regulation of electricity, petroleum, natural gas and water.
2008	Electricity Act	Outlined the rules for the generation, storage and distribution of electricity, including rural electrification.
2014	Electricity Supply Industry Reform Strategy and Roadmap 2014-2025	Describes key reform initiatives and actions for the period 2014-2025, to address current and future demand for electricity, reduce public expenditure, attract private capital and increase electricity connection and access levels.
2015	National Energy Policy	Aimed to attract more private investment and local participation in the Energy Sector, improve efficiency and energy conservation as well as access to modern energy services and increase the share of renewables in the electricity generation mix.

Sources: EEG (2016), EWURA (2019), Leary et al. (2018), Odarno et al. (2017), URT (2003, 2014, 2015a)

[9] See https://microgridnews.com/electric-pressure-cookers-minigrids-solving-global-problem-of-biomass-cooking/

The Electricity Act in 2008 outlined the rules for generation, storage and distribution of electricity and opened the energy sector for private sector participation, ending TANESCO's monopoly (Leary, Batchelor, Sago, Minja, et al., 2019). Tanzania's Development Vision 2025 (URT, 1999), in place since 2000, envisaged the country becoming a middle-income country[10] by 2025 for which an adequate, reliable and affordable electricity supply was integral. The Tanzanian energy policy framework reflects alignment with global initiatives such as SE4All and in support of SDG7, and the 2015 Tanzania SE4All Action Agenda tasks the Ministry of Energy and Minerals (MEM), now the Ministry of Energy (MOE), with improving access to modern cooking solutions (URT, 2015b). Table 2 summarises the energy policies, regulations and acts relevant to e-cooking in Tanzania.

3.5 Key national actors relevant to e-cooking

Key national actors relevant to e-cooking include the MOE, TANESCO, EWURA, REA and the Tanzania Bureau of Standards (TBS). The MOE oversees the energy sector and creates and drives policy, law and regulation. TANESCO, a parastatal, is the main electricity provider and generates, purchases, transmits, distributes and sells electricity across mainland Tanzania. EWURA and REA are, respectively, a multisectoral regulatory authority and an autonomous body tasked with improving energy access in rural areas of Tanzania. The TBS is the authority who formulates and enforces standards, including for cookstoves, although testing is voluntary.

A number of other government associated organisations, such as the Tanzanian Commission for Science and Technology (COSTECH), the Tanzania Industrial Research and Development Organisation (TIRDO), the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC) and the non-governmental Tanzania Renewable Energy Association (TAREA), are involved in clean cooking initiatives and so likely maintain an interest, if not active involvement, in e-cooking developments. A small number of research and academic institutions, international development agencies, NGOs and private sector organisations is actively involved in developing e-cooking in Tanzania and these organisations inform and influence national policymakers. Their extent of involvement in the sector is discussed further in Section 4.3.

Beyond the energy sector, clean cooking – and to a far lesser extent e-cooking – exist as part of the discourse in ministries and departments but without translating into clear policy. The Department of Community Development, Gender and Children has been mandated to deal with issues around improved cookstoves although, for reasons including inadequate budgetary support, these are not prioritised (Kammila et al., 2014). Poor distribution and access to improved cookstoves in rural areas is a concern to regional and district local governments, and forms part of their development plans. Other government bodies with potential interests in the development of e-cooking include the Ministry of Industry, Research

[10] The World Bank announced that, as of 1 July 2020, Tanzania is now categorised as a lower middle income country: https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2020-2021 (accessed 15 July 2020)

and Development and the Tanzania Investment Commission. The Ministry of Natural Resources and Tourism has imposed bans to discourage the production and consumption of charcoal, undertaking initiatives such as the 2014 Biomass Energy Strategy (BEST) that recommend making alternatives (including electricity) competitive on a non-subsidised basis in terms of availability and price (Villema et al., 2018). However, clean cooking does not appear to be a high priority issue for policymakers. It remains poorly supported and underfunded.

3.6 The national e-cooking development trajectory

Emerging e-cooking actors face many of the same barriers as those involved in clean cooking initiatives, namely a lack of policy attention, poorly coordinated strategy and difficulties accessing finance. The now dormant Clean Cooking and Fuels Alliance for Tanzania (CCFAT) is a case in point. CCFAT, formed in 2013 with the support of institutions such as the MOE, TAREA and the University of Dar es Salaam, sought to improve coordination among clean cooking actors and develop an enabling environment. However, funding, activity and interest waned, in part because CCFAT was unable to garner sufficient support from international organisations to sustain itself: the CCA, for instance, has not designated Tanzania a focus country[11]. A functional coordinating body remains key to strengthening the enabling environment around clean and e-cooking in Tanzania.

Other significant barriers to e-cooking include the enormous revenues generated by the overwhelming use of biomass as a cooking fuel in Tanzania, spread across numerous stakeholders with varying degrees of influence, and many with interests in maintaining the status quo. Charcoal and woodfuel are major sources of revenue in both urban and rural areas: charcoal dominates in urban areas and biomass in rural areas. In 2012, charcoal and woodfuel generated approximately USD 1 billion in revenues for producers, transporters and energy sellers (IRENA, 2017).

The market for e-cooking is underdeveloped. There is limited availability of new e-cooking technologies, with prohibitively high upfront costs for e-cooking appliances. Proven innovative and flexible business models are required in order to make them accessible. Even with relatively low electricity prices compared with its neighbour Kenya, and the lifeline tariff allowances, there is the widespread perception in Tanzania that cooking with electricity is expensive. And an unreliable and variable electricity supply, characterised by frequent blackouts, is indisputably a constraint.

There are added practical problems for electricity as an alternative cooking energy, with insufficiently widespread electricity access that is especially acute in rural areas. On the other hand, in these rural areas, there is progress towards expanding electrification, strongly supported by bodies such as REA and TANESCO, and demonstrated with the success of the mini-grid sector in which many experimental e-cooking technology trials are being implemented. Although the regulatory and legal framework is weak around e-cooking, it is robust in adjacent energy initiatives, such as mini-grid development and in

[11] Tanzania is a CCA partner country: i.e. it is one of the countries or individual government ministries who ascribe to the principles of the Alliance.

construction of small power projects (Mokveld & von Eije, 2018). The underlying factors driving the clean cooking agenda remain pressing and are receiving significant international support, albeit inadequately funded (SE4All & CPI, 2019), especially from a health and environmental perspective.

E-cooking is a cross-cutting issue with relevance to national policy on environment and climate change, forestry and health, and science, technology and innovation. Raising awareness, eliciting support and coordinating with institutions outside the energy sector through other ministries such as the Ministry of Natural Resource Management or the Vice President's Office, which is responsible for environmental integrity and sustainable development, may serve to raise e-cooking's profile. An integrated cross-sectoral national strategy with clear policy goals in support of clean and e-cooking, and with the backing of ambitious programmes such as MECS and broader initiatives such as SE4All, may catalyse the transition to modern energy cooking services and further harmonise the currently disconnected clean cooking and energy access agendas.

4 Socio-technical innovation system actors and relations

With an overview of the context of the Tanzanian e-cooking socio-technical innovation system and a sense of its trajectory, we now report the findings from our research gathered through the Pinnsmapping exercise in the Dar es Salaam ISH Workshop, follow-up interviews and further desk-based work. In Section 4.1, we provide a brief review of the technologies in the e-cooking innovation system. Section 4.2 offers two visualisations of the actor-networks associated with e-cooking in Tanzania. We then describe, in Section 4.3, the key actors in the innovation system followed, in Section 4.4, by a discussion of the innovation system's enabling environment. Section 4.5 reviews the relations between actor-groups active in e-cooking in Tanzania. In Section 4.6, we discuss a range of emerging issues and end in Section 4.7 with a brief reflection on the outlook for e-cooking in Tanzania.

4.1 Technologies in the e-cooking innovation system

Of the approximately 48 million people in Tanzania, more than 90% rely on firewood and charcoal as a primary fuel for cooking. Charcoal is the most prevalent cooking fuel in cities and towns, especially in Dar es Salaam. Modern sources of energy for cooking in Tanzania include electricity, solar energy, biogas and liquified petroleum gas (LPG). As of 2016, 68% of Tanzanians in urban areas had access to electricity, but only 19% in rural areas, and just 1.6% use electricity for cooking.

Table 3: Price range of locally available appliances from an online shopping platform in Tanzania

Electric Cooking Appliance	**Price in USD**	
	Minimum	**Maximum**
Electric Pressure Cooker	77	89
Rice Cooker	19	201
Microwave oven	75	323
Electric kettle	11	29
Hot plate	59	503

Source: Authors' Compilation

Where electricity is used for cooking, among the most commonly used appliances are microwave ovens, electric kettles, fabricated coil water heaters, induction stoves, hot plates, mixed liquified petroleum gas (LPG) and stand-alone electric cookers, and thermal pots (see Of the approximately 48 million people in Tanzania, more than 90% rely on firewood and charcoal as a primary fuel for cooking. Charcoal is the most prevalent cooking fuel in cities and towns, especially in Dar es Salaam. Modern sources of energy for cooking in Tanzania include electricity, solar energy, biogas and liquified petroleum gas (LPG). As of 2016, 68% of Tanzanians in urban areas had access to electricity, but only 19% in rural areas, and just 1.6% use electricity for cooking. for indicative prices of some e-cooking appliances in Tanzania). Interestingly, rice

cookers are used quite widely in Tanzania in areas connected to the national grid, especially in urban areas. This is because rice is one of the staple meals in the country, especially in towns and cities. A respondent in our study reported that rice cookers are commonly given as gifts in weddings and bridal showers. Further, university students use rice cookers to not only cook rice but almost all other meals. As the students are using electricity paid for by the university, they do not face the constraint of paying for energy for cooking.

A new entrant into the cooking space is the electric pressure cooker (EPC). EPCs are available in retail stores, and the most readily available brand is Nikai. Because of research and market development activities mostly affiliated with TaTEDO and its commercial spin-off SESCOM Enterprises, the demand for EPCs has started to rise. Several trials have been concluded or are ongoing to establish whether there is indeed a market for EPCs and how that market can be developed (discussed further in Section 4.5). Preliminary results from these trials reveal that EPCs are generally more desirable than biomass cookstoves, especially among charcoal users. This is because EPCs cook food faster, do not produce smoke and keep the cooking environment cool, are safer to use, and enable the cook to attend to other tasks as food cooks autonomously (Leary, Scott, Sago, Minja, et al., 2019; Schreiber et al., 2020). But they tend to be used in combination with other cooking methods, and they are used only for certain meals such as rice and beans. However, another trial found that, upon nudging, almost all meals were cooked on electricity, and thus the inference that EPCs were broadly compatible with Tanzanian cooking practices was made. This finding implies that households are likely to use an EPC for most meals if the right conditions are provided: i.e. uninterrupted power supply, more affordable electricity relative to other energy sources, and better training to use the appliances.

Besides the rice cookers, hot plates, EPCs and other e-cooking appliances already mentioned, there have been efforts to develop biomass stoves that have an electric component to improve their efficiency. Between 2010 and 2011, a Tanzania-based NGO, the Partners for Development (PfD), funded efforts to fine-tune two gasifier cookstove models, Jiko Bomba/Jiko Mbono and Jiko Safi, developed by Kiwia and Lausten Ltd and Jetcity Stoveworks from the US. Both stoves are locally-fabricated using mild sheets and channels and use a small electric fan that improves the efficiency in burning fuels such as pellets from ground agricultural waste and whole seeds. Trials in villages in Singida, Arusha and Shinyanga regions were conducted to evaluate the socio-economic, environmental and technical acceptance of the cookstoves and were said to be successful. Some of the households disliked the technologies because they were unstable and small. However, the fact that they were fast, required less attention, and produced less smoke and soot on the pot rendered them likeable for the most part (Rajabu & Ndilanha, 2013).

Actor abbreviations and acronyms

A2EI	Access to Energy Institute
AMDA	Africa Minigrid Developers Association
CAMARTEC	Centre for Agricultural Mechanisation and Rural Technology
CLASP	Collaborative Labelling and Appliance Standards Program
COET	College of Engineering and Technology
COSTECH	Commission for Science and Technology
D.I.T.	Dar Es Salaam Institute of Technology
DFID	Department for International Development
EDPG	Energy Development Partners Group
EEP	Energy and Environment Programme
EPSRC	Engineering and Physical Sciences Research Council
EU	European Union
EWURA	Energy and Water Utilities Regulatory Authority
FCC	Fair Competition Commission
FMO	Nederlandse Financierings-Maatschappij voor Ontwikkelingslanden (a Dutch development bank)
GCRF	Global Challenges Research Fund
IIED	International Institute for Environment and Development
MECS	Modern Energy Cooking Services Programme
REA	Rural Energy Agency
SE4ALL	Sustainable Energy for All
SESCOM	Sustainable Energy Services Company
SIDA	Swedish International Development Cooperation
SIDO	Small Industries Development Organization
STIPRO	Science Technology and Innovation Policy Research Organisation
TAMISEMI	President's Office: Regional Administration and Local Government
TANESCO	Tanzania Electric Supply Company
TANGSEN	Tanzania Gender and Sustainable Energy Network
TAREA	Tanzania Renewable Energy Association
TaTEDO	Tanzania Traditional Energy Development Organisation
TBS	Tanzania Bureau of Standards
TDC	Technology Development Centres
TIRDO	Tanzania Industrial Research and Development Organisation
TPDC	Tanzanian Petroleum Development Corporation
UNDP	United Nations Development Programme
UNEP	United National Environment Programme
VETA	Vocational Education and Training Authority
VPO	Vice President's Office

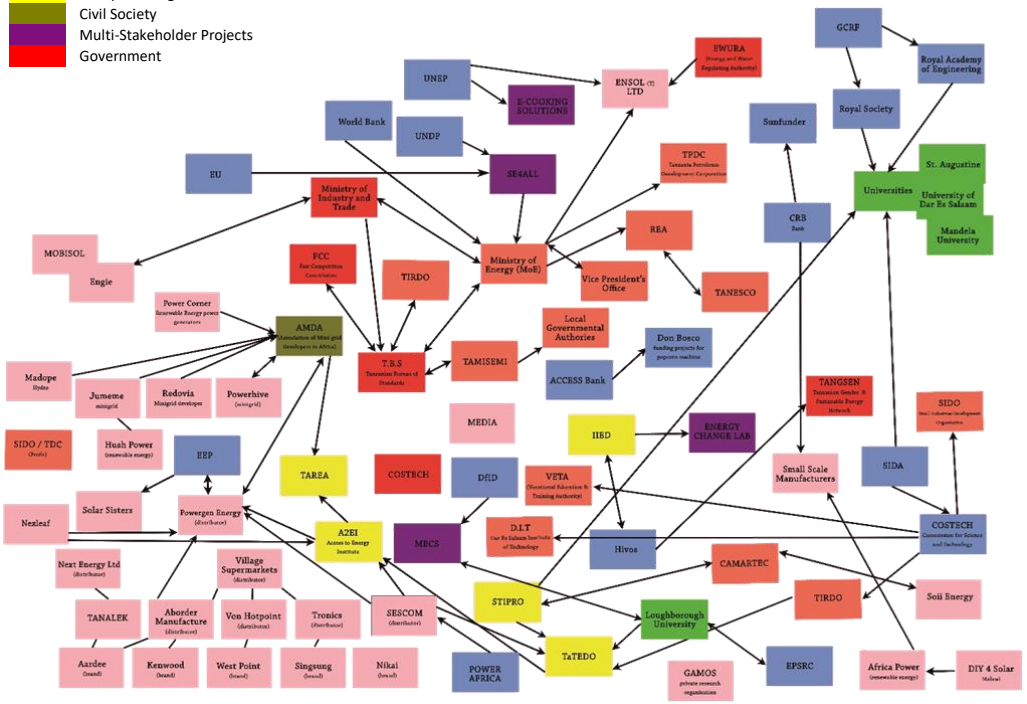

Figure 3: Actor-network map of the Tanzania e-cooking socio-technical innovation system

Source: Authors' construction based on Pinnsmapping and stakeholder interviews

4.2 Actor-network visualisations

Upon identifying which electrical cooking appliances or technologies are being used in Tanzania, we sought to identify and classify specific actors in Tanzania who used or worked with these technologies in different ways. We focussed on organisations and individuals involved in e-cooking through research and development (R&D) activities, quality assurance standard development and enforcement, market development to extend access to e-cooking appliances and supporting technologies and systems, supply-side and demand-side financing of e-cooking technologies and initiatives, education, advocacy and policy support for e-cooking and other related activities. We also investigated whether each actor interacted with others in those activities and the nature of those interactions, and we developed two visualisations of the resulting actor-networks relevant to e-cooking in Tanzania.

Figure 3 depicts the outcome of first iteration of the Tanzania e-cooking actor-network. This map was derived from the Pinnsmapping exercise during the Nairobi ISH Workshop and additional data from follow-up interviews. The actors are colour-coded based on their category: e.g. private sector, regulatory authorities, funders/financiers, and so on, as shown in Figure 3. The figure also includes a set of abbreviations and acronyms. The connections between these actors are depicted with arrows, which indicate the primary 'direction' of the relations. In some cases, the relationship is reciprocal, indicated by a bi-directional arrow. Findings from our interviews and further analysis revealed that this map also captures all those actors who are already doing some work around 'clean cooking' in Tanzania, but are yet to start concrete projects, programmes or initiatives specifically on e-cooking. These actors are enthusiastic about e-cooking and are supportive of any new developments in this area. However, due to their current strategic focus, budgetary constraints, capacity issues and, sometimes, uncertainty or scepticism on when e-cooking efforts are likely to yield measurable outcomes, they are yet to take concrete steps to invest in or promote e-cooking.

In an effort to identify specific actors from the map in Figure 3 who are currently running active projects, programmes of initiatives in e-cooking, we progressively validated this map with each actor interviewed in our study. Our respondents first confirmed if they are doing anything on e-cooking, and identified those with whom they are working in these efforts. They also confirmed – to the best of their knowledge – which other actors in the sector were active in e-cooking, and in which specific initiatives or programmes. Figure 4 depicts the resulting 'core' network of players who are actively promoting e-cooking in some way in Tanzania. The actors are colour-coded in a similar way to Figure 3. This map further captures the nature of the relationships between actors: e.g. funding flows, collaborations in efforts such as cooking demonstrations, product supplies or distribution, and so on. In the following sections, we describe the actors in both visualisations and elaborate on their efforts related to e-cooking, and the relationships in the socio-technical innovation system.

4.3 Key actors in the e-cooking innovation system

As shown in Figure 4, the Tanzanian e-cooking innovation system is composed of just a few core actors. A lot of the work in e-cooking in Tanzania involves piloting cooking technologies on microgrids and mini-grids, market development for e-cooking appliances and early-stage policy advocacy work.

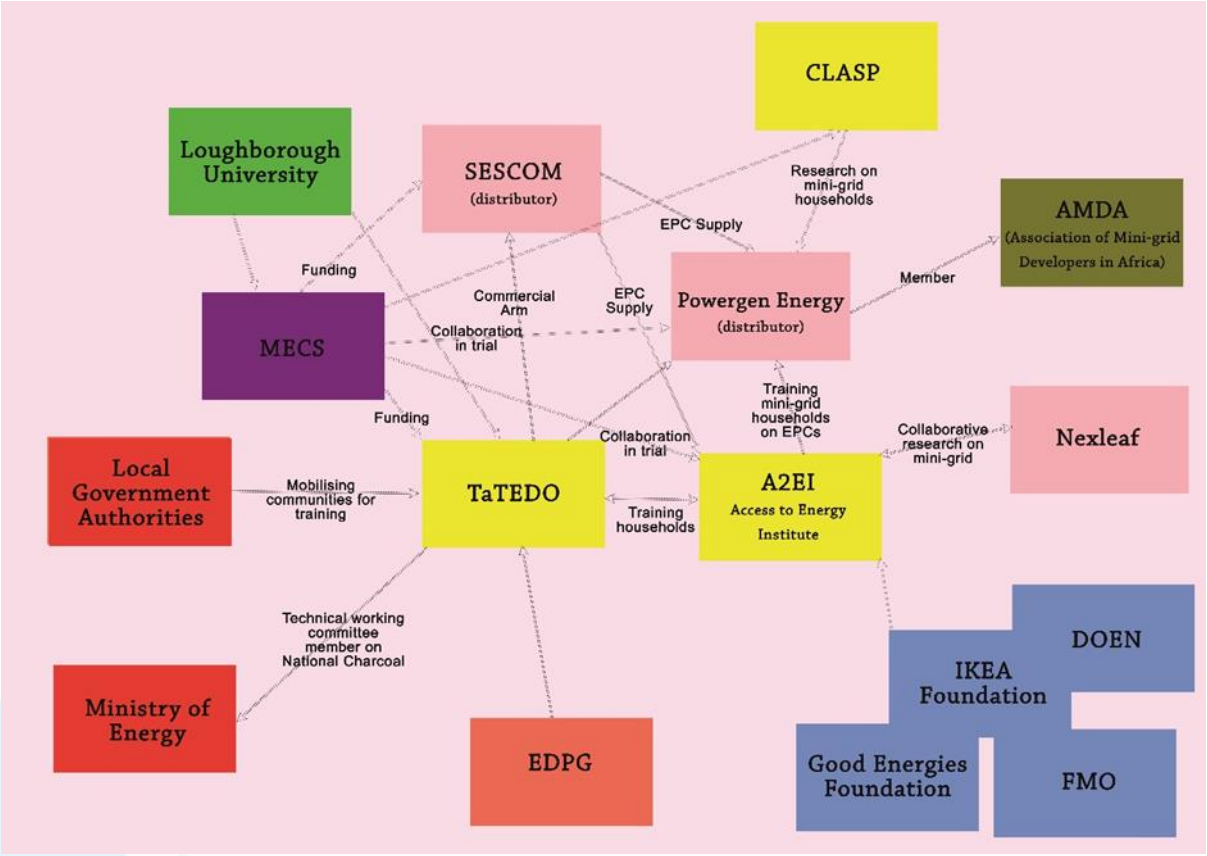

Figure 4: Core actor relations in the Tanzania e-cooking socio-technical innovation system

Source: Authors' construction based on Pinnsmapping and stakeholder interviews
Note: The map shows only those who are active in e-cooking in Tanzania and the nature of their relations

We position the e-cooking innovation system within the broader pre-existing improved cookstoves (ICSs) innovation system, which started to develop in Tanzania in the 1980s. Efforts to improve the efficiency of ICSs continue in Tanzania given that they are considered both accessible and affordable, and the fuels are more readily available. It happens that the ICS and e-cooking innovation systems share the same core actor – the Tanzania Traditional Energy Development Organization (TaTEDO), a non-profit organisation who has been active in the energy sector for 30 years. TaTEDO, and its commercial spin-off the Sustainable Energy

Services Company Limited (SESCOM), are now leveraging their legacy in the ICS sector to develop the e-cooking niche in Tanzania. Therefore, there is the potential that actors or existing networks in the ICS sector may eventually play a role in the evolving e-cooking niche.

It is worth noting that, apart from TaTEDO and SESCOM, most of the other active organisations in the e-cooking innovation system are new entrants to the sector, and a lot of their work is centred on market development for EPCs and piloting the use of these appliances in weak and off-grid areas. Findings from our research reveal that all this work is still at an early stage, and it is being externally funded. The following sections discuss the categories of actors involved in both systems and their interactions.

4.3.1 Non-governmental and non-profit organisations

TaTEDO is a non-governmental organisation established in 1990 and based in Dar es Salaam. It undertakes field implementation of sustainable energy programmes and projects, with a current focus on modern energy services. The organisation is actively involved in promoting clean cookstoves, having facilitated the distribution of more than 2 million charcoal stoves and trained numerous producers and households. Most of this work has been project-led. The NGO has recently ventured into work around e-cooking, especially with EPCs, and was involved in the development of an eCookBook for Tanzania (Sawe & Aloyce, 2020) and a delivery model for scaling up e-cooking. The organisation is also involved in the distribution of EPCs, training of households and advocacy for EPC use. They have long-standing relationships with government actors such as the Ministry of Energy (MOE), and have participated in various policy processes. Currently, TaTEDO interacts with every single actor in the nascent e-cooking innovation system in Tanzania.

A new entrant into the cooking domain in Tanzania is the Access to Energy Institute (A2EI), a research and development non-profit – headquartered in Berlin – supporting product development for the off-grid sector. The A2EI Lab in Tanzania is based in Arusha, and it is currently running a trial around the Lake Zone Areas to test the viability of e-cooking powered by hybrid renewable mini-grids. About 100 EPCs were distributed to households in six villages. Partner organisations in this trial are mini-grid developer PowerGen Renewable Energy, US-based non-profit Nexleaf Analytics and the MECS Programme. A2EI has in addition been doing R&D on agricultural machinery, upgrading manual farm implements to solar-powered efficient machines.

The Collaborative Labelling and Appliance Standards Program (CLASP) is an international non-profit organization working to develop appliances, which it does in tandem with policymakers, technical experts, industry actors, donors, consumer groups and other stakeholders. This is, in part, achieved by understanding consumer behaviour around the use of appliances such as the EPC. In Tanzania, CLASP undertook a study on consumer experiences alongside an EPC pilot on PowerGen's mini-grids. The study involved baseline surveys on household cooking practices, in-person interviews with households about their use of the EPCs, the impact and any challenges experienced over the duration of the study, and the comparison of data on household electricity consumption before and after the adoption of an EPC (Schreiber et al., 2020).

Besides these three non-profit organisations active in the electric cooking sector, the German Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) and Netherlands Development Organisation (SNV) – who coordinate the activities of Energizing Development (EnDev) Tanzania – have participated in efforts to enhance the distribution of improved cookstoves and to facilitate access to finance for stove producers and distributors (discussed further below). However, this work has been focussed exclusively on improved biomass cookstoves. Also worth mentioning is that the Energy Development Partners Group (EDPG), which comprises bilateral and multilateral agencies, has shown interest in an energy sector policy dialogue, including e-cooking.

4.3.2 Private sector

PowerGen Renewable Energy, mentioned above, is an enterprise who builds, owns and operates micro and mini-grids in Tanzania and has a warehouse in Kenya. Their microgrid technology is based on a centralised solar PV-battery hybrid system with a distribution grid connecting households in the same village, and a backup generator. The PowerGen microgrids range from small communities with 100 connections at a 6kW peak to larger sites with 350 connections at a 25kW peak. PowerGen provides households with energy access on a PAYGO basis and a tariff-discount model, which takes into account any shifts in demand for energy during off-peak hours. To explore whether EPCs could be a strong market fit for their customers, PowerGen conducted a small-scale pilot, funded by the MECS Programme, in two of their sites in Central Tanzania.

Another enterprise who is core to the developments around e-cooking in Tanzania is SESCOM Limited. SESCOM is the commercial arm of TaTEDO, providing an avenue for TaTEDO to manage its for-profit work and to test any market hypothesis developed out of ongoing research. SESCOM has participated in the installation of 200 solar PV systems and several mini-grids in rural areas. The enterprise undertakes its business activities through its staff and a broad network of contractors and consultants. SESCOM is now the main local supplier of EPCs, and it is in the process of importing a self-branded EPC that is likely to be distributed not only in Tanzania but also in Kenya and the region.

4.3.3 Financing organisations

The main funding organisation in e-cooking projects and programmes in Tanzania is the UK Department for International Development (DFID) previously through Loughborough University, University of Surrey and Gamos, and currently directly through the MECS Programme. The earlier projects were implemented in Tanzania by TaTEDO and they focussed on research, conducting cooking diaries and gender-related e-cooking studies intended to inform the development of the battery-supported e-cooking concept called eCook. Subsequently, MECS has funded or supported EPC trials, and cooking diary and baseline studies implemented by TaTEDO, PowerGen and A2EI. Within the A2EI trial, MECS is funding a cooking diaries study. MECS is also funding additional research by TaTEDO to promote a market system for modern energy cooking services in Tanzania. The IKEA Foundation, DOEN Foundation, Good Energies Foundation and the Dutch development bank FMO – who have been funding work on renewable energy by A2EI – are also funding the A2EI EPC trial.

Besides these new initiatives on e-cooking, Tanzanian organisations have received funding for clean cooking initiatives, especially with ICSs, from international development agencies involved in the EnDev Programme such as the Dutch Ministry of Foreign Affairs, the German Federal Ministry for Economic Cooperation and Development, DFID, the Swiss Agency for Development and Cooperation, Norwegian Ministry of Foreign Affairs, and the Swedish International Development Cooperation Agency (Sida).

The MECS Programme is the first to focus exclusively on modern energy services for cooking, with a strong focus on e-cooking in Tanzania. As part of its mission to induce a transition away from overreliance on biomass, the Programme has used its Challenge Fund to directly support innovators to develop new technologies and delivery models. Recipients in the e-cooking domain include Smart Villages, who are developing low-cost technologies for storing solar energy for cooking, PowerGen Renewable Energy in the aforementioned EPC trial, and TaTEDO in the aforementioned projects. The goal of these is to stimulate innovation and market development for modern energy cooking technology and systems with a view to advance e-cooking as the cleanest and most sustainable way of cooking. MECS has also supported the 2020 Global LEAP (Global Lighting and Energy Access Partnership) Awards Electric Pressure Cooker competition managed by CLASP.

4.3.4 Civil society

Several civil society organisations exist in the energy sector in Tanzania. However, apart from the Africa Mini-grid Developers Association (AMDA), these organisations are dormant and, as a consequence, actors in the sector lack a platform on which to share knowledge and experiences and a common voice to engage in policy advocacy. An example of one of the dormant organisations is the Improved Cook Stoves Taskforce, which was created in 2011. The MOE (then the Ministry of Energy and Minerals) is the Chair and the Tanzania Renewable Energy Association (TAREA) is the secretariat. The ICS Taskforce was initiated to increase coordination in the ICS sector by engaging stakeholders and developing the market. Several documents were developed by the Taskforce, among them Improved Cook Stoves Assessment and Testing, a technical assessment report of ICSs in Tanzania, market intelligence studies for ICSs in different regions of the country, and an ICS policy analysis.

In 2012, the Clean Cookstoves and Fuels Alliance of Tanzania (CCFAT) was formed by clean cookstove and fuels stakeholders and several members of the ICS Taskforce. CCFAT's goal was to strengthen local actors and stakeholders working in the cookstove and fuels sector and influence the government to facilitate the increased innovation and adoption of clean cookstoves and fuels. However, as mentioned in Section 3.6, the alliance became dormant due to lack of funding for the secretariat. The alliance did not have access to funding and support from the Global Clean Cooking Alliance (CCA), which supported the development of an equivalent association in Kenya. Finally, AMDA is an industry association that represents private utilities developing renewable energy-based localised power grids and includes members from Kenya and Tanzania. In its rhetoric, AMDA promotes e-cooking as one of the (productive) uses of energy generated from mini-grids in Africa.

4.4 The enabling environment

In July 2014, the Tanzanian Country Action Plan for Clean Cookstoves and Fuels reported that the enabling environment has been stifled by policy and market failures, a lack of awareness on the benefits of clean cookstoves, weak government policies and insufficient access to finance (Rajabu et al., 2014). Since then, there have been various efforts to develop the market, largely driven by development partners such as GIZ and SNV.

4.4.1 The regulatory context

In Section 3, we outlined the policy context of the e-cooking innovation system, highlighting the main Government actors: MOE, the Rural Energy Agency (REA), the Tanzania Bureau of Standards (TBS), the Tanzania Commission for Science and Technology (COSTECH), the Ministry of Natural Resources and Tourism, the Ministry of Industry, Research and Development, and the Tanzania Investment Commission. As is already evident, there are many policy actors relevant to the cooking sub-sector, but these actors are loosely coordinated. Tanzania's 2015 energy policy (URT, 2015a) includes a statement to "facilitate adoption of appropriate cooking appliances to promote alternatives to woodfuel", but there are as yet no policy instruments developed in this regard. Similarly, the SE4All Action Agenda (URT, 2015b) set some clean cooking targets, but there is no clear evidence as to whether these targets have been resourced. The Country Action Plan also reported that the Department of Community Development, Gender and Children is sometimes mandated to deal with issues around improved cookstoves, based on the assumption that cooking is a woman's role. However, budgetary allocations are not made accordingly and therefore the issue is not prioritised. Nevertheless, regional and district local governments have begun to recognise that poor distribution of improved cookstoves in rural areas is a significant impediment to the development of the sector, and they have started to incorporate this into their development plans.

Tanzania has yet to develop regulation for the clean cooking sector. Quality assurance standards for cookstoves are lacking and testing for improved cookstoves is voluntary. As a consequence, there is a lack of consumer awareness on the quality of the cookstoves available in the market. Further, there have been poor quality stoves developed by local manufacturers and defective stoves shipped in from foreign sources, which indicates poor control at importation. Thus, there is little trust among both distributing agents and end-users of some improved cookstove brands. The market has relied on larger cookstove brands to conduct national marketing campaigns. These issues point to a lack of political will and low technical capacity to develop and implement quality assurance standards for testing and labelling policies and programmes.

4.4.2 Academic research, education and training

The most active institution doing research and training on electric cooking in Tanzania is TaTEDO. It is worth mentioning that, before the entry of Loughborough University and the MECS Programme that have financed most of the e-cooking research in Tanzania so far, TaTEDO along with the following organisations have been doing or supporting research on clean cooking in general. Tanzania Industrial Research and Development Organization (TIRDO), which is a public institution, has been involved in research and testing

of improved cookstove prototypes. Further, TIRDO provides performance testing of energy systems like ovens and cookstoves, amongst other equipment. COSTECH, another public institution, has been involved in the design of biomass stoves in collaboration with TaTEDO, and it also approves research programmes on clean cooking. However, these institutions lack a platform for sharing expertise, research findings and resources. And the innovation system also lacks skilled labour, finance and equipment, which can hinder research and development activities.

In the energy sector in general, universities and Technical and Vocational Education and Training (TVET) in Tanzania play an important role in training students who then flow into the labour market, and doing academic research on cooking technologies and their health and environmental impacts. Participants in the ISH workshop identified the following institutions as the most active in this area: Dar es Salaam Institute of Technology, the College of Engineering and Technology at the University of Dar es Salaam, and Arusha Technical College. These institutions also produce and diffuse innovations in the energy sector.

4.5 Relations between actor categories in the e-cooking innovation system

The Tanzanian market for clean cookstoves has for a long time been fragmented and supply has been dominated by small-scale informal enterprises. There have also been numerous stove programmes implemented by foreign NGOs, but uptake in rural areas has remained weak. It has also been reported that, once the external funding ended, the programmes stopped. This can in part be attributed to the lack of a coordinating mechanism or platform for activities in the clean cooking sector. Tanzania is also not one of the CCA focal countries and so has not benefited from efforts to coordinate the sector, in contrast to other countries who are categorised as focal. However, as will be evident below, e-cooking actors in Tanzania have formed a community and are performing innovative activities, even though the few actors present are mostly new entrants. Nevertheless, it is worth mentioning some major projects that have had a bearing on the evolution of the clean cooking sector, and may be meaningful for efforts to nurture the e-cooking niche, to connect with policy processes and to scale up R&D and market development activities.

4.5.1 The Sustainable Energy for All initiative

SE4All is a global initiative whose goal is to mobilize stakeholders to take concrete actions towards ensuring universal access to modern energy services, while improving energy efficiency and increasing the share of renewable energy in the energy mix. In Tanzania, an Action Agenda and Investment Prospectus were developed through a consultative and validation process with stakeholders in the energy sector. The African Development Bank hosts the SE4All hub, which provided technical assistance in this process. However, the strategies for clean cooking under these initiatives are focussed on biomass energy and LPG in rural areas.

4.5.2 The Tanzania Domestic Biogas Programme and other related programmes

In terms of improving energy-efficient cooking, there is the Tanzania Domestic Biogas Programme (TDBP) that started in 2009. The first phase was completed in 2013 in which 8,799 plants were installed. The second phase started in 2014 and ended in 2017. Both phases targeted a total of 20,700 plants. The programme was hosted in CAMARTEC and received technical assistance from SNV. It was part of the Africa

Biogas Partnership Programme as managed by Hivos with funding from the Netherlands Directorate for Development Cooperation (DGIS). The Government of Tanzania aimed to contribute with funding to TDBP through REA from 2015 onwards. Another biogas programme was implemented by TDBP, the REA, SNV, the Norwegian Agency for Development Cooperation and the Government of Tanzania with a focus on private sector development and market extension in order to reach at least 10,000 rural households.

4.5.3 EnDev Tanzania programme

In Tanzania, the EnDev Programme is implementing two initiatives: the Tanzania Improved Cookstoves (TICS) Programme and the Results-Based Financing (RBF) for Pico-Solar Market Development project, both implemented by SNV in cooperation with GIZ. The TICS Programme was designed to improve access and sustained use of appropriate cooking technologies for peri-urban and rural households in Tanzania through market linkages with quality private sector ICS product and service providers. The project sought to develop rural markets through delivery of market intelligence, training of local artisans on stove design, entrepreneurship support and local supply chain building. The initiative focussed on 'Jiko Matawi', a multi-purpose stove capable of using both firewood and charcoal. The RBF initiative was implemented by SNV in collaboration with EnDev and DFID to provide quality solar energy to rural households in Tanzania's Lake Zone. The RBF facility focusses on the application of a temporary financial product in mainstream banking that serves to assist the private sector in developing the market for pico-solar products (lanterns, phone chargers and small solar home lighting kits). EnDev established a temporary financial product with Tanzania Investment Bank. The incentive scheme is accessible to import-suppliers actively engaged in distribution chain development. The private sector must pre-finance their sales activities before they are able to earn incentives. Other partners in the two initiatives include the MOE, stove producers and retailers, food vendors and solar companies.

With the entry of R&D initiatives around e-cooking in 2017, there has been a flurry of activities to explore whether e-cooking, and EPCs in particular, have potential to diffuse and transform the cooking sub-sector in Tanzania. Most of these initiatives are fully or partly funded through the MECS Programme. The projects involve a number of actors new to the cooking arena, which is populated by public entities and development partners interacting with stove producers and distributors at the local level. So far, e-cooking actors coalesce around research projects and experimental trials on EPC usage in rural villages mostly in mini-grid and microgrid settings. Below, we provide some of the highlights.

4.5.4 eCook Project and related projects

This project, which was implemented in 2018, brought together a number of actors who are now central to the MECS Programme. These include TaTEDO, Loughborough University, the University of Surrey, Gamos, Innovate UK, and DFID. eCook is a battery e-cooking concept designed to offer clean cooking and access to electricity to poorer households currently cooking on charcoal or other polluting fuels. Studies under this eCook project sought to establish a "strategic long-term mix of interventions that seek to pre-position research and knowledge such that when the pricing of components and systems reaches viability, donors, investors, private sector and civil society can take rapidly eCook to scale" (Batchelor et al., 2019). The programme of research employed methodologies such as cooking diaries (Leary, Scott, Sago, Minja, et al.,

2019), choice modelling surveys (Scott et al., 2019), focus groups (Leary, Sago, Minja, Chepkurui, et al., 2019), techno-economic modelling, gendered analysis (Chepkurui et al., 2019), prototyping (Leary, Sago, Minja, Batchelor, et al., 2019) and stakeholder workshops (Villema et al., 2018).

These studies found that households in Tanzania are willing to adopt electricity for cooking if the price and other conditions were right. The key drivers for adoption of e-cooking were cleanliness, ease of use, and time-saving, while the barriers to adoption were affordability, availability and reliability of e-cooking appliances. The findings also indicated that EPCs are suitable for Tanzanian cuisine and that leapfrogging directly from biomass fuels to EPCs is possible. Finally, the national policy review found that the policy environment is also generally favourable for e-cooking[12]. These findings were a key foundation for subsequent e-cooking pilots in Tanzania.

Following the eCook project, TaTEDO implemented a MECS-funded project *Approach to Designing Delivery/Business Models of Modern Energy Cooking Services in Tanzania* (TaTEDO, 2020). The objective was to understand Tanzania's e-cooking appliances market system – i.e. the market chain, support services and enabling environment – with the view of scaling up e-cooking in Tanzania. Findings from the project determined that demand for e-cooking appliances in Tanzania is very low due to affordability constraints, low customer awareness, cultural barriers[13] linked to cooking practices and an underdeveloped supply chain for e-cooking appliances. TaTEDO then designed a delivery model for e-cooking appliances. The project also yielded an eCookbook for Tanzania (Sawe & Aloyce, 2020). It was followed by another project (still ongoing) *Promoting a Thriving Market for Electric Pressure Cookers* that is implementing the activities and steps recommended in the previous project.

4.5.5 Accelerating Microgrid E-Cooking through Business and Delivery Model Innovations

PowerGen Renewable Energy, with support from the MECS Programme, conducted a small-scale pilot in central Tanzania. When analysing trends in power usage at the household level, the pilot found that most households only used electricity at night for lighting. PowerGen was generating more energy than the demand levels, and thus it began to explore ways of exploiting the unused energy through productive uses and by increasing the portfolio of appliances used in households. The EPC then came into consideration. An EPC pilot study was designed, with a focus on sites that offered significantly lower electricity rates (USD 0.35 per kWh) compared to most rural microgrids in order to make the EPCs cost-competitive with relatively inexpensive and ubiquitous charcoal. To better understand consumer experiences with the EPCs, alongside this pilot, Efficiency for Access (through CLASP) researched participating households. The research included baseline surveys on cooking practices, fuel usage and expenditure prior to EPC adoption,

[12] These are somewhat different to our present analysis, see Section 3.

[13] We would suggest that the notion of cultural 'barriers' is problematic, as it implies said 'barriers' can be dismantled as though part of some technical infrastructure and could be interpreted to mean cultural practices are in some objective sense 'wrong'. Rather, we would argue e-cooking advocates could think about how traditional cooking practices could accommodate e-cooking and that any such accommodation should be achieved through locally embedded social and political processes.

follow-up in-person surveys with 22 of the 25 initial EPC customers on product usage, impacts and challenges after one month of use, and comparison of smart data on household electricity consumption pre- and post- EPC adoption. Efficiency for Access found that EPCs had a positive impact on consumer quality of life and required a minimal shift in behaviour. Findings from the report (Schreiber et al., 2020) indicate that participating households appreciated that cooking with the EPCs saved time, while minimally impacting electricity consumption and cooking cost. Apart from the EPC, households were also using rice cookers and electric kettles. Popcorn makers are being used on the mini-grids commercially by microbusinesses.

4.5.6 Access to Energy Institute trial

This pilot, whose aim is to test the viability of e-cooking powered by village mini-grids, is led by A2EI but also involves PowerGen, Nexleaf and the MECS Programme. One hundred efficient EPCs have been distributed among six villages powered by hybrid renewable mini-grids built by PowerGen. Some of the villages are on the mainland while others are on islands in Lake Victoria. A2EI is responsible for purchasing the EPCs – which were acquired from SESCOM – conducting preliminary training programmes for the women who will be using them, and analysing project data. The objective of the trial is to determine how much energy off-grid households use and the possibility of incorporating EPCs into those settings. The study aims to establish the optimal price point energy companies could set to make sure that most people can afford to cook with electricity. Data at the household level are collected remotely using smart meters. Nexleaf is also simultaneously collecting real-time temperature data using their StoveTrace system, while MECS is conducting a cooking diaries study to determine which foods are being cooked on the EPCs and other appliances during the trial. TaTEDO held cooking demonstrations with A2EI staff and the households to train them on how to use the EPCs. A2EI is now conducting preliminary analysis on the data generated so far.

4.5.7 Summary of actor-relations in the e-cooking innovation system

Analysis of the actor-network maps (see Figure 3 and Figure 4) reveals that TaTEDO and SESCOM are the most centrally-placed organisations with links to almost every actor. TaTEDO has the strongest links with the government and have been involved in energy policymaking. Further, TaTEDO and SESCOM were the first organisations to implement a research programme on e-cooking where studies on choice modelling, gender, and the e-cooking market chain have set a foundation for upcoming developments in the Tanzanian e-cooking innovation system. However, development partners such as GIZ, SNV and the UN Industrial Development Organization (UNIDO), who have contributed to the development of clean cooking in Tanzania, are yet to get involved in the e-cooking innovation system. Similarly, while the government is rhetorically in support of activities around e-cooking, it has yet to make any budgetary commitments in this regard.

4.6 Emerging issues in the e-cooking innovation system in Tanzania

4.6.1 Demand-side and supply-side financing

Initiatives related to improved cookstoves in Tanzania, such as the biogas programmes, and EnDev's TICS and RBF programmes, have illustrated what sorts of market development activities have worked in Tanzania. One approach is to create linkages with the private sector and with small informal enterprises in rural areas. Training of artisans in rural areas has also proved to be useful. Further, incentive structures such as RBFs seem like a viable approach to build distribution channels in rural areas, especially in a vast country like Tanzania. The role of women in market development is also crucial. These approaches have, however, yet to be tested on e-cooking appliances. To a large extent, the market for e-cooking appliances such as rice cookers has been limited to urban areas, where customers purchase their plans from a retail outlet. Thus, there is a lack of evidence on tried-and-tested business models that would work for e-cooking appliances distributed to rural areas, both on the supply side and the demand side. For an expensive appliance such as an EPC, even more innovative business models are necessary.

PAYGO models – which originated in Kenya (Rolffs et al., 2015) and have had varying degrees of success in the solar industry in Tanzania in companies such as Zola Electric, ENSOL and SESCOM – are emerging as one option. PAYGO models leverage information technology to extend end-user finance to remote customers to enable them to acquire energy products such as solar home systems and related accessories such as televisions and radios. However, even with the rapid growth of solar product-based companies and markets, the Tanzanian market is far from being penetrated as only thousands out of the potential millions of households have been reached. This has implications for how this model may be used to scale the use of e-cooking appliances. The model remains untested, as companies in Tanzania have yet to use this approach to collect payments on clean cookstoves. Nevertheless, if considered, PAYGO models need to be carefully structured when implemented by a for-profit company targeting low-income households in rural areas, where credit risk is high. This is illustrated in the case of Mobisol GmbH, one of the solar home system companies who pioneered the PAYGO model in Tanzania, which filed for insolvency in April 2019 due to, among other problems, setting unrealistic expectations of the market. Mobisol has since been acquired by ENGIE.

E-cooking pilot trials and experiments implemented in Tanzania by TaTEDO, PowerGen and A2EI are presenting some learning opportunities for how e-cooking appliances could be diffused into the market. In their EPC trial, PowerGen experimented with a customer financing mechanism that allowed customers to purchase the cookers through a loan facility that entailed a down payment of TZS 50,000 (USD 22) and monthly instalments of TZS 22,000 (USD 9.50) for nine months. 86% of the customers in this trial opted for the loan facility. This approach, which involves partnering with a microfinance institution (MFI) who absorbs the credit risk, presents another option for scaling EPCs in rural Tanzania. TaTEDO has also explored this option, even doing live cooking demonstrations of the EPC to the staff of the headquarters of the largest Bank in Tanzania, National Microfinance Bank. However, the risk of the energy service company failing to provide adequate technical maintenance services to its customers after leveraging the broader

geographical reach of the MFIs needs to be kept in mind. A2EI is currently exploring what models may work to enable customers to purchase EPCs that they were given for free to facilitate the ongoing experiment.

4.6.2 Opportunities and barriers for e-cooking in mini-grid and microgrid settings

So far, several efforts to test the viability of EPCs in Tanzania have been carried out in mini-grid and microgrid environments. These efforts are significant given that these off-grid approaches are seen as least-cost options for rural electrification in Tanzania and so efforts to diffuse e-cooking appliances in rural areas may be targeted at mini-grid connected households.

The development of mini-grids, microgrids and solar home systems in off-grid rural areas has offered a promising opportunity to diffuse e-cooking appliances outside urban areas. However, the design and manufacture of appliances that can be used within these setups have to take into consideration whether the energy supplied is Direct Current (DC), Alternating Current (AC) or a combination of the two. DC systems have proliferated in Tanzania because they are more modular, scalable and cheaper than AC systems. As a consequence, many off-grid households are using DC power, but the market for AC electric cookers is larger and more established globally. This has spurred R&D in DC cookers, a process that is fraught with various technical design challenges, among them the melting of power cables during cooking.

A potential payment option in a mini-grid setting is the recovery of the cost of electric appliances through daily, weekly or monthly tariffs. In this approach, the product and the financing are available from the same source. Energy companies are able to provide longer-term loans than those MFIs can offer, and they can provide relatively large credit amounts to cover the whole cost of the appliance. As payment for the appliance is linked to access to electricity, credit risk is partially mitigated. This approach also enables significant data collection, which can help the enterprise understand customer behaviour and product performance. PowerGen has tested this approach by allowing customers to pay for their EPCs through prepaid tariff payments. While this has created low upfront costs for customers to acquire EPCs, customers complain of the resulting high tariff level. The electricity units and EPC are prepaid through small-denomination vouchers, and customers find that the units they purchase are used up too fast post-EPC purchase compared to pre-EPC purchase. Consequently, they sometimes either opt not to buy prepaid vouchers or not to use the EPC to lower the cost of electricity. The households then resort back to charcoal as the primary fuel and only rely on the EPC for either light meals, in some instances, heavy meals such as beans, or meals that are susceptible to time constraints. These findings are further confounded by the fact that the pilots by PowerGen, and also by A2EI, were and are being conducted in mini-grid sites that offer lower tariff rates compared to most rural mini-grids. Consequently, there are higher costs to e-cooking for a mini-grid connected household, which calls for more innovative business models to facilitate acquisition of appliances. This is pertinent especially for the EPC, which is a relatively expensive appliance to a rural low-income household.

This approach, otherwise broadly referred to as ‘utility-enabled appliance financing’ (Waldron & Hacker, 2020) has also been proposed as a way to diffuse e-cooking appliances to on-grid customers. Given that the tariffs on the national grid tend to be lower than those in mini-grids, leveraging the assets of the national utility Tanzania Electric Supply Company (TANESCO) may be a viable option to scale e-cooking. TANESCO

has invested in infrastructure, customer relationships, payment and disconnection channels, and has regional service delivery outlets. It is also aggressively expanding its reach across the country with new household connections. To increase electricity usage in households beyond lighting, the utility company could complement its core business of selling electricity with retailing electrical appliances to its customers. The utility could partner with retailers to supply appliances, and with MFIs to offer financing options to customers. However, concerns about the capabilities of the national utility to implement such a business model on its own have been raised, with SESCOM, for example, indicating that it would be challenging for TANESCO to obtain the EPCs on their own as it would be a deviation from their core business. Even so, there is optimism that partnerships would indeed be useful. Implementing such a business model in Tanzania would be dependent on regulations and political will.

4.6.3 Product design and the supply chain interventions for the EPC

One of the biggest challenges and opportunities of facilitating a transition from the current reliance and biomass in Tanzania to the use of electricity for cooking is the availability of affordable cooking technologies that align with cultural and behavioural practices around cooking in Tanzanian households, and that can withstand the conditions in weak-grid or off-grid environments in rural areas of the country.

Households in off-grid areas often have little experience with using any electrical appliances apart from lights, televisions, radios and mobile phones. Beyond customer education through demonstration to build confidence in using new appliances, product design is an important issue to ensure that the appliances are intuitive. For instance, enterprises have quickly learned that rural customers prefer to use EPCs that have a rotary dial as opposed to a digital interface. Further, the appliance needs to be easy to clean and it should have few moving parts. There is also resistance to using Teflon pots, which are common in the EPCs in the market; the demand is for steel pots, which are easier to maintain. Finally, there is a preference for larger appliances that can cook big meals in rural households, where households can sometimes comprise up to 15 members and often share meals with many other guests. After doing market research, TaTEDO established that the Nikai rotary dial EPC best suited the market conditions, and they have been distributing this model since 2017. SESCOM has become the supplier of EPCs in trials as evidenced in the PowerGen and A2EI projects. In addition, due to these and other efforts to create market awareness by doing cooking demonstrations in various parts of the country, training programmes that promote alternative cooking energy technologies, and setting up retail outlets, the demand for EPCs in Tanzania has risen dramatically. The importer and local supplier of Nikai-branded EPCs has not managed to keep up with this demand. As a long-term solution to this emerging supply chain issue, SESCOM decided to collaborate with the Chinese manufacturer of the Nikai brand to tweak certain elements of the appliance to the requirements of the Tanzanian market and rebrand it as a SESCOM EPC, and the company has now entered the product into the 2020 Global LEAP Awards Electric Pressure Cooker competition.

A respondent from the A2EI pilot project indicated that, if the price is right, suitable business models are developed, and robust EPCs are available in the market, EPCs can displace rice cookers as the primary electric cooking appliance in Tanzania. EPCs are more versatile than rice cookers, are cheaper in terms of

energy consumption, and are perceived to be more prestigious. With time, EPCs may substitute rice cookers as bridal and wedding gifts.

4.6.4 Gender dynamics and household practices

In most Tanzanian households, food production and food preparation are seen as a woman's role. Thus, decisions about the types of foods cooked daily, and the types of cooking appliances and fuels used, are made by women. This is a case especially because traditional fuels such as firewood and charcoal are cheap and readily available. However, this dynamic changes when there is a need to acquire more expensive cooking appliances, as men traditionally make financial decisions to acquire high-value assets in the home.

A choice modelling study in rural Tanzania (Scott et al., 2019) found that the decision to purchase an EPC is likely to be made collaboratively by both genders in the same household. The findings of the PowerGen pilot study, on the other hand, show that the female head of the household is more likely to decide on which cookstove to purchase, but the male household head pays for it (Schreiber et al., 2020). The PowerGen study also found that men are willing to purchase an EPC for their own use, whether they are living on their own or living with their female partners, to avoid the hassle of using charcoal or firewood. Some men also expressed concern for the welfare of their female partners cooking with biomass and were willing to make investments in EPCs to ease the burden on their wives of using biomass. These findings indicate that efforts to introduce or scale e-cooking appliances in Tanzania should not only be targeted towards women, but also men. This finding goes against the implied policy position of the Tanzanian Government, which has previously mandated its work on clean cooking to the Department of Community Development, Gender and Children, where efforts are meant to be targeted at women.

Results from previous initiatives in the clean cooking sector – e.g. in the EnDev programme – have shown that women play an important role in market development for clean cookstoves, not only as consumers but also as entrepreneurs: i.e. producers, distributors and marketers. However, these enterprises have remained small and informal, and they are in need of accelerated growth through training and results-based incentives.

4.7 Outlook for e-cooking

The Tanzanian government has embarked on an aggressive programme to connect rural households to the national electricity grid. At the same time, the mini-grid and microgrid sector has been growing rapidly, with Tanzania being one of the countries at the frontier of technological development in this area. The fact that many households will soon be connected to some form of electricity presents an opportunity to induce a transition from the reliance on charcoal and firewood for cooking in cities and rural areas respectively to e-cooking. However, these efforts will be faced by several challenges – outlined above – among them an underdeveloped policy environment, an underdeveloped market, challenges posed by locked-in household cooking practices, the relatively low cost and perceived availability of biomass, and the household-level under-appreciation of the environmental effects of deforestation and the potential effects of climate change.

However, e-cooking pilot programmes have shown that, despite these challenges, there are several opportunities. For instance, it is evident that households who participate in training or cooking demonstrations of e-cooking appliances like the EPC are likely to acquire them and incorporate them into their cooking practices. Creating awareness and lobbying policymakers may also potentially change the policy landscape, and endorsement by policymakers in Tanzania would legitimise e-cooking as a viable alternative. Efforts to develop and distribute locally branded EPCs may also go some way to legitimising e-cooking, and further drive demand.

5 Socio-technical innovation system analysis and discussion

5.1 Actors, networks and central technologies

Our Pinnsmapping exercise suggests there is a large number of actors in the socio-technical innovation system around e-cooking in Tanzania (shown in Figure 3). However, our follow-up research revealed that those who could be considered active players in the system are much fewer (shown in Figure 4). We should therefore interpret the Pinnsmap as depicting all those actors who have an interest in e-cooking, active or passive, together with those whose activities have a bearing on e-cooking practice and so should be seen as potential allies in its promotion. Within the core of active players, TaTEDO is clearly the central actor and they have been working with a small number of others to experiment mostly with electric pressure cookers (EPCs) in mini-grid installations. The bulk of funding for these experiments is coming from development partners such as DFID (through the MECS Programme) and foundations. Little, if any, money seems to be flowing from either the private sector or the Tanzanian Government.

To some extent, this is to be expected in what we can describe as an e-cooking niche (to use the terminology of niche theory, mentioned in Section 2.1). That is, e-cooking is a novel socio-technical practice in Tanzania for which there are many uncertainties and in support of which there is only a small number of active players. It has yet to become mainstream practice, and it has not settled on a dominant configuration of technologies and accompanying cultural practices and meanings, so it cannot yet compete effectively with familiar cooking practices around, for example, biomass and fuel-based cookstoves. As such, the e-cooking niche needs to conduct many experiments to build up knowledge about various aspects of the innovation system it could become while building that system in the process. Until the niche begins to demonstrate its viability – to the private sector, for example – its learning will depend on enthusiastic actors and risk-tolerant sources of funding (i.e. donors, foundations, and so on).

Nevertheless, the learning generated so far should encourage us to think that e-cooking could become established as a mainstream practice, if given the time and resources needed to develop and grow the niche. TaTEDO is already working closely in projects with several actors – PowerGen, A2EI, MECS, and its own commercial arm SESCOM – and has strong connections with relevant policymakers and policy-influencing groups. Apart from the learning these collaborations have already generated, the projects will have enabled relations within this core set of actors to become strong and deep. This needs to continue and develop, especially in terms of expanding our knowledge about the ways in which e-cooking appliances are used in a diversity of real settings and how people can pay for the appliances. The projects conducted so far have produced somewhat mixed findings in this respect. Batchelor et al (2018), for example, find significant cost savings and cooks ready to adopt e-cooking appliances. But the experiment with loans repaid through tariffs in the PowerGen mini-grid installations (Schreiber et al., 2020) produced findings that seem at odds with the idea EPCs are cheaper than fuel-based cooking, where users complained about the electricity cost of cooking with EPCs and reverted to charcoal-based cooking for some meals. Experiments in diverse settings, which could include those with poorer groups of people, could help reveal the reasons for these kinds of outcomes. Such experiments could also be designed to include new actors. This would help grow the network, broaden the range of perspectives involved in the niche, generate important

learning, and provide resources with which to construct persuasive narratives targeted at different actors (see the sub-sections below for more on narratives).

Apart from experiments to see whether and how people use e-cooking appliances, and how to pay for them, there are questions about appliance design such as whether EPCs, for example, need to be able to handle meals for large groups and associated questions about how e-cooking disrupts traditional cooking practices. But there are also questions about whether e-cooking appliances can be manufactured in Tanzania. At present, it seems that cookstove manufacturing is taking place in the informal sector while e-cooking appliances are imported. For the time being, the only option is to import e-cooking appliances, but building the capabilities for their local manufacture could be a way to incentivise more policymakers to take e-cooking seriously, and thereby recruit them to the niche network. Clean cooking at the household level appears to be a low priority issue for policymakers at present, considering it is 'relegated' to the Department of Community Development, Gender and Children and has practically no budget. If there are opportunities to develop commercial production of EPCs, for example, this could be attractive to policymakers seeking to realise Tanzania's industrialisation ambitions. Building capabilities for local manufacture, which could begin with simpler local assembly as in the case of solar PV modules in Kenya (Ockwell & Byrne, 2017), is a relatively long-term endeavour and so it would be helpful to begin the groundwork early. This could start with feasibility studies, involving Tanzanian actors so as to grow the e-cooking niche actor-network, and perhaps consult with firms such as BURN Manufacturing in Kenya to understand what would need to be in place for them to invest in Tanzanian production.

The actor-network in Tanzania's nascent e-cooking socio-technical innovation system needs to develop and grow. This can be facilitated by implementing a variety of projects in diverse settings, working with a growing number of both local and international actors. Achieving this will require more resources and a dedicated coordinating actor working over a long period of time. Without sufficient and secure long-term resources, a coordinating actor is unlikely to be effective. The Clean Cookstoves and Fuels Alliance of Tanzania (CCFAT), for example, which could at least be a useful forum for e-cooking actors, has been dormant because of a lack of funding.

5.2 Social practices and narratives

There are signs a narrative is emerging in the Tanzanian e-cooking socio-technical innovation system, and the emerging narrative appears to be connected in some ways with cooking and other social practices, but it is not yet clear or strong. Findings from some of the research and experimentation work done so far are providing pieces with which to construct this and perhaps other new narratives that engage with cooking practices as enacted in household settings. These pieces include evidence on time and cost-savings, and suggestions of user preferences for replacing dirty cooking fuels and practices, but also indications that e-cooking could be attractive to users for other reasons.

The Batchelor, Leary, et al. (2018) study, which offers encouraging signs that traditional cooking practices centred on biomass fuels and cookstoves could be displaced at least to some extent by e-cooking, finds cooks like e-cooking's cleanliness, where 'cleanliness' refers to the avoided sweat and grime of biomass-based cooking. The authors themselves recognise this benefit could be a powerful argument for promoting

e-cooking among ordinary Tanzanians, in contrast perhaps to the notion dominating development discussions of 'clean' as smoke-free. And the PowerGen study (Schreiber et al., 2020) suggests the smoke-free argument may not have strong traction, where some study participants said that smoke-related health issues arising from biomass-based cooking were "less of a problem". Rather, participants were more interested in the time-savings and improved safety (especially in regard to children) of cooking using EPCs. Nevertheless, 'welfare' played a role in deciding to buy an EPC, with four men purchasing the appliance to "ease the cooking process for their wives". This is suggestive of the kinds of meanings (or values) that people might weave into e-cooking practices and, as we noted in Section 4.6.4, indicates that narratives to promote e-cooking should include attention to men, not just women. But, in terms of targeting women, suggestive evidence of another piece of material for constructing narratives is a quote from the PowerGen study of a participant who said the EPC is "the go-to appliance for the empowered woman". And the familiarity in Tanzania with rice cookers, their widespread use, and the practice of gifting them in bridal showers and weddings, opens up a possibility that the enhanced prestige some say is attached to EPCs could be another route to develop narratives based on powerful social meanings.

The evidence for the above reflections is only weak at present. But it does reveal potential entry points for more specific research to understand the social meanings and values with which e-cooking might resonate among ordinary Tanzanians and so ease the way to disrupting currently dominant cooking practices in favour of electricity-based clean cooking. Research to date has not investigated social practices deeply; the revelations have emerged from studies more heavily tilted towards many of the technical features of e-cooking practice. More specifically targeted work to understand practices in the full sense of the concept, conducted across a wide diversity of settings in Tanzania, would likely yield much stronger evidence and many useful insights for actors in the e-cooking socio-technical innovation system to help them develop powerful narratives. These new narratives will be important for persuading ordinary Tanzanians to adopt e-cooking practices, but they will also be important for persuading policymakers to drive clean cooking higher up their agendas.

5.3 Policy narratives and enabling environment

Our findings suggest there is a need to persuade policymakers to take clean cooking more seriously than they currently do and so there is a need to develop narratives that can spur policymakers into action. Although clean cooking is mentioned in the energy policy, several pieces of evidence indicate that policy support is largely rhetorical. With responsibility for the issue vested in the Department of Community Development, Gender and Children rather than a more powerful actor such as the Ministry of Energy (MOE), with little or no budget allocation to promote clean cooking practices, and with a weak regulatory regime for cookstoves, it is clear there is minimal political will to promote clean cooking of any kind. There are several pressures clean cooking can help relieve, such as climate change, deforestation and air pollution. And there are, already, indirect actions foundational to the development and growth of e-cooking, in particular, such as the electrification strategy. But the policy problem, judging by the few statements given in the energy policy, seems to be one of fuel-switching facilitated with appropriate appliances. In practice, this seems to translate into the promotion of improved cookstoves and some ambition towards greater use of liquified petroleum gas (LPG). Advocates for e-cooking will need to widen

the boundaries of the policy problem, as it is understood by policymakers, and create narratives that argue for government intervention that extends beyond simply promoting technologies. Useful elements of such narratives can be seen in the need to relieve the pressures we just noted and in making use of the electrification strategy. But more needs to be done.

There are also opportunities to link e-cooking with Tanzania's development ambitions. Chief among these ambitions, perhaps, is the industrialisation goal articulated in the country's development vision for 2025 to achieve a strong and competitive economy (URT, 1999). Although the country has achieved middle-income status five years earlier than its ambition stated in the development vision, its gross national income is only just above the threshold for the lower middle income category, and it has not yet achieved the diversified and resilient economy envisioned. The local design and manufacture of e-cooking appliances could make an important contribution to Tanzania's economic diversification aspirations. Achieving local manufacture is certainly a long-term endeavour, considering that local cookstove production is predominantly in the informal sector for now and is said to be of poor quality. However, with suitable interventions conducted over the long-term, local production of e-cooking appliances may be in reach. Efforts will need to start early and may need to begin with feasibility studies to determine what practical steps must be taken before constructing narratives that include such ambitions, but the policy resonance of this agenda is likely to be strong. Potential barriers to progress include the extent to which biomass-based cooking interests will be threatened and so these should also be investigated. If such interests are real and powerful, it may be possible to work with those vested in biomass-based cooking to help them shift to the production of e-cooking appliances.

The gender dimension of clean or e-cooking practice also needs addressing. Household cooking may be a deeply gendered practice, but assuming this means the promotion of clean cooking should only speak to women is probably short-sighted. Women and men may perceive different benefits in clean cooking practices, but policy needs to consider both genders in its interventions. Moreover, narratives that speak in constructive terms about clean cooking and men could help raise the status of the practice, both in the country generally and in policy circles specifically. Raising its status may push it higher up the policy agenda and this, in turn, could lead to its inclusion in the mandates of more powerful state actors along with winning more resources for its promotion. This is a long chain of possibilities and so achieving success will likely be a long-term process. Therefore, as with the industrialisation argument discussed above, efforts need to start early.

Ultimately, the point is to create in Tanzania a more enabling policy environment for the promotion of e-cooking practices, and the building of an e-cooking socio-technical innovation system, the specific focus of this paper. The policy environment as it currently exists is only partially conducive to strong action in favour of e-cooking practices. Much work remains to be done but there are actors present in Tanzania who are already pushing e-cooking, and there are some in policy circles who have at least demonstrated sympathetic support for clean cooking, such as members of CCFAT, albeit in terms of improved biomass and alternative fuel cookstoves. Narratives that link currently felt pressures – e.g. climate change, deforestation, air pollution – hopeful governmental action such as increased electrification, and potentially

powerful socio-political agendas – industrialisation, better gender outcomes, poverty eradication – can help create social pressure and strong policy motivations to substantially improve the enabling environment for e-cooking.

5.4 Summary

In summary, the e-cooking socio-technical innovation system in Tanzania is nascent at present. Its actor-network consists of a small core but has potential to draw in many others, as identified in our Pinnsmapping exercise. Central to the core set of actors is TaTEDO, who also have a long history working with others around cooking practices in general in Tanzania. TaTEDO has already been involved in a small number of experiments with e-cooking appliances, working with a handful of actors including the MECS Programme, from which several promising indicators of the potential for e-cooking have emerged. Among these indicators, there is evidence that EPCs are attractive to ordinary Tanzanians, both women and men, and that EPCs can be easily adopted, could reduce cooking costs and indoor air pollution, and improve cooking safety. Also, from these experiments, there are suggestions of elements that could form the basis for strong narratives to promote e-cooking practices. However, only a small number of people have been involved in these experiments and they have only been conducted in a few settings. Constructing e-cooking narratives that resonate with ordinary Tanzanians will be helped by conducting more research in a wider diversity of settings, especially research that investigates the relationships between e-cooking technologies, the skills needed to use them, and the meanings (and values) that could be embedded into e-cooking practices, in the fullest sense of the practice concept. Meanings and values such as welfare, prestige, cleanliness (in the sense of less sweat and grime endured during cooking), safety, empowerment and modernity were all detected in the experiments conducted so far. Others could be revealed with more research and the evidence for any or all of them could be strengthened. Uncovering these meanings could also shape the specifics of technology designs by helping designers target what ordinary users value.

Much more work also needs to be done on other dimensions of the socio-technical innovation system. An important and obvious weakness at present is the policy environment. Although there are some positive developments that support e-cooking, such as the electrification strategy, they are only indirect. Achieving more direct and active policy interventions to nurture the evolution of the socio-technical innovation system will require, among other things, narratives that are persuasive to policymakers whose support for clean cooking, it would seem, remains largely rhetorical. Again, there are elements that can be used to construct such narratives, such as addressing climate change, deforestation and air pollution, along with perhaps more 'positive' goals such as contributing to Tanzania's industrialisation ambitions. Such narratives might be constructed quite quickly, but the efforts to achieve a more nurturing policy environment, and the many efforts needed to build the wider socio-technical innovation system, will be needed over the long-term. Short-term wins are likely to be small and so the effort will need to be sustained through the provision of risk-tolerant funding, which means donors and other development partners will need to be the primary sources of money. And the work to build an e-cooking socio-technical innovation system will entail strategic implementation of numerous multi-stakeholder projects of various kinds – technological development, experiments with finance, understanding social practices, building capabilities, advocating

for specific policies, managing actor-networks, circulating learning, and more – and so it would be better to establish a well-resourced coordinating actor tasked with such objectives. It would also be helpful if that actor were based locally and dedicated to building the innovation system. In the long-term, it would be difficult for the MECS Programme to take on this role, given that it is already responsible for multiple multi-partner projects across many countries. Instead, the MECS Programme could seek to determine a suitable local actor or help establish one.

6 Recommendations for the MECS Programme

Our study has revealed there is a large number of relevant and interested players who could form the actor-network in Tanzania's e-cooking socio-technical innovation system, but there is only a small core who are active at present. TaTEDO, a long-standing player in the Tanzanian cooking domain, is clearly the central actor in this small core. Together with a few other players, including the MECS Programme, TaTEDO have been involved in several e-cooking projects, experimenting mainly with electric pressure cookers (EPCs) in mini-grid installations. Evidence emerging from these experiments is encouraging that EPCs are attractive to ordinary Tanzanians for various reasons, including some that could contribute to positive 'developmental' outcomes such as savings in energy costs and cooking times, improved cooking safety and reduced health problems. But other characteristics of EPC-based cooking are also attractive to cooks, especially their cleanliness compared with biomass-based cooking: i.e. cooking with an EPC results in much less sweat and grime. At a deeper level, the experiments conducted so far suggest, albeit with only weak evidence for now, that EPCs can resonate with meanings and values such as welfare, prestige, modernity and empowerment, amongst others. These technical and social findings are helpful for constructing narratives designed to communicate the benefits of e-cooking to ordinary Tanzanian women and men. And, together with the small core of active players, there is a useful basis upon which to start building in earnest an e-cooking socio-technical innovation system. However, the policy environment is clearly weak in its support for clean cooking and so effort is needed to work with policymakers, among others, to raise the status of cooking on policy agendas and to develop policy instruments that will help nurture the long-term building of the innovation system.

To this end, we offer here some recommendations for the MECS Programme to consider in its efforts to contribute to the building of a Tanzanian e-cooking socio-technical innovation system. Readers should take note, however, that we will be conducting further research to understand how the current nascent innovation system has evolved in Tanzania and, based on this further work, we will likely be able to say more about how MECS can support the development of the system. In this sense, the recommendations given below are somewhat tentative. It may also be the case that the MECS Programme is already implementing or planning to implement the recommendations given here. We offer our recommendations even if this is the case.

1. **Increase the number and variety of multi-stakeholder projects conducted in diverse settings across Tanzania**

   Much more learning about the full range of socio-technical innovation system dimensions is needed. These dimensions include, but are not limited to, technology development. They also include the 'breadth' of the actor-network, and the nature and strength of relations between actors in the network. Alongside these, the system includes social practices, the policy environment, supply chains, business models, actors' capabilities, and more. To achieve learning across these dimensions, MECS should seek to implement an increase in the number and variety of e-cooking projects across a diversity of settings in Tanzania. Moreover, these projects need to involve multiple stakeholders. This will increase the chances of learning and facilitate the circulation of that learning through the resulting

expansion of the innovation system's actor-network. Multiple stakeholders working together in a range of projects will also likely build trust and deepen actor-relations.

2. **Conduct more research that specifically investigates cooking and related social practices**

   The research conducted so far in Tanzania has revealed some promising aspects of experimenting with e-cooking that connect with potentially important social meanings and values. But more evidence – gathered across diverse settings – is needed before developing strong and clear e-cooking narratives that will resonate with ordinary Tanzanians. Meanings and values evoked through the e-cooking experiments to date include welfare, safety, prestige, modernity, empowerment and cleanliness. But the evidence for this is weak at present. Research targeted specifically at cooking and related practices will help reveal the extent to which e-cooking is disruptive of biomass-based cooking practices and the ways in which e-cooking can evolve with new practices through which ordinary Tanzanians can express meanings and values that are powerful for them. The results will not only be useful for persuading Tanzanians of the benefits of e-cooking but could also be useful for evolving technology designs to align more closely with the preferences of Tanzanians.

3. **Help policymakers to widen their conception of the clean cooking challenge beyond promoting improved cookstoves and alternative fuels**

   The policy environment for clean cooking is currently weak in Tanzania, and policymakers do not seem to take the issue seriously, despite policy statements committing to SE4All and the sustainable development goal on energy access. The MECS Programme can work with others such as TaTEDO, who already have good connections with policymakers and policy-influencing actors, to help policymakers widen their conception of the clean cooking challenge and its opportunities. This includes not only persuading policymakers to think of the issue beyond technology and alternative fuels but also to understand the systemic nature of meeting the clean and e-cooking challenge. By systemic nature of the challenge, we mean the interlinkages between cooking practices and various pressures policymakers need to relieve such as climate change, deforestation, air pollution, among others. These interlinkages are only weakly articulated in the Government's policies and actions. The electrification strategy is one positive example of where these issues are connected. But more opportunities exist in e-cooking's potential that could be used to further Tanzania's development goals. Among these opportunities is the possibility to develop local manufacture of e-cooking appliances and so further Tanzania's industrialisation ambitions. We will return to this in the next recommendation. However, policymakers will need to be persuaded to take clean cooking more seriously and they will need to understand the interconnections e-cooking can help articulate. To do this, it would be useful for MECS to work with local partners to construct policy-focussed narratives that join the various issues and opportunities together coherently. Evidence from the increased number of projects, recommended above, would go some way to providing the pieces from which to construct such narratives.

4. **Understand the broader forces at work that may hinder, either passively or actively, the building of a strong e-cooking socio-technical innovation system**

   It is important to understand the other factors that may impede progress with e-cooking, beyond policymakers' narrow conception of the challenges and beyond the specific challenges of making e-cooking appliances work in Tanzanian contexts. The biomass sector generates significant revenues for its supply-side actors, and biomass cooking practices are deeply embedded in Tanzanian life. These are two signals that suggest there is a powerful and rigid 'dirty' cooking socio-technical regime in place in Tanzania (to use the conceptual language of socio-technical transitions). The nascent e-cooking niche must compete with this regime yet does not have the same powerful resources at its disposal as the regime. Research to understand the dirty cooking regime would be useful for characterising the nature of the challenge facing the e-cooking niche and may even identify ways in which to 'destabilise' it in favour of the niche practice. Alternatively, or in addition to understanding the regime, political economy analysis of dirty cooking could be helpful (e.g. see Sander et al., 2013 for a political economy analysis of the charcoal sector in Tanzania).

5. **Investigate the potential for local production of e-cooking appliances**

   At present in Tanzania, there is production of biomass cookstoves. But this is taking place mainly in the informal sector and is said to be of poor quality. E-cooking appliances must be imported. As part of building the e-cooking socio-technical innovation system, MECS could support the investigation of local production of e-cooking appliances. Establishing full-scale manufacture is likely to be a long-term effort but there may be short-term potential to begin assembly of products. As shown elsewhere – e.g. with the electronics industry in East Asia (Hobday, 1995), and with solar PV in Kenya (Ockwell & Byrne, 2017), amongst many others – the establishment of new industrial sectors can begin with local assembly and over time move up the value chain to original equipment manufacture. Tanzania has ambitions to industrialise and the e-cooking industry could be a candidate to help realise this ambition. Generating the evidence for how this could happen would be helpful in persuading policymakers to take clean cooking more seriously. Investigation could begin with feasibility studies including, perhaps, the involvement of those who currently produce cookstoves as well as EPC manufacturers such as BURN in Kenya. This should lead to an understanding of what needs to be in place for appliance manufacturers to invest in Tanzanian production. But the process to develop local manufacturing will be a long-term endeavour so it will need risk-tolerant funding, which likely means funding from public sources such as donors, and strategic implementation.

6. **Make the argument for more active public intervention to help build the e-cooking socio-technical innovation system**

   The MECS Programme can make the argument for more active public interventions to build the socio-technical innovation system. The money to fund interventions can come from the Tanzanian government but, as we noted above, the bulk of it will likely be needed from donors and other development partners. This is because it will be a long-term effort with perhaps only small short-term wins and so will need risk-tolerant funders prepared to stay for the long-term. Without active publicly

supported interventions, of the kind discussed in the recommendations above, the socio-technical innovation system will emerge extremely slowly and is unlikely to evolve beyond importing products and business models designed and developed elsewhere. As a result, Tanzanians may get access to e-cooking appliances but there will be few, if any, economic gains and perhaps even economic losses, where profits are extracted by companies based outside the country.

7. **Establish a local dedicated actor to strategically coordinate socio-technical innovation system building**

   The recommendations given above imply a range of complicated and long-term efforts are needed to build the e-cooking socio-technical innovation system in Tanzania. The MECS Programme can spearhead some of these for the time-being, working with key local actors. However, it is unlikely that MECS can perform this role for long, especially if the number of projects proliferates – as it needs to do – and the number of actors in the innovation system's network expands substantially. It would therefore be wise to begin establishing a well-resourced local actor who can focus efforts on analysing the state of the innovation system, and on designing and implementing the kinds of projects mentioned above. Such an actor can also convene forums for e-cooking stakeholders, manage actor-relations, advocate for policy interventions, and more. In effect, the actor will be a socio-technical innovation system builder for e-cooking in Tanzania, much the same as system builders played important roles in the solar PV innovation systems in Kenya and Tanzania (Byrne, 2011; Ockwell et al., 2019; Ockwell & Byrne, 2017).

References

Avila, E., Lawrence, G., Lin, J., Howard, N., Mohamed, B., & Ally, H. (2019). *The Desirability of Clean Cooking in Off-Grid Households*. Access to Energy Institute.

Batchelor, S., Brown, E., Leary, J., Scott, N., Alsop, A., & Leach, M. (2018). Solar electric cooking in Africa: Where will the transition happen first? *Energy Research & Social Science*, *40*, 257–272. https://doi.org/10.1016/j.erss.2018.01.019

Batchelor, S., Leary, J., Sago, S., Minja, A., Chepkurui, K., Sawe, E., Shuma, J., Scott, N., Leach, M., & Brown, E. (2019). *Opportunities & Challenges for eCook Tanzania*. https://mecs.org.uk/wp-content/uploads/2019/10/eCook-TZ-Country-Working-Paper-24-10-18-COMPRESSED.pdf

Batchelor, S., Leary, J., Sago, S., Minja, A., Sawe, E., Shuma, J., Scott, N., Leach, M., & Brown, E. (2018). *eCook Tanzania Country Report: Opportunities and Challenges in Tanzania* (August; MECS Working Paper). Modern Energy Cooking Services Programme. https://www.researchgate.net/publication/327535651_eCook_Tanzania_Country_Report_Opportunities_and_Challenges_in_Tanzania_August_2018_Working_Paper

Byrne, R. (2011). *Learning drivers: rural electrification regime building in Kenya and Tanzania*. University of Sussex.

Byrne, R., Mbeva, K., & Ockwell, D. (2018). A political economy of niche-building: Neoliberal-developmental encounters in photovoltaic electrification in Kenya. *Energy Research & Social Science*, *44*, 6–16. https://doi.org/10.1016/j.erss.2018.03.028

Chaminade, C., Lundvall, B.-Å., Vang, J., & Joseph, K. (2009). Designing innovation policies for development: towards a systemic experimentation-based approach. In B.-Å. Lundvall, K. Joseph, C. Chaminade, & J. Vang (Eds.), *Handbook of Innovation Systems and Developing Countries: Building Domestic Capabilities in a Global Setting* (pp. 360–379). Edward Elgar.

Chepkurui, K., Leary, J., Minja, A., Sago, S., & Batchelor, S. (2019). *eCook and Gender in Tanzania* (MECS Working Paper).

Douthwaite, B., Alvarez, S., Keatinge, J. D. H., Mackay, R., Thiele, G., & Watts, J. (2009). *Participatory Impact Pathways Analysis (PIPA) and Research Priority Assessment*. Cabi Publishing. https://doi.org/10.1079/9781845935665.0008

EEG. (2016). *Tanzania Energy Sector Overview*. Applied Research Programme on Energy and Economic Growth.

Ely, A., & Oxley, N. (2014). *STEPS Centre Research: Our Approach to Impact* (No. 60; STEPS Working Paper).

EWURA. (2019). *Annual Report for the year ended 30th June 2019*. Energy and Water Utilities Regulatory Authority, United Republic of Tanzania.

Freeman, C. (1987). *Technology and Economic Performance: Lessons from Japan*. Pinter.

Freeman, C. (1997). The National System of Innovation in Historical Perspective. *Cambridge Journal of Economics*, *19*, 5–24.

Geels, F. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy*, *31*, 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, *33*, 897–920. https://doi.org/10.1016/j.respol.2004.01.015

Hobday, M. (1995). East Asian latecomer firms: Learning the technology of electronics. *World Development*, *23*(7), 1171–1193. https://doi.org/10.1016/0305-750X(95)00035-B

Hudson, D., & Leftwich, A. (2014). *From political economy to political analysis* (DLP Research Paper).

IRENA. (2017). *Renewables Readiness Assessment in the United Republic of Tanzania*. International Renewable Energy Agency.

Kammila, S., Kappen, J. F., Rysankova, D., Hyseni, B., & Putti, V. R. (2014). *Clean and Improved Cooking in Sub-Saharan Africa: A Landscape Report*. World Bank.

Leach, M., Scoones, I., & Stirling, A. (2010). *Dynamic Sustainabilities: Technology, Environment, Social Justice*. Routledge.

Leary, J., Batchelor, S., Leach, M., Brown, E., & Alsop, A. (2018). *eCook Global Market Assessment: Where will the transition take place first?* (MECS Working Paper). Modern Energy Cooking Services Programme. https://doi.org/10.13140/RG.2.2.22612.30082

Leary, J., Batchelor, S., Sago, S., Minja, A., Chepkurui, K., Sawe, E., Shuma, J., Leach, M., Scott, N., & Brown, E. (2019). *Policy & National Markets Review for eCook in Tanzania* (MECS Working Paper). Modern Energy Cooking Services Programme.

Leary, J., Sago, S., Minja, A., Batchelor, S., Chepkurui, K., Sawe, E., Shuma, J., Leach, M., Scott, N., & Brown, E. (2019). *eCook Tanzania Prototyping* (MECS Working Paper).

Leary, J., Sago, S., Minja, A., Chepkurui, K., Sawe, E., Shuma, J., & Batchelor, S. (2019). *eCook Tanzania Focus Group Discussions Summary Report* (MECS Working Paper).

Leary, J., Scott, N., Sago, S., Minja, A., Batchelor, S., Chepkurui, K., & Sawe, E. (2019). *eCook Tanzania Cooking Diaries* (MECS Working Paper).

Lundvall, B.-Å. (1988). Innovation as an interactive process: from user-producer interaction to the national system of innovation. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg, & L. Soete (Eds.), *Technical Change and Economic Theory*. Pinter.

Lundvall, B.-Å. (1992). *National systems of innovation: towards a theory of innovation and interactive learning*. Pinter.

Mokveld, K., & von Eije, S. (2018). *Final Energy report Tanzania*. Netherlands Enterprise Agency.

Ockwell, D., & Byrne, R. (2016). Improving technology transfer through national systems of innovation: climate relevant innovation-system builders (CRIBs). *Climate Policy*, *16*(7), 836–854. https://doi.org/10.1080/14693062.2015.1052958

Ockwell, D., & Byrne, R. (2017). *Sustainable Energy for All: Innovation, Technology and Pro-Poor Green Transformations*. Routledge.

Ockwell, D., Byrne, R., Chengo, V., Onsongo, E., Fodio Todd, J., & Atela, J. (2019). *Transforming access to clean technology: Learning from Lighting Africa* (No. 110; STEPS Working Paper). STEPS Centre. https://opendocs.ids.ac.uk/opendocs/handle/123456789/14684

Odarno, L., Sawe, E., Swai, M., Katyega, M. J. J., & Lee, A. (2017). *Accelerating Mini-Grid Deployment in Sub-Saharan Africa: Lessons from Tanzania*. World Resources Institute.

OECD/Eurostat. (2019). *Oslo Manual 2018* (4th ed.). OECD. https://doi.org/10.1787/9789264304604-en

Rajabu, H., & Ndilanha, A. (2013). *Improved Cook Stoves Assessment and Testing*. ICS Taskforce Tanzania.

Rajabu, H., Rweyemamu, L., Sago, S., Sawe, E., Laswai, E., Matimbwi, M., Lelievre, M., & Magessa, F. (2014). *Country Action Plan for Clean Cookstoves and Fuels*. ICS Taskforce in collaboration with Clean Cookstoves and Fuels Alliance of Tanzania (CCFAT).

Raven, R. (2005). *Strategic niche management for biomass: a comparative study on the experimental introduction of bioenergy technologies in the Netherlands and Denmark* [Technische Universiteit Eindhoven]. http://alexandria.tue.nl/extra2/200511821.pdf

Rolffs, P., Ockwell, D., & Byrne, R. (2015). Beyond technology and finance: pay-as-you-go sustainable energy access and theories of social change. *Environment and Planning A*, *47*(12), 2609–2627. https://doi.org/10.1177/0308518x15615368

Sander, K., Gros, C., & Peter, C. (2013). Enabling reforms: Analyzing the political economy of the charcoal sector in Tanzania. *Energy for Sustainable Development*, *17*(2), 116–126. https://doi.org/10.1016/j.esd.2012.11.005

Sawe, E., & Aloyce, K. (2020). *The Tanzania eCookbook: Plus eRecipes for Tanzanian Staple Foods*. TaTEDO. https://mecs.org.uk/wp-content/uploads/2020/07/Tanzania-Ecook-Book-text-web.pdf&usg=AOvVaw2TM-zTOkCve3M0m5DJ2sIz

Schreiber, K., Waceke, M., & Blair, H. (2020). *Electric pressure cooking: accelerating microgrid e-cooking through business & delivery model innovations*. Efficiency for Access.

Scott, N., Leary, J., Sago, S., Minja, A., Batchelor, S., Chepkurui, K., & Sawe, E. (2019). *eCook Tanzania Discrete Choice Modelling* (MECS Working Paper).

SE4All, & CPI. (2019). *Energizing Finance: Understanding the Landscape 2019*. Sustainable Energy for All.

TaTEDO. (2020). *Approach to Designing Delivery Models of Modern Energy Cooking Services in Tanzania*.

Modern Energy Cooking Services Programme. https://mecs.org.uk/wp-content/uploads/2020/06/MECS-TRIID-Tatedo-Final-Project-Report-1.pdf

URT. (1999). *The Tanzania Development Vision 2025*. Planning Commission, United Republic of Tanzania.

URT. (2003). *The National Energy Policy*. Ministry of Energy and Minerals, United Republic of Tanzania.

URT. (2014). *Electricity Supply Industry Reform Strategy and Roadmap*. Ministry of Energy and Minerals, United Republic of Tanzania.

URT. (2015a). *National Energy Policy*. Ministry of Energy and Minerals, United Republic of Tanzania.

URT. (2015b). *Tanzania's SE4All Action Agenda*. Ministry of Energy and Minerals, United Republic of Tanzania.

Villema, N., Sago, S., Sawe, E., Minja, A., Leary, J., Chepkurui, K., Shuma, J., Brown, E., Batchelor, S., & Leach, M. (2018). *The National Stakeholders' Solar Electric Cooking Workshop* (MECS Working Paper). Modern Energy Cooking Services Programme. https://mecs.org.uk/downloads/the-national-stakeholders-solar-electric-cooking-workshop/

Waldron, D., & Hacker, S. (2020). *Electric Bankers: Utility-Enabled Finance in Sub-Saharan Africa* (May; Consultative Group to Assist the Poor Working Paper). https://www.cgap.org/research/publication/electric-bankers-utility-enabled-finance-sub-saharan-africa

Watson, J., Byrne, R., Morgan-Jones, M., Tsang, F., Opazo, J., Fry, C., & Castle-Clarke, S. (2012). *What are the major barriers to increased use of modern energy services among the world's poorest people and are interventions to overcome these effective?* Collaboration for Environmental Evidence. http://www.environmentalevidence.org/SR11004.html

Annex I: Interview guide for organisations in the Pinnsmap

[Name of organisation]

SECTION A. General questions

1. About the respondent
   a) Name
   b) Role/designation in the organisation
   c) No. of years worked in current organisation
   d) No of years worked in the energy sector; e-cooking subsector
   e) Previous organisations and roles on those organisations (related to energy and cooking)

2. About the organisation
   a) When did the organization start work on energy?
   b) What is the scope of work done by [the organisation] in the country in the energy sector? What are the focus areas of the organisation?
   c) Involvement in e-cooking:
      i) When did the organisation first get involved in the cooking sector?
      ii) Which departments are involved in projects or initiatives in the e-cooking sector? How large are those departments?
      iii) Does the organisation do any research and development (R&D)/ in e-cooking?
      iv) List and describe the organisation's independent projects on e-cooking (chronologically)
      v) List and describe the organisation's multi-partner/multi-stakeholder projects on e-cooking
         (1) When did it start? Ongoing? Has it ended? When?
         (2) Which partners does the organisation work with in these projects?
         (3) What stimulated the formation of the partnership/ project? e.g. which events, new policies/policy changes, opportunities, etc?
         (4) What were the objectives of the partnership/interaction?
         (5) What technology(ies) was (were) being focused on in the project/partnership?
         (6) What were the achievements of the project? Successes and failures in the interaction?
         (7) Was there any resistance within the project/partnership?
         (8) What were the lessons learned?
         (9)
      vi) Beyond the projects above, what activities has the organisation engaged in to advocate/lobby for e-cooking diffusion and adoption?

vii) What other factors in the operating environment have influenced the development of e-cooking projects/initiatives/partnerships in the organisations? e.g. specific events, policies, opportunities, technological developments, etc.

SECTION B. Specific questions (based on the Pinnsmap)

- Show the Pinnsmap to the respondent
- Probe the respondent to respond to their organisation's position on the map, the identified partners, and description of interactions
- If there are interactions in the map that were not mentioned in Section A, part 2, move on to question 3 below.

3. Please expound further on this organisation's relationship with:
[Point out the previously omitted organisations that interact with the respondent, and probe further based on the specifics of that interaction. The questions below would help pre-empt some answers on the relationship on the Pinnsmap]

Example for TaTEDO

a) <u>SESCOM to market EPCs</u>:
   i) Tell us more about the partnership.
   ii) To what extent has this partnership worked so far??
      (1) How many households and enterprises have you reached so far?
   iii) Which cooking technologies have you been marketing?

b) <u>TIRDO for testing and cookstoves</u>
   i) When did this partnership begin?
   ii) What technologies have you focused on under this partnership?
   iii) Have you tested any electric cooking technologies under the partnership? If yes, what testing protocols form the basis of the tests?

c) Are there interactions between TaTEDO and other organizations in electric cooking that are not highlighted on the map?
   i) If yes, tell us about them.

SECTION C. The bigger picture

1. To the best of your knowledge, is the rest of the map accurate? Are there stakeholders or players that are key to e-cooking in Tanzania that were left out of the map?
2. Are the interactions between the players captured accurately? Do you know of collaborations that are not highlighted within the map?
3. Which actors on the map are the most powerful? What is their influence?
4. Which actors are creating resistance in the development of e-cooking in Tanzania?
5. Which ones have potential to influence the map (the e-cooking innovation system) significantly in the future?
6. What are your thoughts on the trajectory of the e-cooking innovation system in Tanzania?
7. What role has policy /government played in e-cooking, beyond rhetoric?
8. What other elements of the operating environment or context are missing on the map?

Follow-up

9. Do you have partner organizations or contact persons working in e-cooking in Rwanda and/or Kenya?
10. Who else can you recommend that we speak to for a richer understanding of e-cooking?

Annex II: List of organisations and persons interviewed

Organization	Name of Representative	Designation
A2EI	Ansila Kweka	Senior Research Associate
CLASP	Hannah Blair	Communications Associate
	Monica Wambui	Associate
PowerGen	Eliud Mjuni	Customer Care and Site Manager
SESCOM	Shukuru Meena	Manager
	Mary Lema	Project Manager
	Katarina Aloyce	
TaTEDO	Eng. Estomih Sawe	Executive Director
	Jensen Shuma	Resource Mobilization and Information officer