Policy & National Markets Review for eCook in Tanzania

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1 Executive Summary

This report summarises the findings from a review of policy and national markets in Tanzania, with the aim of informing the development of a battery-supported electric cooking concept, eCook. Each country has unique market dynamics that must be understood in order to determine which market segments to target are and how best to reach them. It is part of a broader programme of work, designed to identify and investigate the opportunities and challenges that await in high impact markets such as Tanzania. The study had two dimensions:

1. to review the **current regulatory framework** in Tanzania and assess which polices are likely to **accelerate the uptake** of the eCook concept and which may present **significant barriers**.
2. to assess the st**ate of the existing clean cooking and grid/mini-grid/off-grid electrification markets,** which may provide the foundation for future eCook products/services

1.1 Aligning the electrification and clean cooking sectors

This review has confirmed that there is a **strong market for eCook products and services in Tanzania**. Electrification and clean cooking are currently seen as two separate domains, however **eCook has the potential to unite the two**. To date, progress in electrification has been relatively rapid, whilst clean cooking has lagged behind. Tanzania has a **world leading mini-grid sector** and the **market for solar home systems is developing rapidly**. It is also one of the world's **biggest charcoal markets**, creating several global deforestation hotspots. eCook presents a transformative opportunity to leverage this encouraging progress to drive forward the equally important goal of ensuring universal access to clean cooking by 2030, in line with SDG 7.

The potential impact of eCook cuts across various national development priorities – from gender equity to sustainable forestry. As in most countries, Tanzania presents a complex mix of institutions & responsibilities. Since eCook is not obviously an 'improved stove' in the biomass sense (it is also mechanism to increase access to reliable electricity) it is difficult to know which stakeholders to lobby & in which sequence. Whilst **TANESCO** is clearly the major stakeholder for Grid-eCook, and **REA's** mandate suggest they will be an important player in the off-grid space, however the SPPs (**Small Power Producers**) open up new opportunities in rural areas via Mini-Grid-eCook. The private sector is likely to drive ecook forward, as by 2020 it should be possible to create systems that are profitable to the developer, yet cheaper to the consumer than expenditures on charcoal or kerosene. In rural Tanzania, **off-grid solar systems now outnumber grid connections**, creating a huge opportunity for PV-eCook.

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1.2 Cooking with grid electricity

Frequent blackouts and voltage fluctuations on TANESCO grid suggest supporting electric cooking appliances with a battery would enable much more widespread adoption of electricity as a primary cooking fuel. Voltage instability can affect cooker performance as much as blackouts. Cooking with appliances designed for 220V is noticeably slower below 200v and impossible below 150v. TANESCO has a high dependence on hydropower, which is likely to lead to further load shedding in future dry seasons

In fact, the cooking diaries show that **smaller households with efficient appliances can cook using TANESCO's 75kwh/month lifeline tariff**. However, lobbying EWURA to increase lifeline tariff allowances or create a time of use tariff could be key enablers for larger households or those with shared meters. However, further tariff increases should be expected as despite rising 40% in 2012, TANESCO is still unable to cover its costs. Importantly though, **eCook offers TANESCO the opportunity to increase its revenue per connection** & reduce dependence on emergency generators through distributed storage. What is more, if all new connections included distributed household storage via Grid-eCook, the load profile would be much flatter and supporting infra-structure could be much smaller and cheaper.

In fact, the 120USD that many Tanzanian households have already paid for a grid connection is likely to be more than enough for a deposit on a PV-eCook system. What is more, the techno-economic modelling shows that at 700USD, the investment cost of a PV-eCook system in 2020 is likely to be less than grid extension or mini-grids, which have to recover the majority of their costs through consumption charges.

1.3 The opportunity for cooking on mini-grids and solar home systems

Tanzania is a **global leader in mini-grid development,** presenting a diverse range of opportunities. Mini-grid-eCook should target **spare capacity at off-peak hours** on hydropower mini-grids or load limited solar mini-grids with battery-supported cooking appliances. In fact, mini-grids with spare capacity at peak times could begin to market **off-the-shelf electric cooking appliances today**. Time of use tariffs could incentivise off-peak cooking. Tariffs on private mini-grids are currently significantly higher than TANESCO's, but efficient appliances such as the electric pressure cooker are still likely to be cost effective. The **resources available in each part of the country vary significantly**, creating different opportunities for Mini-Grid-eCook. In wet and hilly topography, such as Kilimanjaro, Mbeya or Njombe, **hydropower is still the most cost-effective option**. Meanwhile, **solar mini-grids are opening up new opportunities** for renewable generation in regions without hydro or biomass resources.

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In communities where many households are already paying for cooking fuel, eCook could greatly **enhance the development impact of mini-grids**. Mini-grids in peri-urban areas are likely to be more attractive for Mini-Grid-eCook, as people are more likely to be paying for cooking fuel than in rural areas.

So**lar lighting in Tanzania is booming - in 2014 the industry was reportedly worth 9 million USD**. M-kopa, Zola & Mobisol seem to be the market leaders in Tanzania's solar home system market. Working with them to develop a cooking upgrade for their existing customers will be an obvious route to scale for PV-eCook.

Strong solar irradiation & a hot, but not extreme climate make the Tanzanian climate virtually ideal, as PV panels will produce more, batteries are unlikely to be damaged by extreme temperatures & stoves are not expected to perform the dual function of space heating, greatly reducing energy demand & therefore battery size/cost. PV-eCook systems at the foot of Kilimanjaro would need almost twice as much PV as in Dodoma. Fortunately, most of Tanzania is much less cloudy. However, **PV is no longer the major cost in off-grid solar systems**, it is battery storage, which would be equal in both cases. The solar resource is high & steady throughout the year in almost all of Tanzania, so PV-eCook systems can be cost-effectively designed for year round use. Targeted **exchange programs for, in particular, female solar entrepreneurs in the clean cooking industry** could help prepare them for PV-eCook.

1.4 Clean cooking

The review revealed that **policy support is already in place for key drivers behind eCook**: **environmental protection** (deforestation and climate change), **health** (indoor air pollution), **gender equity** and **energy access** (electricity). The SEforAll GTF (Global Tracking Framework) currently measures **access to clean cooking solutions in Tanzania at just 2%.** A quantum leap will be required to meet the >75% target for 2030! However, no coordinated clean cooking strategy yet exists, leaving the future direction unclear. Biomass still dominates cooking and to date there have been few alternatives.

Charcoal use in Dar es Salaam is causing a **global deforestation hotspot**. Current mitigation strategies focus on improving the efficiency of charcoal supply and reducing demand through more efficient biomass stoves and LPG. A Biomass Energy Strategy (BEST) has been developed, however, there is a growing awareness globally that the strategy of 'improved cookstoves' needs something new to break out of this 'business as usual' cycle. Charcoal is the fuel of choice for the rich and as Tanzania's economic hub, Dar es Salaam is the epicentre, with 88% of the population cooking with

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charcoal. **Dar residents spend an average of 50,000TZS (22USD) every month**, creating an attractive potential revenue stream for future Grid-eCook products.

Tanzania's population will double by 2050. Not only will this push up urban demand for charcoal, but unless firewood collection is well managed, rural people will have to walk further & further. Tanzania's rapid population growth is likely to accentuate the problem of deforestation even further, **pushing up the price of wood fuels** to even higher levels. This will only amplify the economic argument for ecook, as the existing expenditures on biomass fuels will be even greater & broader.

Although harmful, **charcoal does create livelihoods for many rural people**. There is a long term view of local fabrication/assembly, however at least initially, eCook would substitute a local industry for imported technology & potentially change the foreign exchange balance by up to $1 billion dollars! Stove manufacture is an important industry in Tanzania. Whilst microwaves & induction stoves may require hi-tech production lines, **local manufacture of simple resistive insulated cooking devices** such as rice cookers, hotplates & electric pressure cookers should be possible in the medium-/long-term.

LPG is displacing kerosene as the fossil fuel of choice in Tanzanian kitchens. Tanzania has recently started to produce gas in Mtwara & piped gas connections are being trialled in Dar es Salaam. However, it remains to be seen whether the costs of establishing the piped infrastructure plus maintenance & fuel costs can be competitive with bottled LPG.

Electricity for cooking is declining in popularity in Tanzania, whilst charcoal is gaining – perception of affordability & lack of generating capacity have been major barriers. Lack of capacity may well change, however historically little has been done to challenge the perception of affordability, as it has ensured slow uptake in line with increases in generating capacity. This common assumption on the affordability of electric cooking is challenged by the findings from the cooking diaries. The behavioural change challenges should absolutely not be underestimated; however, neither should the drivers for sustained use – primarily convenience & cost savings. **Dispelling the myth that electric cooking is expensive** is likely to be much easier with prepaid meters, as customers will see how much they are spending much quicker.

1.5 The experience of cooking with electricity

eCook will take the cook into a new experience, where smoke is no longer an issue (unless they burn the food by accident). Harm from indoor air pollution is one of the greatest public health crises of our time. Deaths by air pollution rival the sum of malaria, HIV & TB combined. Chimneys may improve the situation for the cook, however, studies in china suggest that a whole village using

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chimneys experiences just as much outdoor air pollution. Recent studies indicate that even using an improved tier 2 or tier 3 biomass stove still doesn't change health outcomes.

Time savings & the ability to multitask will be important selling points for future eCook devices, especially in urban areas. Foods that require long cooking times can be cooked with much more efficiently by simply retaining heat within the pot. In the latter days of the cooking diaries trial, it became obvious that use of the multicooker for 'long' cooks was very energy efficient (compared to gas or charcoal). The insulated, pressurised environment can cook beans with a fraction of the energy of an open pan. Ugali, pilau, ndizi nyama, mtori, wali maharage & wali nazi can be cooked very easily and efficiently on insulated electric appliances like electric pressure cookers or rice cookers. However, maandazi, vitumbua, mikate and skonzi are more challenging as they require deep frying or baking.

1.6 Finance

There are two domains of finance: suppliers need major capital to set up & expand their business., whilst households will also need finance to **repay the high upfront cost of the individual systems**. Both must be in place for ecook to succeed. High interest rates could be a significant problem for ecook. The discount rates in Leach and Oduro's (2015) model are at 5% and 20%, and even at 20% eCook can work. However, it may not be the interest per se that creates challenges so much as identifying finance that is willing to take the risk & finding the finance in the first place. Users may shy away from 4-5yr payback periods, as solar lighting typically works on 1yr. However, utility models address this - users never own equipment, instead **purchasing cooking services**.

Engaging with TBS & TAREA to ensure **quality eCook products & components can be imported without taxes & poor quality items are kept** out will be key. VAT and tariff exemptions have been applied to imports of small solar products. However, **batteries are not exempted from VAT**, which causes particular issues for operators selling solar home systems where component parts of the product are separate. This may be one of the more important policy changes required to make Grid-eCook affordable.

Tanzania is one of the **world leaders in mobile money transfers** (mobile phone-based money transfer), with 44% of adults having access to it and a total of 16m subscribers. The prevalence of mobile money systems in rural areas will be a key enabler for the innovative business models that PV-eCook will require. Creating awareness of PV-eCook amongst vikobas, SACCOs, trust funds & MFIs will be key to unlocking the financing that rural people will need. The lack of collateral is also likely to be an issue for peri-urban potential PV-eCook customers living in rented homes & with no agricultural assets.

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2 Introduction

This report presents one part of the detailed in country research carried out to explore the market for eCook in Tanzania. In particular, this in country work aims to gain much greater insight into culturally distinct cooking practices and explore how compatible they are with battery-supported electric cooking. The report is rich with detail and is intended to provide decision makers, practitioners and researchers with new knowledge and evidence.

This report presents findings from a policy and national markets review designed to inform the future development of eCook within Tanzania. It is one component of a broader study designed to assess the opportunities and challenges that lay ahead for eCook in high impact potential markets, such as Tanzania, funded through Innovate UK's Energy Catalyst Round 4 by DfID UK Aid and Gamos Ltd. (https://elstove.com/innovate-reports/). A much deeper analysis of the data collected during this project was supported by the Modern Energy Cooking Services (MECS) programme, which included the writing of this report.

The overall aims of the Innovate project, plus the series of interrelated projects that precede and follow on from it are summarised in in *Appendix A: Problem statement and background to Innovate eCook project*.

2.1 Background

2.1.1 Context of the potential landscape change by eCook

The use of biomass and solid fuels for cooking is the everyday experience of nearly 3 billion people. This pervasive use of solid fuels and traditional cookstoves results in high levels of household air pollution with serious health impacts; extensive daily drudgery required to collect fuels, light and tend fires; and environmental degradation. Where households seek to use 'clean' fuels, they are often hindered by lack of access to affordable and reliable electricity and/or LPG. The enduring problem of biomass cooking is discussed further in *Appendix A: Problem statement and background to Innovate eCook project*, which not only describes the scale of the problem, but also how changes in renewable energy technology and energy storage open up new possibilities for addressing it.

2.1.2 Introducing 'eCook'

eCook is a potentially transformative battery-supported electric cooking concept designed to offer access to clean cooking and electricity to poorer households (HHs) currently cooking on charcoal or other polluting fuels (Batchelor, 2013, 2015a, 2015b). Enabling affordable electric cooking sourced from renewable energy technologies, could also provide households with sustainable, reliable, modern energy for a variety of other purposes.

A series of initial feasibility studies were funded by UK Aid (DfID) under the PEAKS mechanism (available from https://elstove.com/dfid-uk-aid-reports/). Slade (2015) investigated the technical viability of the proposition, highlighting the need for further work defining the performance of various battery chemistries under high discharge and elevated temperature. Leach & Oduro (2015) constructed an economic model, breaking down PV-eCook into its component parts and tracking key price trends, concluding that by 2020, monthly repayments on PV-eCook were likely to be comparable with the cost of cooking on charcoal. Brown & Sumanik-Leary's (2015), review of behavioural change challenges highlighted two distinct opportunities, which open up very different markets for eCook:

- PV-eCook uses a PV array, charge controller and battery in a comparable configuration to the popular Solar Home System (SHS) and is best matched with rural, off-grid contexts.
- Grid-eCook uses a mains-fed AC charger and battery to create distributed HH storage for unreliable or unbalanced grids and is expected to best meet the needs of people living in urban slums or peri-urban areas at the fringes of the grid (or on a mini-grid) where blackouts are common.

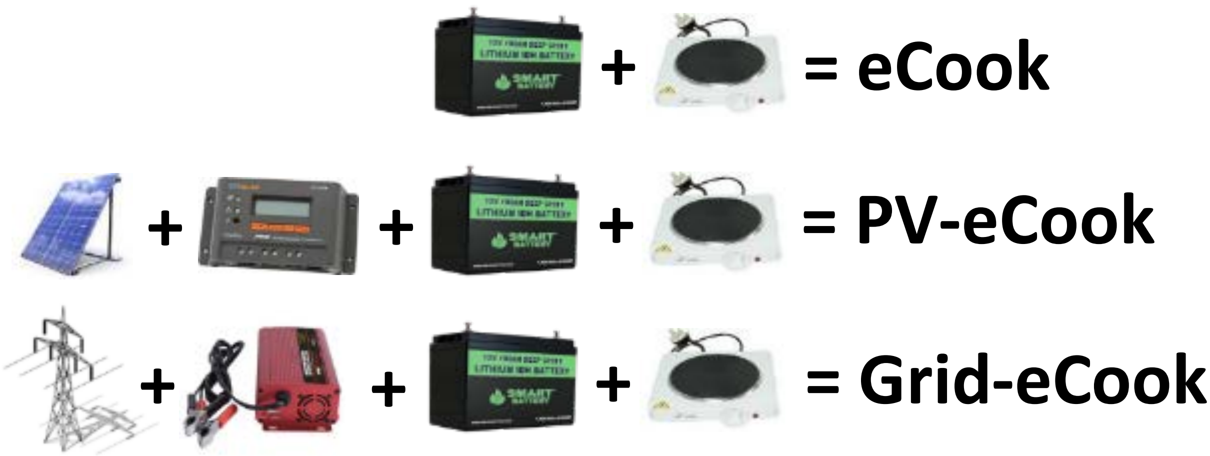

Figure 1: Pictorial definitions of 'eCook' terminology used in this report.

2.1.3 eCook in Tanzania

Given the technical and socio-economic feasibility of the systems in the near future, Gamos, Loughborough University and the University of Surrey have sought to identify where to focus initial marketing for eCook. Each country has unique market dynamics that must be understood in order to determine which market segments to target are and how best to reach them. Leary et al. (2018) carried out a global market assessment, which revealed Tanzania as the second most viable context for PV-eCook, due to its strong SHS industry and the fact that it is one of the world's biggest charcoal markets, creating several global deforestation hotspots.

The accompanying reports from the other activities carried out in Tanzania can be found at: https://elstove.com/innovate-reports/ and www.MECS.org.uk.

2.2 Aim and objectives

The aim of this study was to understand the intersect between 'cooking', which has traditionally meant biomass, in particular improved biomass stoves, and 'energy access', which has tended to focus on electricity and grid access.

The objectives are twofold:

1. To review the current regulatory framework in Tanzania and assess which polices are likely to accelerate the uptake of the eCook concept and which may present significant barriers.
2. To assess the state of the existing clean cooking and grid/mini-grid/off-grid electrification markets, which may provide the foundation for future eCook products/services.

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3 Methodology

A framework for the policy/markets analysis was developed by Gamos, Loughborough University and the University of Surrey, focussing on the following key areas:

- Clean cooking (health, deforestation, climate change, fuel/stove markets, etc.)
- Electrification (renewable energy, energy-efficiency, grid/mini-grid/off-grid markets etc.)
- Cross-cutting issues (gender, business environment, demographics, etc.)

The elements of the framework were based upon the factors that are most likely to affect the uptake of eCook products/services and the size of key market segments. These factors were first identified by Brown & Sumanik-Leary (2015), then further extended and contextualised by Leary et al. (2018).

Drawing upon their extensive experience in both the Tanzanian clean cooking and electrification sectors, our Tanzanian partners, TaTEDO, prepared a series of responses to the questions posed by the framework, which was supplemented by a literature review. The full framework can be found in *Appendix B: Policy/markets review framework*.

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4 Results

4.1 Overview of energy access in Tanzania

Tanzania has a growing economy with an abundance of natural resources and strong potential for renewable energy development. It is endowed with diverse energy sources including biomass, natural gas, hydro, coal, geothermal, solar and wind (WB, 2010), making the potential of generating energy from renewable sources large, however to date, it remains largely untapped. The estimated total energy consumption in Tanzania is more than 22 million tons of oil equivalents (TOE), equal to almost one billion gigajoules (GJ) or 0.7 TOE per capita.

The majority of rural Tanzanians have limited access to modern energy services; however, the government is aware that rural areas in Tanzania cannot be transformed into a modern economy and livelihoods cannot be improved significantly without a dramatic improvement in their access to modern energy services. Modern energy, particularly electricity, plays a key role in rural development with respect to the country's goal of achieving an industrialized economy at the small and medium scales. Access to affordable, reliable and safe electricity can greatly improve food, education and health services, as well as improve opportunities for income generation as well as speeding up economic growth.

4.2 National Energy Policy Framework

4.2.1 Energy policy

The National Energy Policy of 2003 laid the foundation for promoting renewable energy sources and encouraging private sector participation in Tanzania. Energy Policy Statement No. 36 established norms, codes of practice, guidelines, and standards for facilitating and creating an enabling environment for sustainable development of renewable energy. This policy was replaced by the National Energy Policy of 2015, which seeks to facilitate the adoption of renewable energy technologies in order to increase their contribution to the electricity generation mix.

The National Energy Policy (2015) focuses on market mechanisms and hopes to achieve an efficient energy sector with a balance between national and commercial interests. The overall aims of the policy are to:

- enable access to affordable and reliable energy across the whole country;
- reform the market for energy services to facilitate investment;

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- enhance the development and utilization of indigenous and renewable energy sources and technologies;
- adequately take into account environmental considerations for all energy activities; and
- increase energy efficiency and conservation in all sub-sectors.

> POLICIES & STRATEGIES ADDRESSING COOKING TEND TO FOCUS ON TRANSITIONS TO MODERN FUELS – ECOOK IS THEREFORE LIKELY TO FIND HIGH LEVEL SUPPORT.

The National Energy Policy includes reference to cooking and biomass consumption under the Electricity Sub-sector and only addresses an ambition to transition to modern fuels. Specifically, the relevant objective is: "To improve quality of life through use of modern fuels", and the associated policy statements include; i) Enhance fuel switch from wood fuel to modern energy; and (ii) Facilitate adoption of appropriate cooking appliances to promote alternatives to wood fuel.

The Electricity Act (2008) opened the Tanzanian energy sector for private companies and ended the monopoly held by the power utility in the energy sector. Private energy operators are now allowed to enter the energy business, although penetration so far has been limited, but is steadily increasing.

Some of the key regulations governing Tanzania's energy and renewable energy sectors are stipulated in the Energy and Water Utilities Authority (EWURA) Act 2001 and 2006. EWURA was established as a regulatory authority empowered to (i) promote effective competition and economic efficiency; (ii) protect consumer interests; and (iii) protect the financial viability of efficient suppliers.

> ITS NOT SURPRISING THAT THE FUTURE DIRECTION IS UNCLEAR. IN A COUNTRY WHERE BIOMASS STILL DOMINATES COOKING, TO DATE THERE HAVE BEEN FEW ALTERNATIVES. THERE IS A GROWING AWARENESS GLOBALLY THAT THE STRATEGY OF 'IMPROVED COOKSTOVES' NEEDS SOMETHING NEW TO BREAK OUT OF THIS 'BUSINESS AS USUAL' CYCLE.

Cooking energy is also supported by several uncoordinated sectoral policies. In particular, the gender, forestry and environment policies (discussed below). The future direction of energy for cooking is not clear although some national energy documents are supporting Sustainable Energy for All and the Energy Policy (2015) by putting action plans of efficient use of biomass resources and looking for alternative clean cooking solutions. However, efforts for provision of the rural clean energy solutions for cooking are still inadequate and priority of allocating resources for rural cooking energy development programmes is low.

The Biomass Energy Strategy (BEST, 2014) recommended improved charcoal cook stoves (ICS) as a key area for action to reduce charcoal energy demand in one of the quickest, least expensive ways. The

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document stipulated that charcoal ICS are also an important way to reduce household charcoal expenditures, which would be a key equity and distributional issue if sustainable charcoal becomes widespread. The BEST recommended for a major, commercially-oriented, mainstream improved cook stove business to be funded and launched, prioritizing urban households, and commercial and institutional consumers, with a target of reducing urban charcoal demand by an indicative 50% by 2030.

INTERESTINGLY THE FOCUS OF THE B.E.S.T. IS ON URBAN CHARCOAL. THIS A MARKET WHERE PEOPLE ARE PAYING REAL MONEY FOR THEIR FUEL. THIS IS A MAJOR OPPORTUNITY FOR ECOOK.

4.2.2 Supporting policies

Odarno et al. (2017) outlined several national policies with implications for clean cooking and electrification:

- “he National Forest Policy of 1998 seeks to enhance the contribution of the forest sector to the sustainable development of Tanzania and the conservation and management of its natural resources for the benefit of present and future generations.
- The National Environmental Policy of 1997, which was revised in 2004, calls for the enactment of an environmental framework law and the establishment of environmental standards. It directs the undertaking of an Environmental and Social Impact Assessment (ESIA) as an instrument for achieving sustainable development. The National Environmental Policy of 2015 (draft) aims to promote diversified sources of energy by exploiting renewable energy sources.
- The National Investment Promotion Policy of 1996 encourages investment in the development of all possible commercial and alternative sources of energy, with emphasis on the use of domestic resources, with the aim of ensuring continuity of supplies.
- The Small and Medium Enterprises Developmental Policy aims to foster job creation and income generation by promoting new SMEs, improving performance and competitiveness of existing SMEs and increase their participation and contribution in the economy of Tanzania. The policy intends to promote business services, by using affordable and efficient energy services.
- The National Gender Policy of 2002 aims at establishing strategies to eradicate poverty, with an emphasis on gender equality and equal opportunity for men and women to participate in development undertakings and to value the role played by each member of society.”

THE POTENTIAL IMPACT OF ECOOK CUTS ACROSS VARIOUS NATIONAL DEVELOPMENT PRIORITIES – FROM GENDER EQUITY TO SUSTAINABLE FORESTRY.

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4.2.3 National targets

Tanzania's Development Vision 2025 (GoT, 2000) aims to develop Tanzania into a middle-income country by 2025 by balancing human activities and the environment. Access to sustainable energy will be key in achieving this - Table 1 shows Tanzania's national goals developed under the UN Sustainable Energy for All (SE4All) framework. Figure 1 shows that the renewable energy share simply needs to be maintained to meet the target and the target for electricity access may be achievable, however, the clean cooking target seems to be far out of reach.

THE SE4ALL GTF CURRENTLY MEASURES ACCESS TO CLEAN COOKING SOLUTIONS AT 2%. A QUANTUM LEAP WILL BE REQUIRED TO MEET THE >75% TARGET FOR 2030!

Table 1: Tanzania's SE4All targets for 2030 (MINISTRY OF ENERGY AND MINERALS, 2015)

Universal access to modern energy services		Doubling global rate of improvement of energy efficiency	Doubling share of renewable energy in global energy mix	
Percentage of population with electricity access	Percentage of population with access to modern cooking solutions	Rate of improvement in energy intensity	Renewable energy share in Total Final Energy Consumption	
			Power	**Heat**
>75%	**>75%**	**-2.6% per year**[1]	**>50%**[2]	**>10%**

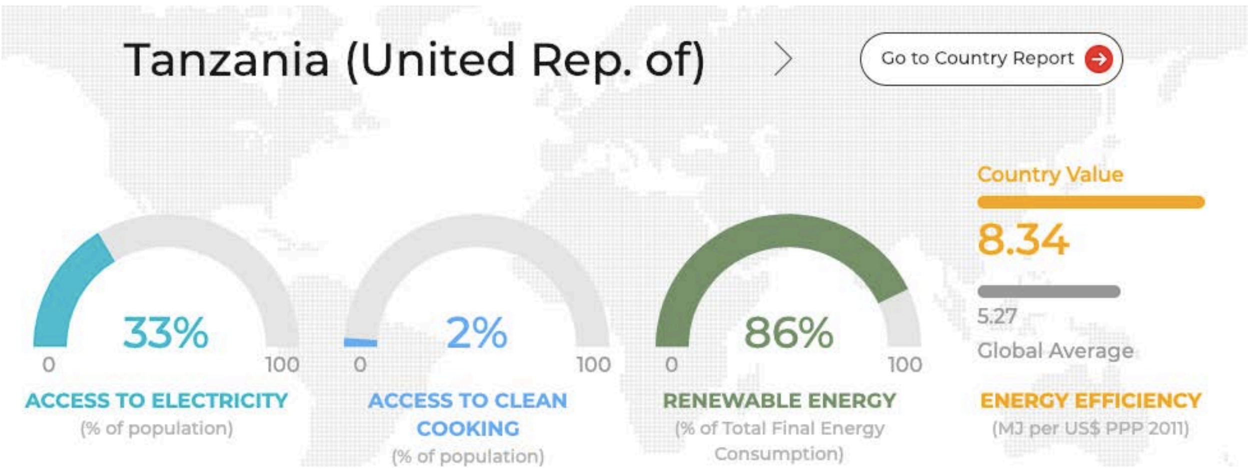

Figure 2: Progress towards achieving Tanzania's SE4All targets by 2018 (GTF, 2018).

4.3 Key Actors

The energy sector has a variety of stakeholders operating from the national to local levels. The main categories of stakeholders are as shown in Table 2.

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Table 2: Key Government, NGO, Research and Private Sector actors

SECTOR/INSTITUTION	ROLE
GOVERNMENT	
Ministry of Energy (ME)	Develop policies, strategies, regulations and programmes to manage the energy sector.
Tanzania Electric Supply Company (TANESCO)	Electricity utility responsible for generation, transmission and distribution of electricity.
Energy and Water Utilities Regulatory Authority (EWURA)	Multi-sectoral regulatory authority responsible for the technical and economic regulation of electricity, petroleum, natural gas, and water sectors.
Rural Energy Agency (REA)	Promote, stimulate, facilitate, and improve modern energy access in rural areas of mainland Tanzania to support economic and social development.
RESEARCH INSTITUTIONS	Generation of knowledge through research and studies for the energy sector.
PRIVATE SECTOR	Ensure energy products are available and supply them directly to retail customers.
CSO SECTOR	Promote and advocate for increased access to sustainable and renewable energy technologies and services.

4.3.1 Government

The key stakeholders in the government related to electrification and clean cooking are the Sectoral Ministries: the Ministry of Energy and the Ministry of Natural Resources and Tourism. Other actors include Rural Energy Agency (REA), Energy and Water Utilities Regulatory Authority (EWURA), Tanzania Electric Supply Company (TANESCO) and Tanzania Bureau of Standards (TBS).

AS IN MOST COUNTRIES, TANZANIA PRESENTS A COMPLEX MIX OF INSTITUTIONS & RESPONSIBILITIES. SINCE ECOOK IS NOT OBVIOUSLY AN 'IMPROVED STOVE' IN THE BIOMASS SENSE - IT IS ALSO MECHANISM TO INCREASE ACCESS TO BOTH ON- & OFF-GRID ELECTRICITY - IT IS DIFFICULT TO KNOW WHICH STAKEHOLDERS TO LOBBY & IN WHICH SEQUENCE.

4.3.1.1 Ministry of Energy (ME)

The ME is mandated to develop energy resources and manage the sector. It is responsible for the formulation and articulation of policies to create an enabling environment for stakeholders. Promoting renewable energy is part of its mandate. The ME plays an essential policy guidance role, complementing the other major players (i.e., REA, TANESCO, EWURA, private companies, NGOs, and financiers). The government, through the Ministry of Energy, is fulfilling the following roles:

- Formulating and overseeing implementation of policies, laws and

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regulations.

- Developing and implementing plans and programmes in the energy sector.
- Attracting investment and technology in the sector; mobilization of financial resources and participating strategically in energy investments.
- Safeguarding energy infrastructure and overseeing the implementation of Local Content initiatives and the Corporate Social Responsibility Action Plan in the Energy Sector.
- Ensuring review of Standardized Power Purchase Agreement and Tariff for small power developers as well as Model Power Purchase Agreements based on the resource.

4.3.1.2 Tanzania Electric Supply Company (TANESCO)

The Tanzania Electric Supply Company Limited (TANESCO) is the sole electricity provider in Tanzania. Fully owned by the Government, TANESCO is the only vertically integrated electricity supplier in Tanzania. TANESCO is responsible for generation, transmission and distribution of electricity and to improve governance, performance, financial and commercial viability of the power sector, as well as service delivery of electricity services. Currently, it provides nearly 60 percent of the 18GW effective generating capacity of the national grid, and is responsible for transmission and distribution, serving customers on the main grid and in 20 isolated grids. Therefore, the private sector also generates grid electricity, but only TANESCO distributes it and retails it to end users.

> WHILST T.A.N.E.S.C.O. IS CLEARLY THE MAJOR STAKEHOLDER FOR GRID-ECOOK, THE S.P.P.S OPEN UP NEW OPPORTUNITIES IN RURAL AREAS VIA MINI-GRID-ECOOK.

4.3.1.2.1 IPPs & SPPs

Independent Power Producers (IPPS) are private large plants (more than 10 MW) that sell power to the national grid. They include Symbion at Ubungo, IPTL at Tegeta, and Songas at Ubungo.

Small Power Producers (SPPs) are small independently operated power producers defined as having an export capacity of up to 10 MW. They may be private individuals, companies, cooperatives, or communities. SPPs sell power to TANESCO, into the national grid, to isolated grids, and/or directly to rural communities if they have a distribution network. They are classified by regulators based on their size, fuel used, and technology.

> LOBBYING EWURA TO INCREASE LIFELINE TARIFF ALLOWANCES OR CREATE A TIME OF USE TARIFF COULD BE KEY ENABLERS FOR GRID-ECOOK.

4.3.1.3 Energy and Water Utilities Regulatory Authority (EWURA)

EWURA is an autonomous, multi-sectoral regulatory authority established by the Energy and Water Utilities Regulatory Authority Act. It is

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responsible for the technical and economic regulation of Tanzania's electricity, petroleum, natural gas, and water sectors. EWURA is vested with the responsibility of regulating energy industry. The roles of EWURA include:

- licensing, tariff review, monitoring performance and standards with regards to quality, safety, health and environment;
- promoting effective competition and economic efficiency, protecting the interests of consumers; and
- promoting the availability of regulated services to all consumers including low income, rural and disadvantaged consumers in the regulated sectors.

R.E.A.'S MANDATE SUGGESTS THEY ARE THE PRIMARY STAKEHOLDER REGARDING PV-ECOOK AND MINI-GRID ECOOK, WHICH WILL FOCUS ON RURAL MARKETS.

4.3.1.4 Rural Energy Agency (REA)

The REA is an autonomous body under the ME that became operational in October 2007. Its principal responsibilities are to:

- promote, stimulate, facilitate, and improve modern energy access in rural areas of mainland Tanzania to support economic and social development;
- promote rational and efficient production/use of energy and facilitate the identification and development of improved energy projects and activities in rural areas;
- finance eligible rural energy projects through the REF;
- prepare and review application procedures, guidelines, selection criteria, standards, and terms and conditions for the allocation of grants;
- build capacity and provide technical assistance to project developers and rural communities; and
- facilitate the preparation of bid documents for rural energy projects.

THE PRIVATE SECTOR IS LIKELY TO DRIVE ECOOK FORWARD, AS BY 2020 SYSTEMS IT SHOULD BE POSSIBLE TO CREATE SYSTEMS THAT ARE PROFITABLE TO THE DEVELOPER, YET CHEAPER TO THE CONSUMER THAN EXPENDITURES ON CHARCOAL OR KEROSENE.

4.3.1.5 Research Institutions

Various universities and research/training institutions focus on generating knowledge through research studies for the energy sector. These include the University of Dar es Salaam, Dar es Salaam Institute of Technology, University of Dodoma, Tanzania Commission of Science and Technologies, Mbeya Institute of Science and Technology, Arusha Technical College and the Vocational Education Training Authority (VETA), Research on Poverty Alleviation (REPOA), Institute of Research Assessment (IRA), etc.

Research@gamos.org | PV-ecook.org

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4.3.1.6 Private and CSO Sectors

In addition to the IPPs an SPPs mentioned previously, various private companies are engaged in small-scale renewable power development to sell energy services and technologies directly to retail customers. Private Companies involved with renewable energy include:

- Kampuni ya Kusambaza Teknologia (KAKUTE)
- Rex Solar Ltd
- Mobisol Tanzania
- Zola Solar Ltd
- Mkopa Solar Ltd
- Step Solar Ltd
- BP Solar
- Alternative Energy
- ZARA Ltd
- Baraka Solar Ltd
- ENSOL Tanzania
- RESCO Tanzania
- Sustainable Energy System Company (SESCOM) Ltd
- Solar Sisters
- SEECO Ltd.

4.3.1.7 CSO Sector

Various NGOs promote access to sustainable and renewable energy. Most of these private institutions are already working in rural areas. Some of the CSOs working in renewable energy include:

- Tanzania Traditional Energy Development Organisation (TaTEDO - Centre for Sustainable Energy Services)
- Tanzania Renewable Energy association (TAREA)
- Appropriate Rural Technology Institute (ARTI)
- World Wild Fund (WWF)
- Centre for Sustainable Development Initiatives (CSDI)
- CARE Tanzania
- Renewable Energy Zanzibar Association (REZA)

THERE WILL LIKELY BE A SLIGHT MISMATCH IN PV-ECOOK MARKETS. SOLAR LIGHTING HAS BEEN SUCCESSFUL SUBSTITUTING EXPENDITURES ON KEROSENE, CANDLES & TORCH BATTERIES - YET MANY RURAL DWELLERS PAY NOTHING FOR COOKING FUEL. MUCH WILL DEPEND ON WHETHER USERS SEE TIME SAVINGS AS IMPORTANT (EXPLORED IN THE FOCUS GROUPS).

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Though not specifically classified as renewable energy organisations, a number of faith-based organisations utilise renewable electricity to meet the rural energy needs of their communities.

4.4 Clean Cooking

4.4.1 What do Tanzanian's cook and how?

People in Tanzania cook a variety of foods, most of which are also found in other East African countries. The country's food portfolio is largely based on starches and proteins like maize, rice, bananas, cassava, potatoes, millet, beans, animal meat, milk, vegetables, etc. These foods are grown in specific rural areas of the country and distributed across the country. Most foods are cooked at home, but nowadays, some people in urban areas are eating from restaurant in the morning and afternoon while at home in the evening.

UGALI, PILAU, NDIZI NYAMA, MTORI, WALI MAHARAGE & WALI NAZI CAN BE COOKED VERY EASILY AND EFFFICIENTLY ON INSULATED ELECTRIC APPLIANCES LIKE ELECTRIC PRESSURE COOKERS OR RICE COOKERS. HOWEVER, MAANDAZI, VITUMBUA, MIKATE AND SKONZI ARE MORE CHALLENGING AS THEY REQUIRE DEEP FRYING OR BAKING.

There is limited variation in cooking technologies and practices across different areas of the country. Most regions cook similar foods, including ugali, choma/kuku (grilled meat/chicken), pilau (spiced rice), ndizi nyama (green banana with fish or meat), mtori (plantain soup), wali maharage (rice & beans), wali nazi (rice cooked in coconut milk), vitumbua (coconut rice cakes), maandazi (doughnuts), mikate (breads), skonzi (scones, rolls). However, people around the lakes and coast cook more sea-food and staple foods of their regions such as ndizi (Kilimanjaro, Kagera, etc.). The methods for cooking involve boiling, simmering, frying, grilling, warming and baking, often for several hours in order to rehydrate dried foods or soften tough fibres.

Food in poor families is typically cooked on inefficient and polluting traditional cookstoves. The main types of stoves used by urban dwellers are charcoal stoves and LPG, while rural dwellers use mainly firewood stoves. In rural areas, open three stone stoves with thermal efficiency of 7-12 percent are used. In urban areas, metal charcoal stoves with thermal efficiency of 10-15 percent on average are widely used.

Efficiency and fuel saving are very important factors, but other requirements of the users should not be ignored. Some of the user's needs, besides fuel saving include type of food, cooking comfort, portability and safety.

- The length of time the food takes to cook is also an important factor in the stove efficiency consideration design. Some foods e.g. dry maize and beans take six hours to cook. Clay and

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sand stoves with high thermal mass will take the heat for the first 30 minutes but continue cooking as the fire slowly extinguishes.

- Many pots used cannot fit very well on the pot rest and some stoves cannot use some pots, especially clay made pots.
- Some foods require pounding as they cook, which influences the way the pot has to sit on the stove.
- Gender aspects are important because most household users are generally women. The most successful way to design a stove that will be widely appreciated and used is to involve women in the design.
- Cooking comfort is also an important factor. The cookstoves should be adapted to the most comfortable cooking posture, which depends on the type of food and cultural norms - sometimes standing or sometimes sitting down.
- Saving time is important, especially for urban households, who are more likely to be in paid employment. To save time, many households use electricity to boil water, especially using an electric kettle. Saving time for rural women is also important - one of the major drawbacks of the rural three stone fire place is that one is required to be in the kitchen during the whole cooking period as the cook has to feed the stove with wood every few minutes, which increases the time required for tending the fire.
- Safety is also very crucial - Improved biomass stoves enclose the flame inside the stove.

FOODS THAT REQUIRE LONG COOKING TIMES CAN BE COOKED WITH MUCH MORE EFFICIENTLY BY SIMPLY RETAINING HEAT WITHIN THE POT.

TIME SAVINGS & THE ABILITY TO MULTITASK WILL BE IMPORTANT SELLING POINTS FOR FUTURE ECOOK DEVICES, ESPECIALLY IN URBAN AREAS.

IMPROVED BIOMASS STOVES MAY ENCLOSE THE FLAME, BUT ELECTRIC STOVES ARE EVEN SAFER AS THERE IS NO FLAME AT ALL!

4.4.1.1 *How compatible are these foods & practices with battery-supported electricity?*

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The evidence from the cooking diaries and focus groups has shown that low power and energy-efficient electric appliances are capable of cooking typical Tanzanian dishes. In particular, rice cookers (typically 700-1,000W) and electric pressure cookers (typically 800-1,200W) have shown particular promise, with the former directed more towards staples such as rice and ugali and the latter towards 'heavy foods' such as beans, makande or meat stew. Such 'heavy foods' would likely flatten the battery on a battery-supported cooker if using an electric hotplate, however the electric pressure cooker essentially flattens these big peaks in demand. This regulates daily energy demand, which is much more compatible with a limited supply of battery-supported electricity.

IN THE LATTER DAYS OF THE COOKING DIARIES TRIAL, IT BECAME OBVIOUS THAT USE OF THE MULTICOOKER FOR 'LONG' COOKS WAS VERY ENERGY EFFICIENT (COMPARED TO GAS OR CHARCOAL). THE INSULATED PRESSURE ENVIRONMENT COULD COOK BEANS FOR A FRACTION OF THE ENERGY OF AN OPEN PAN.

However, this will no doubt require public awareness creation to facilitate adoption of energy-efficient appliances and practices, particularly amongst biomass users. The transition is likely to occur more rapidly in urban areas, where electric appliances are more established within everyday life, people are likely to be paying for their cooking fuel and time savings are likely to translate more directly into new income generating opportunities. In colder regions, such as Kilimanjaro, open fireplaces or stoves are also used for space heating, which makes transitioning to an efficient electric stove that retains heat inside the cooking pot less attractive than in hot regions, such as Dar es Salaam. In contexts Energy saving, health reasons and cost saving will be main drivers for adopting the electric appliances and battery supported electricity.

STOVE MANUFACTURE IS AN IMPORTANT INDUSTRY IN TANZANIA. WHILST MICROWAVES & INDUCTION STOVES MAY REQUIRE HI-TECH PRODUCTION LINES, LOCAL MANUFACTURE OF SIMPLE RESISTIVE INSULATED COOKING DEVICES SUCH AS RICE COOKERS, HOTPLATES & ELECTRIC PRESSURE COOKERS SHOULD BE POSSIBLE IN THE MEDIUM-/LONG-TERM.

4.4.2 Which fuels are popular in Tanzania today and why?

Most Tanzanians depend fully or partly on firewood and charcoal for daily cooking needs. Cooking is mainly done on traditional, low-efficiency stoves, that use charcoal produced locally through informal and uncontrolled value chains and with basic, low-yield technology. Alternative fuels and technologies that are suitable for domestic cooking are available, but have seen only very limited market development so far, although LPG is rapidly increasing in popularity, especially in urban areas (see Table 3).

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Most improved biomass cookstoves are manufactured in Tanzania by NGOs, private sector and stove groups in the informal sectors in Dar es Salaam and then distributed nationwide. Standards and product certification have not yet been introduced. LPG, biogas and electric stoves are imported from outside the country and sold to customers by local shops.

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Table 3: Current status and outlook for key fuels in Tanzania today.

Stove	Description
Improved biomass CookStoves (ICS)	Generally available in urban, peri-urban and rural areas, but total distribution of less than 300,000 ICS per year. Approximately 40% of people in Dar es Salaam and about 10% in the countryside are using ICSs. Production and distribution of ICS are performed by NGOs, private sector and artisans' groups in the informal sector.
LPG	LPG is generally available in urban areas, and to a somewhat lesser extent in peri-urban areas. The Tanzania National Energy Policy of 2015 emphasizes promoting utilization of alternatives to biomass for cooking energy such as LPG, natural gas and electricity. The industry estimates that with the right fiscal environment and commitment to invest in the gas sector, the market could grow to 100-150 million tons LPG within a few years
Kerosene	Kerosene stoves are used in some high to middle income households to cook light foods, due to cost involved in purchasing of fuels. The use of kerosene in urban areas has gone down due to high price of kerosene and availability of other alternative cheap fuels. Most of these stoves are imported or supplied from outside the country (countries like China, India, South Africa, etc.).
Biogas	Biogas utilization for cooking in households in Tanzania was initiated in by the Government through SIDO in 1975. According to the SE4ALL 2015 Action Agenda, the use of biogas was estimated to be 0.1% in urban areas, 0.00% in rural. Its use is limited to places with suitable feedstock and by the high upfront cost of bio-digesters. Biogas stoves are similar to LPG stoves and are also imported.
Electricity	Imported electric cookers, ovens and microwaves are used in some medium and high-income households and food businesses. The use of electric stoves is highly correlated with income levels due to high appliance costs and the perception of high electricity costs. It is also vulnerable to blackouts and the use of the more efficient appliances requires changes in cooking habits.

The Energy Access Situation Report (NBS and REA, 2017) confirms that firewood is still the dominant energy source, with 71% of all households and 92% of rural households in mainland Tanzania reporting it as one of their sources of energy for cooking (Figure 3). This is followed by charcoal (37%), LPG (7%) and kerosene (5%), with just 0.3% of households using electricity for cooking. Charcoal use is most common in urban areas (79%), in particular in Dar es Salaam (88%), where kerosene (22%) and LPG (27%) use is also highest and firewood use is lowest (14%) (

L.P.G. IS DISPLACING KEROSENE AS THE FOSSIL FUEL OF CHOICE IN TANZANIAN KITCHENS.

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Table 4). Charcoal use is above 10% in all regions, with Pwani (54%), Katavi (47%), Morogoro (43%), Mara (42%) and Mwanza (42%) also big markets for charcoal. Firewood is unsurprisingly the most widely used fuel amongst the poorest households (97%), whilst charcoal is the fuel of choice for the richest (84%). Even for the richest households, electricity is barely used for cooking (1.5%).

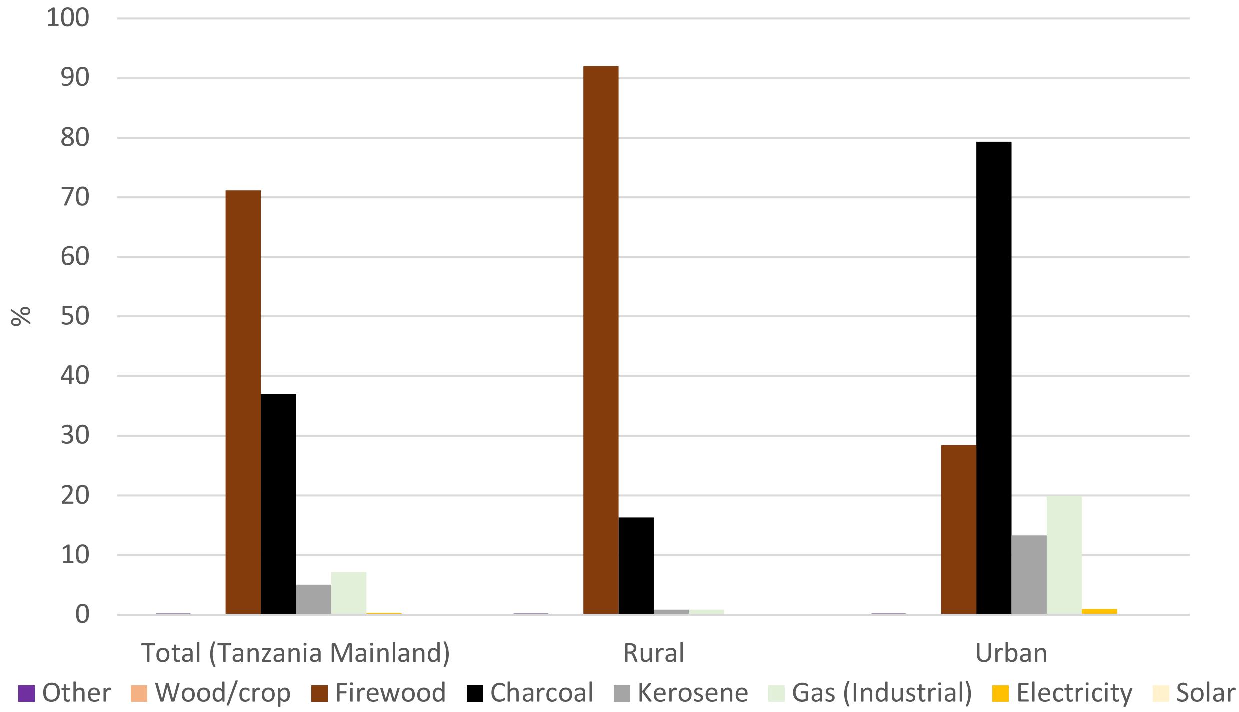

Figure 3: Cooking fuel use in urban/rural areas of the Tanzanian Mainland. Data source: NBS & REA (2017).

CHARCOAL IS THE FUEL OF CHOICE FOR THE RICH AND AS TANZANIA'S ECONOMIC HUB, DAR ES SALAAM IS THE EPICENTRE, WITH 88% HHS COOKING WITH CHARCOAL.

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Table 4: Cooking fuel use by region (NBS and REA, 2017).

Place of Residence	Kerosene	Charcoal	Firewood	Gas (Industrial)	Electricity	Solar	Wood/ crop	Other
Dodoma	0.8	21.0	86.7	3.1	0.3	0.0	0.0	0.0
Arusha	17.9	28.3	61.3	19.0	1.0	0.0	1.0	0.0
Kilimanjaro	9.2	21.3	83.8	13.8	0.3	0.0	0.0	2.1
Tanga	2.0	32.1	74.5	5.4	0.5	0.0	0.0	0.0
Morogoro	2.8	42.9	70.2	3.6	0.0	0.0	0.0	0.0
Pwani	8.2	54.3	72.8	6.1	0.5	0.0	0.0	0.5
Dar es Salaam	22.1	88.2	14.3	26.7	1.3	0.0	0.0	0.3
Lindi	0.8	24.9	90.0	0.5	0.0	0.3	0.0	0.0
Mtwara	0.8	23.1	84.6	2.1	0.0	0.0	0.0	0.0
Ruvuma	0.5	24.9	83.0	1.0	0.0	0.0	0.0	0.0
Iringa	0.8	22.6	85.9	5.9	0.0	0.0	0.3	0.0
Mbeya	0.5	38.2	68.9	7.4	0.0	0.0	0.0	0.3
Singida	1.6	28.2	82.0	1.8	0.5	0.0	1.5	0.0
Tabora	1.3	32.5	82.6	2.1	0.3	0.0	0.0	0.0
Rukwa	0.3	28.5	73.0	0.5	0.8	0.3	0.0	0.0
Kigoma	0.0	27.7	82.6	2.3	0.0	0.0	0.0	0.0
Shinyanga	0.5	23.9	85.3	3.1	0.0	0.0	0.0	0.0
Kagera	1.0	19.5	85.1	1.5	0.0	0.0	0.0	0.3
Mwanza	0.3	41.6	69.2	6.1	0.0	0.3	0.0	0.0
Mara	1.8	41.6	79.2	1.3	0.0	0.0	0.0	0.0
Manyara	3.6	24.4	82.5	6.4	1.0	0.0	0.0	0.0
Njombe	0.8	27.2	83.6	1.0	0.3	0.3	0.0	0.0
Katavi	1.0	47.4	64.1	1.5	0.3	0.3	0.0	0.0
Simiyu	1.3	16.9	94.3	1.3	0.0	0.0	0.0	0.0
Geita	0.0	35.6	78.1	1.0	0.0	0.0	0.0	0.0
Songwe	0.3	24.1	79.8	1.3	0.0	0.0	0.0	0.0

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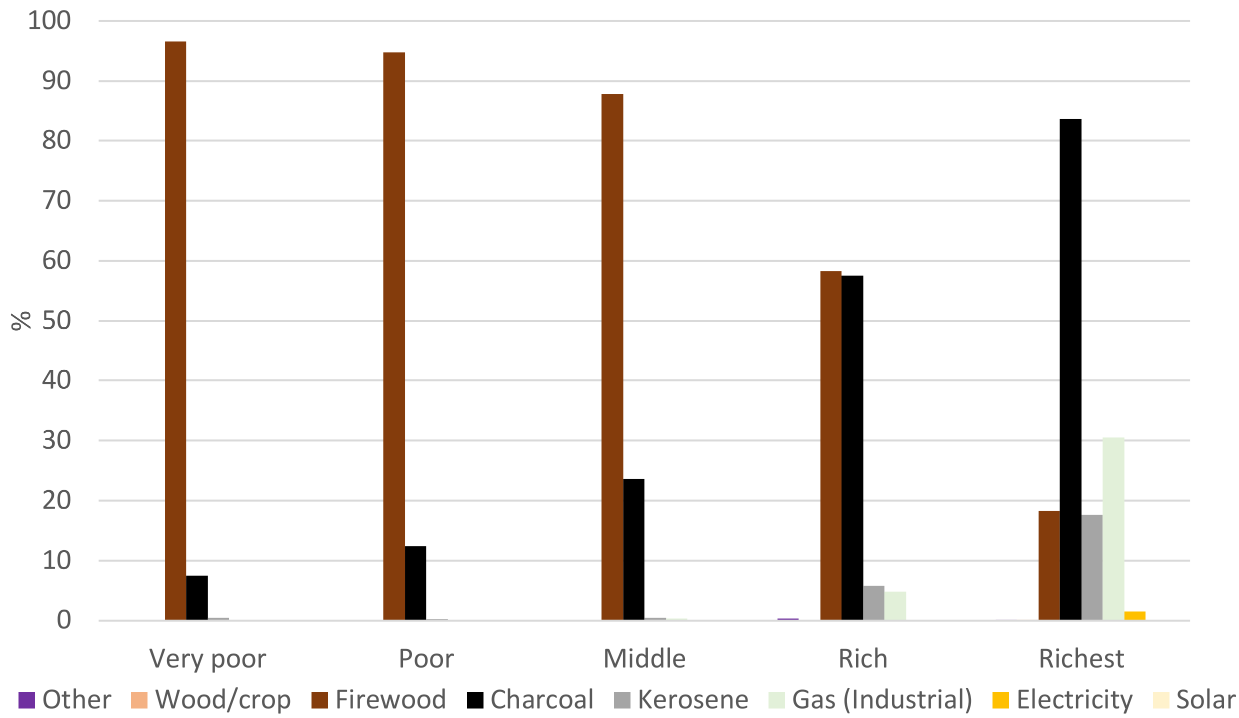

Figure 4: Cooking fuel use by wealth quintile. Data source: NBS & REA (2017).

NBS & REA (2017) note that contrary to REA's achievement in increasing household use of electricity for lighting, Table 5 shows the opposite for electricity for cooking (1.8 to 0.3% from 2000 to 2016). LPG is the only modern source of cooking energy that has increased in popularity in the last two decades (0.3 to 7.3% from 2000-2016). In the same time period, kerosene use has stuck at 5% and firewood has declined slightly (79 – 71%), however, charcoal use has dramatically increased from 14 to 37%. The use of solar (assumed to be solar thermal), generators/private electricity and biogas have not proven popular in Tanzania nor are coal or crop residues.

ELECTRICITY FOR COOKING IS DECLINING IN POPULARITY, WHILST CHARCOAL IS GAINING.

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Table 5: Percentage Distribution of Households by Sources of Energy for Cooking; Tanzania Mainland; 2000/01, 2002, 2007, 2011/12 and 2016 (NBS and REA, 2017).

Source of Energy for Cooking	HBS 2000/01	Census 2002	HBS 2007	REA 2011	HBS 2011/12	REA 2016
Electricity (Grid/Off-Grid)	1.8	0.9	0.5	0.2	0.3	**0.3**
Gas – industrial	0.3	0.1	0.2	0.1	0.8	**7.2**
Gas – biogas	0.1	0.0	0.0	0.0	0.0	**0.0**
Paraffin or Kerosene	5.0	4.4	3.0	0.9	2.5	**5.0**
Coal	0.1	0.0	0.2	0.0	0.2	**0.0**
Charcoal	14.2	16.6	22.7	10.3	28.2	**37.0**
Firewood	78.5	77.4	73.1	88.0	66.3	**71.2**
Wood or farm residuals	0.0	0.0	0.1	0.3	0.0	**0.1**
Solar	NA	0.0	NA	0.0	0.1	**0.0**
Generator or Private	NA	0.0	NA	0.0	0.2	**0.0**
Other	**0.1**	**0.5**	**0.1**	**0.2**	**1.3**	**0.2**

88% OF DAR ES SALAAM HHS COOK WITH CHARCOAL & SPEND AN AVERAGE OF 50,000TZS (22USD) EVERY MONTH - AN ATTRACTIVE POTENTIAL REVENUE STREAM FOR FUTURE GRID-ECOOK PRODUCTS.

NBS & REA (2017) found that average household expenditures on charcoal exceeded 30,000TZS/month and in Dar es Salaam, almost 50,000TZS/month (Figure 5 & Table 6). Expenditures on LPG were marginally higher at 31,874TZS/month and kerosene significantly lower at 18,000TZS/month. Interestingly, people are paying more to cook on firewood than kerosene (21,000TZS/month). There are significant regional variations, with LPG reaching 50,000TZS/month in Singada and Simiyu, firewood exceeding 40,000TZS/month in Dodoma and Arusha and Kerosene exceeding 30,000TZS/month in Rukwa and Ruvuma. It should be noted that HHs may be fuel stacking, as NBS & REA's (2017) questionnaire asked participants to list all the fuels they used for cooking and their expenditures on each. As a result, these figures represent both the regional price of the fuel and the proportion of cooking that households use that fuel for. For example, although households cooking with kerosene in Singada reportedly spend 3,866TSh/month on it in, it could be because kerosene is very expensive, so these HHs only use it occasionally or because it is very cheap, so they do all their cooking on it.

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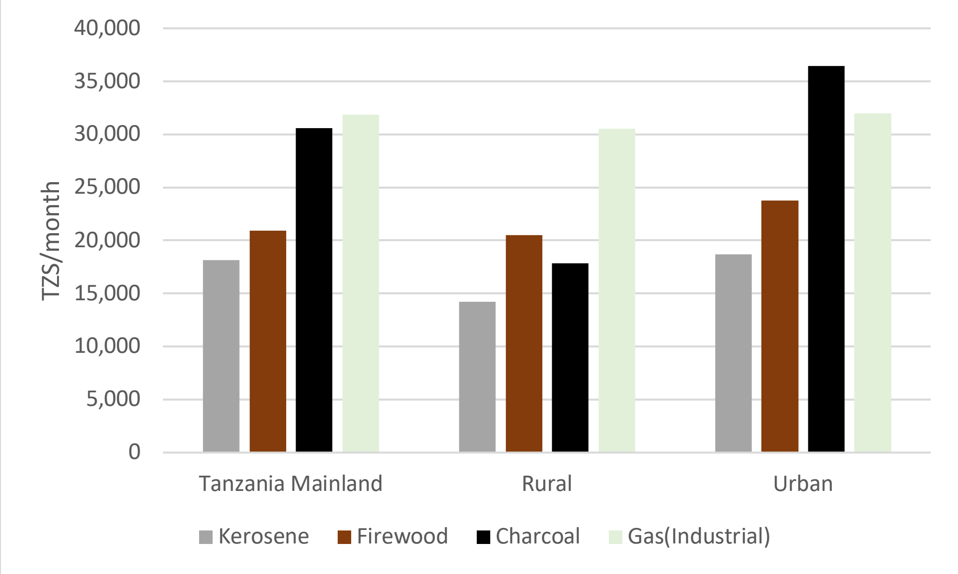

Figure 5: Average rural/urban HH expenditures per month on cooking energy by fuel. Data source: NBS & REA *(2017).*

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Table 6: Average Cost per Month (Paid by Households) by Place of Residence, Region and Source of Energy for Cooking (NBS and REA, 2017).

Region	Kerosene	Firewood	Charcoal	Gas (Industrial)
Dodoma	8,185	40,768	20,075	46,000
Arusha	16,109	41,645	33,959	26,768
Kilimanjaro	15,156	35,022	29,885	28,386
Tanga	11,224	19,645	24,203	36,722
Morogoro	14,458	17,448	25,544	43,518
Pwani	22,191	23,787	21,815	24,750
Dar es Salaam	20,883	19,885	49,081	34,981
Lindi	6,786	13,618	19,069	0.0
Mtwara	7,280	21,884	19,387	18,000
Ruvuma	31,348	15,610	25,519	0.0
Iringa	11,157	15,036	21,378	31,302
Mbeya	8,000	20,857	27,369	19,563
Singida	3,866	19,499	29,460	50,000
Tabora	4,667	11,926	13,467	0.0
Rukwa	30,000	12,648	23,791	34,266
Kigoma	0.0	17,619	22,409	0.0
Shinyanga	14,500	13,518	25,469	25,000
Kagera	9,737	20,971	19,661	27,350
Mwanza	12,000	20,522	36,593	31,977
Mara	16,349	28,349	19,369	0.0
Manyara	12,579	21,076	26,520	17,000
Njombe	7,645	19,302	18,212	0.0
Katavi	5,500	17,743	16,052	0.0
Simiyu	5,521	17,850	19,778	50,000
Geita	0.0	15,988	16,203	0.0
Songwe	8,000	13,432	20,575	32,500

Fossil fuels in Tanzania are almost exclusively imported, however, the discovery of natural gas in Mtwara changed this trend. Natural gas is transported to Dar es Salaam by pipeline and currently only used for electricity generation, although trials have been undertaken for cooking and other energy services. So far, three hotels, one garage, 70 houses and 36 factories in Dar es Salaam are connected to the piped natural gas network.

TANZANIA HAS RECENTLY STARTED TO PRODUCE GAS IN MTWARA & PIPED GAS CONNECTIONS ARE BEING TRIALED IN DAR ES SALAAM. IT REMAINS TO BE SEEN WHETHER THE COSTS OF ESTABLISHING THE PIPED INFRASTRUCTURE PLUS MAINTENANCE & FUEL COSTS CAN BE COMPETITIVE WITH BOTTLED LPG.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

4.4.3 Key drivers for cleaner cooking solutions

4.4.3.1 Health

It has been reported that indoor air pollution levels in households using traditional biomass stoves can reach levels 100 times above the WHO acceptable standards (REA, 2017). According to WHO, on a global scale, 4 million deaths annually are linked to respiratory and other diseases, attributable to indoor air pollution from solid fuel use (WHO, 2018). In Tanzania, the same cause is believed to represent close to 5% of disease burden.

HARM FROM INDOOR AIR POLLUTION IS ONE OF THE GREATEST PUBLIC HEALTH CRISES OF OUR TIME. DEATHS BY AIR POLLUTION RIVAL THE SUM OF MALARIA, HIV & TB COMBINED.

The majority of Tanzania's rural population use traditional stoves. Major drawbacks of the traditional stoves, especially the three stone fires, are dispersion of flames and heat because of the wind, poor control over the fire, exposure to heat and smoke, and fire hazard.

CHIMNEYS MAY IMPROVE THE SITUATION FOR THE COOK, HOWEVER, STUDIES IN CHINA SUGGEST THAT A WHOLE VILLAGE USING CHIMNEYS EXPERIENCES JUST AS MUCH OUTDOOR AIR POLLUTION.

Reduction of in-door smoke and harmful emissions from the households, institutions and SMEs are important considerations for improved biomass stoves. The use of these stoves contributes a lot to the improved kitchen environment especially with regard to cleanliness and health. The amount of smoke that is being produced by the traditional stoves are reduced tremendously and hence the level of coughing, headache and eye irritation also be reduced.

RECENT STUDIES INDICATE THAT EVEN USING AN IMPROVED TIER 2 OR TIER 3 BIOMASS STOVE STILL DOESN'T CHANGE HEALTH OUTCOMES.

Various studies have associated the smoke from traditional stoves with health risks including acute respiratory infections in children, chronic obstructive lung diseases (such as asthma and chronic bronchitis), lung cancer and pregnancy-related problems. Specifically, indoor air pollution affects women and small children far more than any other people in the society. Women typically spend three to seven hours per day, cooking breakfast, lunch and dinner. This situation exposes them to smoke, often with young children nearby or strapped on their backs. Properly designed improved cook-stoves with chimneys can dramatically improve this situation by reducing smoke exposure for the rural women and children.

ECOOK WILL TAKE THE COOK INTO A NEW EXPERIENCE, WHERE SMOKE IS NO LONGER AN ISSUE UNLESS THEY BURN THE FOOD BY ACCIDENT.

However, changes in traditional beliefs and attitudes may be required for users of traditional stoves, particularly regarding the use of chimneys in

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firewood stoves. For example, some like the smell of smoke and believe that it adds to the flavour to food. Smoke naturally repels insects, animals and termites. Non-portable stoves restrict cooking to one location.

4.4.3.2 Environmental protection

Extensive and inefficient use of biomass fuel, combined with unsustainable harvesting practices is the single largest cause of demand for biomass and depletion of forest reserves. The situation does not only represent a threat for the environment, but adverse socio-economic effects of the current practices make the lack of access to sustainable cooking solutions a poverty trap and create high barriers for economic development.

Odarno *et al.* (2017) note that "The Paris Declaration recognizes that development of a low-carbon economy must be delivered through implementation of concrete projects at the local and national levels in renewable energies, energy security and energy efficiency, transportation and mobility, waste management, food security, and related economic sectors. Under the agreement, all countries are to prepare Nationally Determined Contributions (NDCs), which indicate how they plan to reduce greenhouse gas emissions. Tanzania's NDC indicates that it will reduce its emissions by 10–20 percent by 2030 relative to the business as usual scenario of 138–153 million tonnes of carbon dioxide equivalent (MtCO2e)."

- The National Climate Change Strategy, adopted in 2012, commits Tanzania to address climate change adaptation and participate in global efforts to reduce greenhouse gasses in the context of sustainable development.

- The Reducing Deforestation and Forest Degradation (REDD+) Strategy of 2013 aims at curbing deforestation. It seeks to guide the implementation and coordination of mechanisms required for Tanzania to benefit from a post-2012 internationally approved system for forest carbon trading, based on demonstrated emission reductions from deforestation and forest degradation."

TANZANIA'S POPULATION WILL DOUBLE BY 2050. NOT ONLY WILL THIS PUSH UP URBAN DEMAND FOR CHARCOAL, BUT UNLESS FIREWOOD COLLECTION IS WELL MANAGED, RURAL PEOPLE WILL HAVE TO WALK FURTHER & FURTHER. OFTEN THE WAY PEOPLE COLLECT (COPPICING OR CUTTING TREES) GREATLY AFFECTS THE DEFORESTATION EFFECT.

The main cause of deforestation in Tanzania is agriculture, followed by use of wood for charcoal production. With regard to environmental impact of reliance on wood biomass for rural energy, deforestation and forest degradation are the main reason for concern. According to NAFORMA (2010), the estimated forest cover loss in Tanzania amounts to 372,816 hectares per year. The wood

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deficit from legal sources is around 19.5 million m^3 per year, which is met by overharvesting in the accessible forests and illegal harvesting in protected forests.

Charcoal production is a major contributor to deforestation. The sector is characterised by weak governance and weak market chains. According to World Bank (2010), charcoal production causes an annual loss in forest cover of 100,000-125,000 hectares. The energy efficiency of charcoal production is also poor, with conversion efficiencies of 15% or less. This is, mainly, due to a high degree of reliance on traditional Basic Earthmound Kilns (BEK), combined with rushed carbonisation of the wood by some charcoal producers.

4.4.4 Clean cooking interventions to date

Efforts of facilitating cleaner cooking solutions started in 1990 when the Energy department was established by the Government and later TaTEDO adopted some technologies introduced by WB Energy I project which was implemented by the Ministry of Energy. TaTEDO developed different prototypes of stoves and introduced solar cookers and fireless cookers in some communities. The current production of stoves is around 15,000 units per month, with the majority informally developed and marketed. In Dar es Salaam, the adoption of improved cookstoves is more than 40% while in the countryside it is about 10% (TaTEDO, 2015). Improved charcoal cookstoves are mostly manufactured in Dar es Salaam, then distributed to other regions and even exported. Recently several imported charcoal stoves have entered the market.

Solar PV is used extensively for lighting and other low power applications, but the authors are unaware of any solar electric cooking systems. Solar cookers using direct thermal methods have been introduced, however adoption is still very low. The level of income, prices and availability are among the determinants of the level of use of any source of energy in a particular area, household, institution and enterprise. Income, prices and availability are likely to be key factors limiting the adoption of solar electric cooking systems and battery-supported electric cooking appliances more broadly. However, innovative pay-as-you-go systems that package complete systems that can offer a modern cooking service to users for a lower regular cost than they are currently paying for biomass have the potential to rapidly scale.

PV-ECOOK MAY NOT HAVE THE ONGOING LOGISTICAL COSTS OF L.P.G. BUT COMPETING WITH BIOMASS IN RURAL AREAS WHERE FUEL IS OFTEN COLLECTED WILL STILL BE CHALLENGING.

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Economic analyses of relevant alternatives to traditional cooking show that increased use of improved biomass fuel based cook stoves (ICS) gives the highest economic net gain for society as a whole (Table 7). Investment and running costs are compared with the benefits in terms of saved forest resources and economic savings for consumers in purchase/collection of wood fuel. The cost of implementing promotional programmes and the public efforts required for rolling out the solutions are not accounted for in the analyses. Sustainable charcoal production was also found to have an important role, as was LPG, both of which had higher impact than kerosene, biogas or electricity according to the assumptions made in the study.

1.4GWH /YEAR? 5% OF 45 MILLION IS 2.25 MILLION, GIVING 622 KWH/PERSON/YEAR, OR 1.7 KWH/PERSON/DAY – THE COOKING DIARIES FINDINGS SUGGEST THIS IS AN OVERESTIMATION.

THE 800MW PEAK LOADING ASSUMPTION SEEMS MORE REASONABLE – 355 W/PERSON FOR 2.25 MILLION, I.E. 1.8KW FOR A 5 PERSON HH. OF COURSE, WITH A BATTERY-SUPPORTED STOVE, THIS WOULD BE MUCH LOWER, AS THE HIGH PEAK LOAD WOULD BE SPREAD OUT THROUGHOUT THE DAY.

Table 7: Biomass substitution effect of different forms of improved cooking.

OPTION	SUBSTITUTION EFFECT	RELEVANCE
Efficient charcoal production	93% improved production would alone stabilize demand at 2016 level.	High impact
Improved cook stoves	100% usage would cut biomass consumption by almost half	High impact
LPG	Each additional 10% LPG would reduce biomass consumption by 7%	High impact
Biogas	Each biogas digester of 8 to 10 m3 can supply on average one rural household. 100 000 plants would only reduce overall demand by 1%	Low impact
Electricity	1.4 GWh per year or close to 800 MW capacity required to increase market share to less than 5%	Low impact
Kerosene	Substitution potential approximately half of that of LPG	Medium impact

Source: REA 2017

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The second highest economic viability is represented by LPG as an alternative to charcoal in urban areas. It represents significant forest saving gains and avoidance of CO2 emissions. Due to higher logistical costs, less significant fuel cost savings and wood fuel per replaced user, LPG as an alternative for cooking with firewood in rural areas was predicted to represent low economic value for the society overall. LPG represents lower long-term average costs for the households, but challenges, however it has logistical challenges; dependence on import of LPG influences the level of energy security of this option; and for the users requires higher investments in equipment than ICS. Cooking with gas further implies changes in people's habits. All these challenges are more difficult to overcome in rural areas than urban areas.

THIS COMMON ASSUMPTION ON THE AFFORDABILITY OF ELECTRIC COOKING IS CHALLENGED BY THE FINDINGS FROM THE COOKING DIARIES. THE BEHAVIOURAL CHANGE CHALLENGES SHOULD ABSOLUTELY NOT BE UNDERESTIMATED; HOWEVER, NEITHER SHOULD THE DRIVERS FOR SUSTAINED USE – PRIMARILY CONVENIENCE & COST SAVINGS.

The government has provided tax relief to stimulate the use of LPG in the country. Over the past ten years, LPG supply for household cooking has increased significantly. The total volume of LPG imported in financial year 2010/11 was 24,470 MT compared to 69,148 MT in financial year 2014/15. The trend shows that the LPG market is growing rapidly especially in urban centres (NEP, 2015).

In rural areas, where agricultural by-products are available, biogas digesters appear highly economically attractive. Savings on cooking fuel, combined with the value of fertilizer produced will yield financial gains for household investments in biogas digesters. A large-scale rollout of biogas is however not realistic due to raw material availability limitations. The implementation, promotion and investments also represent barriers, as demonstrated by previous efforts to establish biogas plants that have produced results significantly below their targets.

ALTHOUGH HARMFUL, CHARCOAL DOES. CREATE LIVELIHOODS FOR MANY RURAL PEOPLE. THERE IS A LONG-TERM VIEW OF LOCAL FABRICATION/ASSEMBLY, HOWEVEER AT LEAST INITIALLY, ECOOK WOULD SUBSTITUTE A LOCAL INDUSTRY FOR IMPORTED TECHNOLOGY & POTENTIALLY CHANGE THE FOREIGN EXCHANGE BALANCE BY UP TO $1 BILLION DOLLARS!

Electricity is the cleanest way of cooking food, however with the current domestic electricity tariffs in Tanzania it is not affordable for most households. However, the economic value for the society as a whole is limited, and transition to electric cookers requires significant changes in people's cooking habits. The relatively costly electric cookers also make this option unaffordable, with exception for upper middle- and high-income population groups. Electricity is expected to remain highly

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marginal as cooking energy in rural and urban areas under the current situation.

4.4.4.1 Biomass Energy Strategy (BEST)

Tanzania's Biomass Energy Strategy (BEST) was designed and developed in 2014 by the MEM with the support of the EU, to identify the means of ensuring a sustainable supply of biomass energy; increasing the efficiency with which the biomass energy is produced and utilised; promoting access to alternative energy sources wherever appropriate and affordable; and ensuring an enabling institutional environment for implementation The BEST baseline projections show that demand for charcoal, without supply- and demand-side interventions, will double by 2030, from approximately 2.3 million tons of charcoal in 2012[1].

Commercial biomass energy is a major source of rural and urban livelihoods. Charcoal and commercial firewood generated approximately TZS 1.6 trillion ($1 billion) in revenues for hundreds of thousands of rural and urban producers, transporters and wood energy sellers in 2012[2]. Commercial biomass energy is the largest source of cash income in rural Tanzania. Additionally, biomass energy provides the major energy source for a wide range of rural and urban activities, including commercial, institutional and industrial uses. It is estimated that this non-household demand is equivalent to approximately 15% of urban household consumption amounting to 300,000 tons of charcoal in 2012.[3]

The main conclusion from the BEST Tanzania is that forestry biomass energy demand is unsustainable. Demand for wood energy has led to increasingly negative environmental, agricultural and other local and macro-impacts. Unsustainable biomass energy demand is accelerating year-on-year because of:

- The low priority that is accorded to biomass energy by almost all key government agencies.
- The lack of a national policy framework for biomass energy.
- Poor public awareness of biomass energy efficiency issues and options.
- Complicated, often contradictory and poorly-regulated governance of commercial biomass energy production and trade.

[1] Assumes 50m^3 per hectare national average (MNRT, 2013). If charcoal consumption in 2012 was 2.3 million tonnes, assuming 19% wood to charcoal conversion, then, the equivalent of nearly 350,000 ha of woodland was harvested to produce that charcoal.

[2] BEST Team charcoal market surveys, TFCG, 2013; NBS, 2013b, Census data, others.

[3] Malimbwi, R.E. and Zahabu, E., 2009. Norad, 2009.

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- A lack of replicable examples of, or models for sustainable charcoal.
- No mainstream commercially competitive biomass alternatives to charcoal and fuel wood.

ELECTRICITY IS IDENTIFIED BY THE BEST AS A DEMAND SIDE MANAGEMENT OPTION, A GOVERNMENT AGENDA THAT ECOOK COULD STRONGLY CONTRIBUTE TO.

To address these issues, the BEST Tanzania recommended the following interventions.

On the supply side, the BEST recommended to broaden the mandate for the Tanzania Forest Services (TFS), expand its budget significantly, recruit personnel and mobilize other resources. This should enable TFS to place major emphasis on working with local authorities (district and municipal councils), villages and the private sector to develop and register forest management plans that will significantly increase participatory forest management (PFM), community-based forestry management (CBFM), joint forestry management (JFM) and overall sustainable wood energy production by an indicative target of 20% by 2030 (on 2012 levels);

Local Government should support local NGOs and other activities (e.g., MEM and REA) that promote and commercialize biomass energy from agricultural wastes (e.g., rick husks, coffee husks, sisal residues, etc.) and the technology to utilize those wastes through briquettes, biogas, among others; and Charcoal producers need to be organized commercially, their activities licensed, their wood supplies sourced sustainably and their production efficiencies increased substantially with a target of achieving and indicative target of 50% efficiency improvement at a national level by 2025 (TFS and MEM).

PERCEPTION OF AFFORDABILITY & LACK OF GENERATING CAPACITY HAVE BEEN MAJOR BARRIERS. LACK OF CAPACITY MAY WELL CHANGE, HOWEVER HISTORICALLY LITTLE HAS BEEN DONE TO CHALLENGE THE PERCEPTION OF AFFORDABILITY, AS IT HAS ENSURED SLOW UPTAKE IN LINE WITH INCREASES IN GENERATING CAPACITY.

On the Demand Side, The BEST recommended for establishing a major, commercially-oriented, mainstream improved cookstoves programmes which will give priority to major consumption areas such as urban households, and commercial/institutional consumers, with a target of reducing urban charcoal demand by an indicative 50% by 2030.

The BEST also emphasized on use of biomass energy alternatives (particularly biomass briquettes and biogas). These resources are supposed to be commercially mainstreamed with an indicative target of reducing current demand (2012) for charcoal and commercial fuel wood of 5% by 2030. and,

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The BEST also highlighted the need to make non-biomass alternatives, particularly kerosene, LPG and electricity, competitive on a non-subsidized basis in terms of availability and price.

4.5 Electrification

Low access rates, especially in rural areas are a big barrier for electric cooking in Tanzania, but clearly not the only one. Currently only 16% of Tanzanians (9 million) have access to the national grid, however only 1% (600,000) use electricity as their primary cooking fuel (WHO, 2017; World Bank, 2019).

9 million Tanzanians live in urban slums, 11 million urban Tanzanians are not yet connected to the grid, and 16 million with charcoal or kerosene (WHO, 2017; World Bank, 2019). It is likely that these three market segments overlap considerably, creating an opportunity for Grid-eCook to leverage existing expenditures on polluting fuels to offer both access to clean cooking facilities and electricity to millions of people who are currently well within reach of the grid, but not yet connected to it.

The increasing pace of electricity connection, especially in rural areas is one of the fundamental principles behind establishing the Rural Energy Agency (REA). The 2016 Energy Access Situation Survey (NBS and REA, 2017) results show a significant improvement of electricity connection at the household level in both rural and urban areas of the Tanzanian mainland since 2011. The 2011/12 Household Budget Survey and the 2011 Baseline Survey Report for Energy Access and Use in Tanzania Mainland showed that 6.1% of rural households were connected to grid electricity (TANESCO, mini/micro grids, solar and other private sources). Likewise, the 2012, Population and Housing Census recorded 7.4% of rural households as connected to any form of electricity. The 2016 Energy Access Situation Survey findings show that 16.9% of rural households in Tanzania Mainland were connected to electricity of any form, with 32.8% of all households and 65.3% in urban areas.

Solar systems now account for 25% of all electricity connections, with grid electricity accounting for almost all of the remainder (NBS and REA, 2017). However, in rural areas, the trend is reversed and solar makes up 65% of connections. There are also big regional differences (Figure 6), with Dar es Salaam unsurprisingly showing the highest connectivity rate (75%) and the Western provinces of Rukwa, Songwe, Kigoma, Geita, Shinyariga and Simiyu all below 15%. Figure 7 shows that off-grid solar has been most successful in Lindi, Njombe, Mtwara and Katavi, where it represents 76%, 63%, 61% and 58% of connections respectively.

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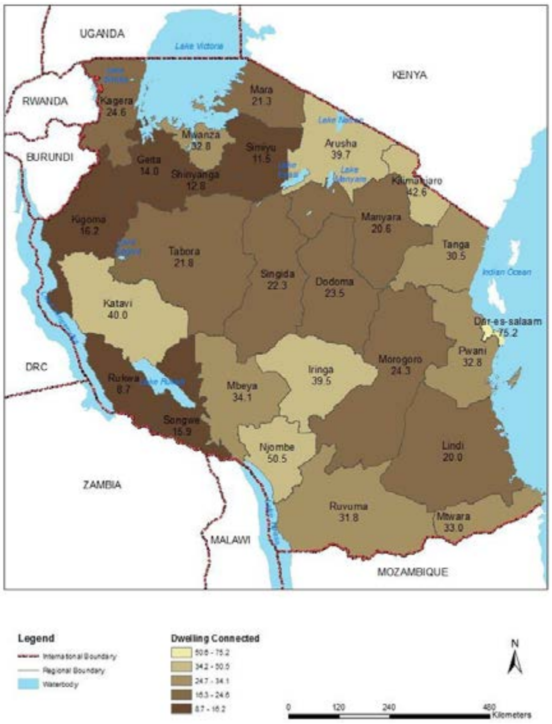

Figure 6: Percentage of households with access to electricity by region.

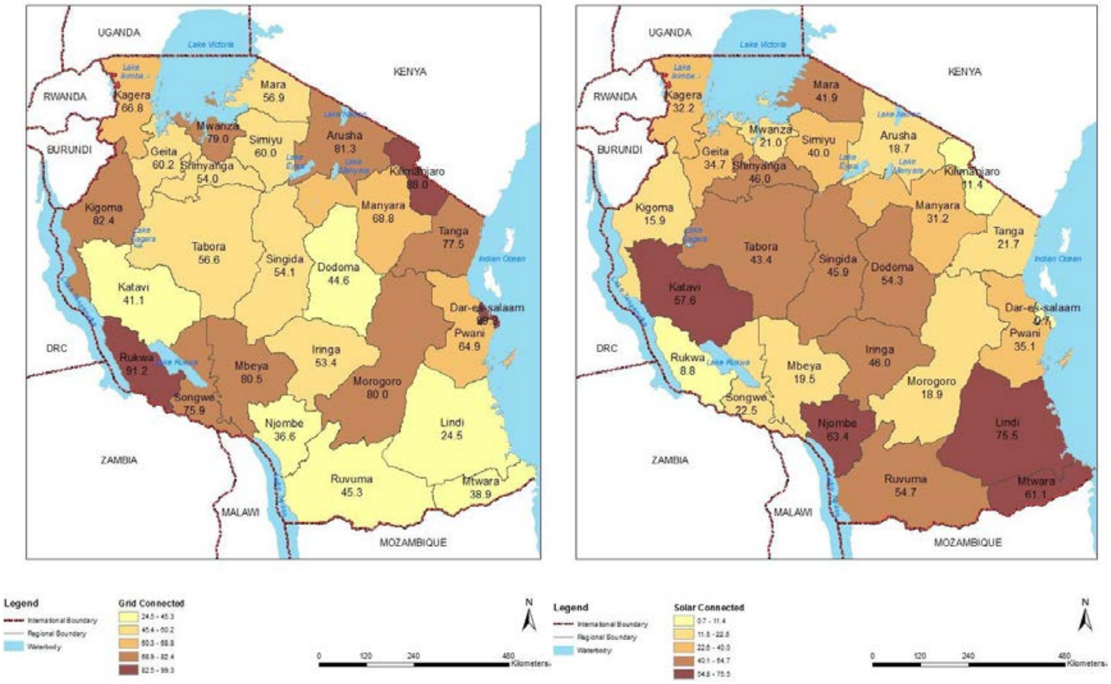

Figure 7: Type of electricity connection: a) grid electricity (left) or b) solar (right).

IN RURAL TANZANIA, OFF-GRID SOLAR SYSTEMS NOW OUTNUMBER GRID CONNECTIONS, CREATING A HUGE OPPORTUNITY FOR PV-ECOOK.

IED's (2013) GIS analysis of Tanzania and found that 46% of the population could be most economically electrified by extending TANESCO's grid, 20% through mini-grids and 33% using off-grid

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solutions. Figure 8 shows the size and location of key settlements in Tanzania and their current electrification status, clearly showing the unevenly distributed population that will require complimentary grid-extension, mini-grid and off-grid electrification programmes to achieve universal access to electricity. Tanzania's National Electrification Program Prospectus projects that by 2022 about 5,500 settlements will be electrified through the grid connection plan between 2013–22 and a further 6,000 settlements could be electrified with off-grid electrification and distributed technologies (Odarno *et al.*, 2017).

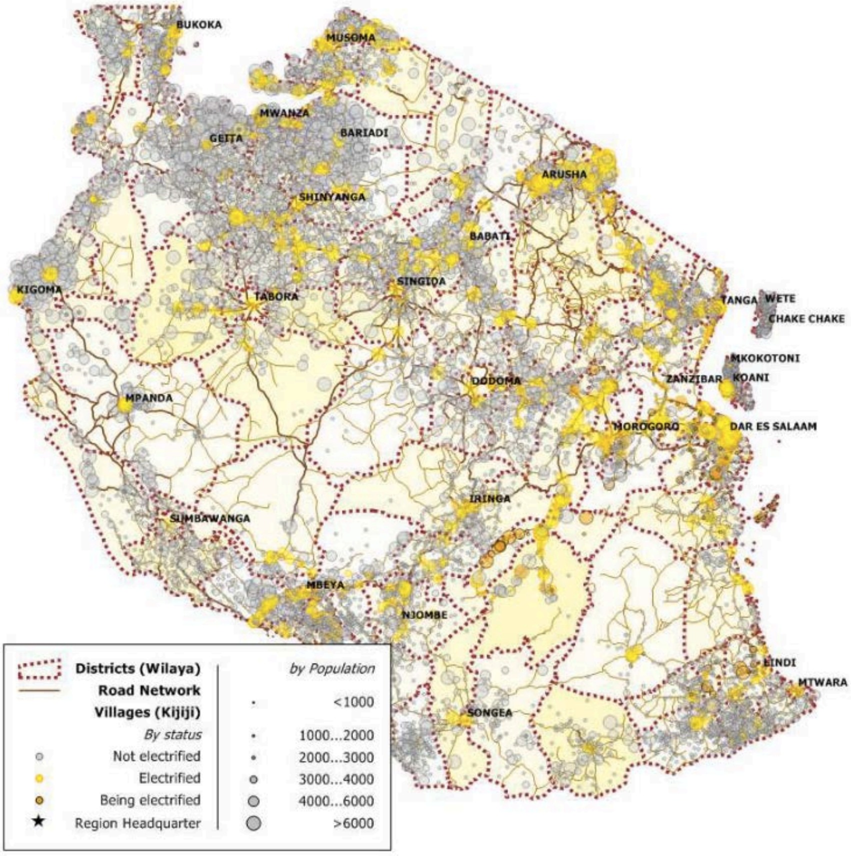

Figure 8: Electrified and unelectrified settlements in Tanzania (IED, 2014).

4.5.1 Grid electrification

4.5.1.1 Renewable energy

Tanzania is heavily reliant on biomass, so has a relatively high share of renewable energy in its total energy mix (87%), but when considering just electricity, this falls to 42% (IRENA, 2016b; SEforALL Africa Hub, 2018). Figure 9 shows that whilst hydropower used to be Tanzania's main source of electricity, in recent years, natural gas has overtaken it. IRENA (2016) note that expensive oil

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generation accounts for a fifth of electricity generation, principally for off-grid and emergency backup generation for the grid. They lament that despite Tanzania's excellent wind, solar, geothermal and biomass resources, only less than 5% of non-hydropower renewables are planned in the Electricity Industry Reform Roadmap 2014-2025, which instead focusses on expanding hydro and natural gas and diversifying into coal and uranium.

ECOOK OFFERS TANESCO THE OPPORTUNITY TO INCREASE ITS REVENUE PER CONNECTION & REDUCE DEPENDENCE ON EMERGENCY GENERATORS THROUGH DISTRIBUTED STORAGE.

Feed-in tariffs and small power purchase agreements (SPPAs) for grid-connected projects both exist, however investment has been limited due to TANESCO's (who they have no choice but to sell to) weak financial status and the lack of government guarantees in the case of default.

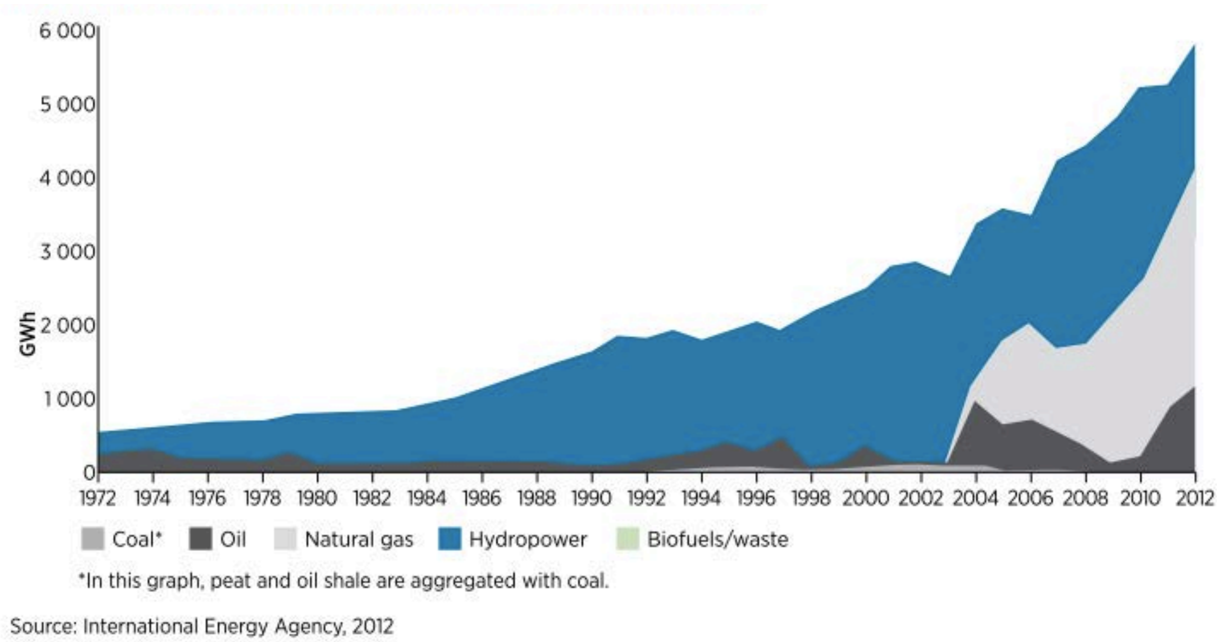

Figure 9: Electricity generation by source in Tanzania (IRENA, 2016b).

4.5.1.2 Reliability

Tanzania's dependence on hydropower leaves it exposed to rolling blackouts during droughts and a big bill for emergency oil-based backup generation (IRENA, 2016b). As part of their Doing Business surveys, The World Bank (2017) reported an average of 7 blackouts per month in business districts of Dar es Salaam, however in urban slums with illegal connections and in rural areas at the end of long transmission lines, this

LACK OF ACCESS IS NO LONGER A BARRIER FOR MANY URBAN COOKS, HOWEVER, UNRELIABILITY STILL IS.

figure is likely to be much higher. In terms of consumer perception, NBS & REA's (2017) household survey showed that the consumer perception of blackouts was worse in rural areas. However, the actual difference in number of blackouts per month could have been much higher than in urban areas, as there could well be the expectation that the power will go off more regularly in rural areas.

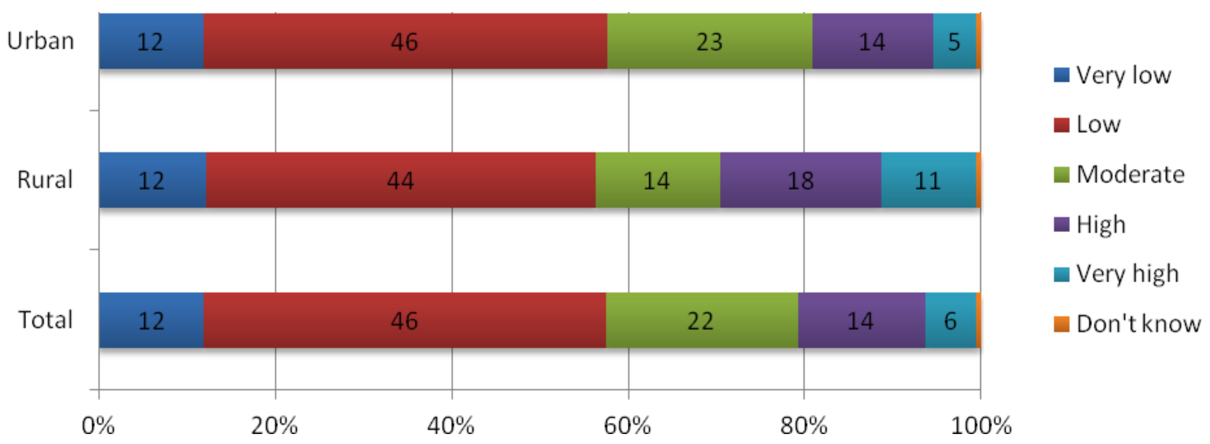

Figure 10: Perception of Households on Electricity Interruptions/Cut off by Place of Residence (NBS and REA, 2017).

NBS & REA (2017) found that only 4% of HHs rated the quality of electricity they received as very good. Surprisingly, perceptions of power quality were higher in rural areas than urban. Although being at the end of long lines in rural areas is likely to result in voltage fluctuations, so is the overloading of transformers in rapidly expanding urban areas, especially where there are many informal connections.

VOLTAGE INSTABILITY CAN AFFECT COOKER PERFORMANCE AS MUCH AS BLACKOUTS. COOKING WITH APPLIANCES DESIGNED FOR 220V IS NOTICABLY SLOWER <200V & IMPOSSIBLE <150V.

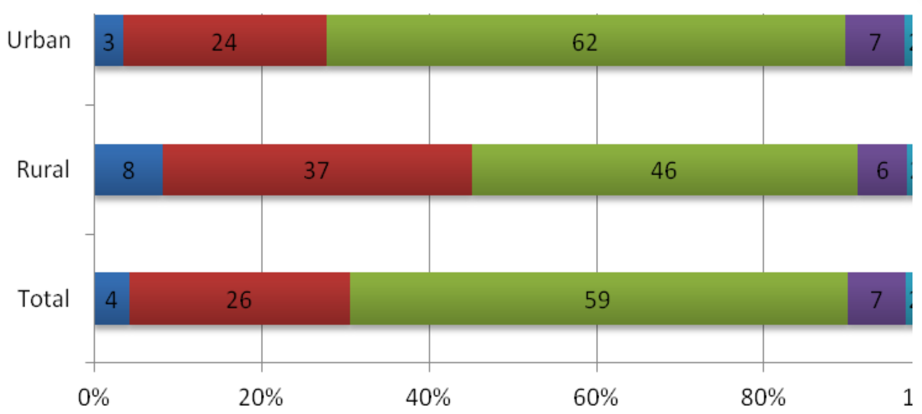

Figure 11: Perception of Households on the Quality of Electricity Services Supplied by Place of Residence (NBS and REA, 2017).

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Figure 12 shows a typical daily load profile, with a big peak in the evening for households. The consequence of this is that all of the supporting infrastructure has to be sized to meet this peak demand, from household wiring, to transmission and distribution, all the way to generation.

IF ALL NEW CONNECTIONS INCLUDED DISTRIBUTED HH STORAGE VIA GRID-ECOOK TO FLATTEN THE LOAD PROFILE, THE SUPPORTING INFRA-STRUCTURE COULD BE MUCH SMALLER & CHEAPER.

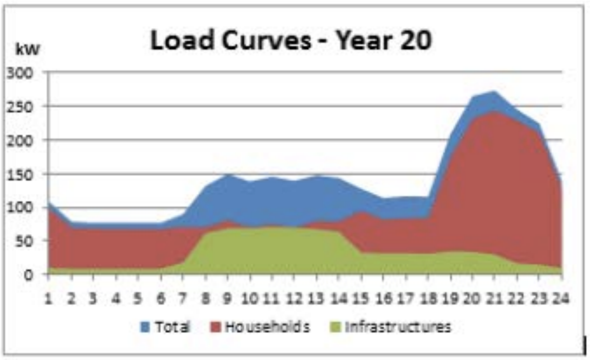

Figure 12: Load profile used during the development of the National Electrification Programme Prospectus (IED, 2014).

4.5.1.3 Costs and tariffs

FURTHER TARIFF INCREASES SHOULD BE EXPECTED AS DESPITE RISING 40% IN 2012, TANESCO IS STILL UNABLE TO COVER ITS COSTS.

IRENA (2016) and Odarno et al. (2017) note that despite a 40% tariff increase in 2012, TANESCO is still not able to cover its costs, leaving the utility insolvent. TANESCO stated that current tariffs bring in an average revenue of 198 TZS/kWh (USD 0.10/kWh), while costs total 332 TZS/kWh (0.16 USD/kWh), leaving a shortfall of 134 TZS/kWh (63%) (TANESCO, 2013), resulting in a loss of 142 million USD in 2012 alone (IED, 2014). TANESCO's tariffs are approved by the Ministry of Energy and Minerals and then EWURA, taking into account a range of factors including production/distribution costs, social and political objectives (TANESCO, 2013). Generation costs are currently high, primarily due to dependence on emergency diesel generating plants, which account for 13% of installed capacity (TANESCO, 2013). What is more, the inefficient transmission and distribution infrastructure results in a quarter of the power generated being lost before it even reaches the consumer (IRENA, 2016b).

THE COOKING DIARIES SHOW THAT SMALLER HHS WITH EFFICIENT APPLIANCES CAN COOK USING TANECO'S 75KWH/MONTH LIFELINE TARIFF.

Despite recent tariff increases, grid electricity in Tanzania is still relatively cheap (see Figure 13). TANESCO offer a cross-subsidised lifeline tariff (D1), enabling HHs using less than 75kWh/month to pay just 100TZS/kWh

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(0.043US/kWh) and avoid the fixed monthly fee (see Figure 13). In 2015, TANESCO estimated 1.85 million customers, 52% T1, 47% D1 and 1% in other categories (IRENA, 2016b). Even above 75kWh/month, the unit cost is still relatively cheap at 306TZS/kWh (0.13USD/kWh).

TARIFF	DESCRIPTION	SERVICE CHARGE (T SH/MONTH)	ENERGY CHARGE (T SH/KWH)	DEMAND CHARGE (T SH/KVA/MONTH)
D1	Low voltage (230V) consumption of less than 75 kWh	0	100	0
T1	Low voltage (230–400V) consumption of more than 75 kWh	5,520	306	0
T2	Low voltage (400V) demand of less than 500 kVA per month, consumption of more than 7,500 kWh	14,223	205	15,504
T3 MV	Medium-voltage supply at 11/33 kV, demand of more than 500 kVA per month, consumption in kWh	16,769	163	13,200
T3 HV	High-voltage supply at 132/220 kV, demand in kVA per month, consumption in kWh	0	159	16,550

Source: TANESCO Marketing Department (2016).

Note: Tariffs were in effect between 2015 and 2016.

Figure 13: TANESCO retail tariffs (Odarno *et al.*, 2017).

Figure 14 shows that poorer households consume considerably less than better off households. Across the three regions listed as sample data by IED (2014), poorer households used an average of 30kWh/month, which would leave an additional 45kWh/month within the current 75kWh/month lifeline allowance for cooking.

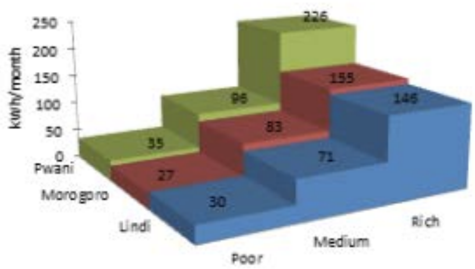

Figure 14: Household consumption data in selected regions, disaggregated by socio-economics (IED, 2014).

DISPELLING THE MYTH THAT ELECTRIC COOKING IS EXPENSIVE IS LIKELY TO BE MUCH EASIER WITH PREPAID METERS, AS CUSTOMERS WILL SEE HOW MUCH THEY ARE SPENDING MUCH QUICKER.

NBS & REA (2017) found that over 90% of Tanzanian households had prepaid meters and on average, use 53kWh/month, corresponding to monthly expenditure of 19,000TZS or 8USD. Rural households use slightly less (44kWh/month), while urban households slightly more (55kWh/month).

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

Regionally, Dar es Salaam is the highest at 61kWh/month and Iringa and Lindi lowest at 31kWh/month. Half of the households reported that monthly electricity bills were moderate, while one third said high and 11% very high. Just 3% said they were low or very low, indicating that affordability is an issue for many HHs.

IRENA (2016) noted that connection fees were a major barrier preventing poorer households from accessing the lifeline tariff, they were substantially reduced in 2012 (TANESCO, 2013) to 120USD for urban and 68USD for rural customers. However, NBS & REA (2017) found that one third of had still paid over 300,000TZS (130USD). One quarter paid 100,000-300,000TZS (43-130USD) and another third less than 100,000TZS (43USD). Only 2% were able to acquire a loan for the connection fee and just 1% were fully subsidised.

THE 120USD MANY HHS HAVE ALREADY PAID FOR A GRID CONNECTION IS LIKELY TO BE MORE THAN ENOUGH FOR A DEPOSIT ON A PV-ECOOK SYSTEM.

However, the true cost of grid extension is much higher (Figure 15). IED (2014) estimated that under Tanzania's National Electrification Programme, just to make the final connection to the household, rural connections would have to be subsidised by an average of 51% and urban by 35%. Overall, this would equate to a 701 million USD subsidy for household connection costs alone.

	Consultant's Cost Estimate	Connection Fees	
		Urban Area	Rural Area
SINGLE-PHASE SUPPLY	**US$**	**US$**	**US$**
Overhead service-line, single-phase, 30 meters			
D1 and T1 with LUKU meter	350	201	111
Overhead , single-phase, 70 meters, 1 pole required			
D1 and T1 with LUKU meter	550	322	211
Overhead , single-phase, 120 meters, 2 poles required			
D1 and T1 with LUKU meter	800	435	284

Figure 15: Comparison of cost estimates with actual connection fees charged to new customers (IED, 2014).

The National Electrification Programme Prospectus outlines an ambitious plan to extend the electricity grid to reach a total of 31% of the population by connection an additional 6.1 million HHs between 2013 and 2022 at a total cost of 3.5 billion USD. Table 8 shows the average cost of adding a household to TANESCO's infrastructure under this plan. Densification is the cheapest method (385USD/HH), as it involves simply connecting

THE TECHNO-ECONOMIC MODELLING SHOWS THAT AT 700USD THE INVESTMENT COST OF A PV-ECOOK SYSTEM IN 2020 IS LIKELY TO BE LESS THAN GRID EXTENSION OR MINI-GRIDS.

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households already within reach of the existing distribution infrastructure. Extending the transmission and distribution network in a 4-phase 'Turnkey' programme (see Figure 16) cost roughly double (857USD/HH). A combination of micro-hydro, biomass gasifier and PV/diesel mini-grids were most expensive (1,800USD/HH), however this was the only category where the cost of the generation system was also included.

Table 8: Cost of grid connection by densification of connections around existing grid infrastructure, extension of the transmission network and mini-grid under the National Electrification Programme. Data source: IED (2014).

	New connections by 2022	Investment cost (USD)	Average cost per new connection (USD/HH)
Densification	3.9 million	1.5 billion	385
Grid extension ('Turnkey' program)	2.1 million	1.8 billion	857
Mini-grid (inc. power plant)	0.1 million	0.18 billion	1,800

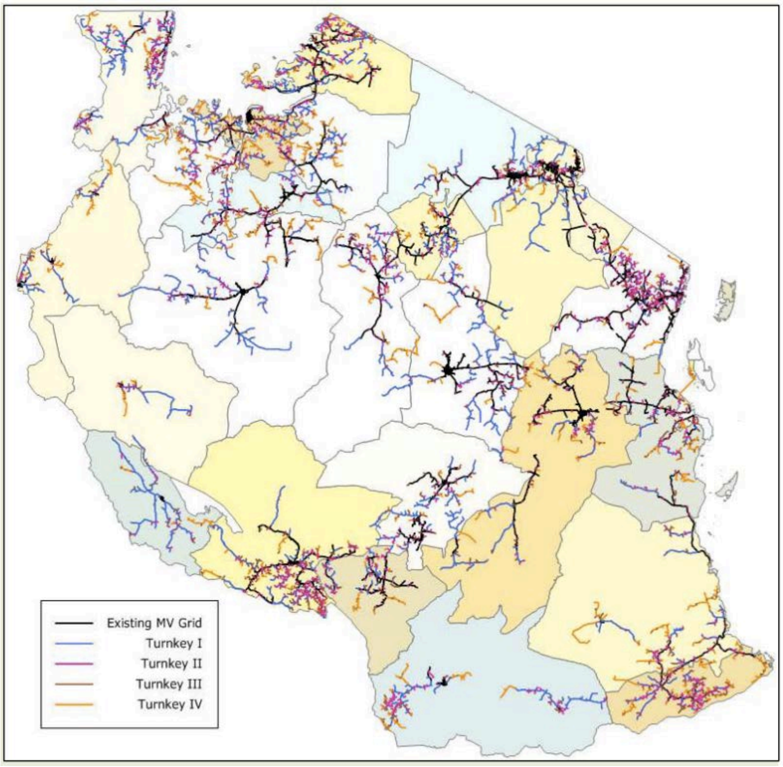

Figure 16: Existing TANESCO grid and planned extensions ('Turnkeys') by 2022 (IED, 2014).

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4.5.2 Mini-grids

4.5.2.1.1 Insights from WRI & TaTEDO

This section draws out relevant sections from WRI and TaTEDO's recent collaborative publication '*Accelerating Mini-grid Deployment in Sub-Saharan Africa - Lessons from Tanzania*' (Odarno *et al.*, 2017) and provides a commentary on their relevance to eCook.

"Mini-grids—electrical generation and distribution systems of less than 10 megawatts (MW)—represent a relatively rapid means of providing electricity to rural centres that are far from grid infrastructure and unlikely to be connected in the short or medium term. Unlike small solar home systems, which generally provide power for lighting, mobile phone charging and appliances like fans and televisions, mini-grids can provide electricity for productive uses, such as grain milling, and they can be built in ways that allow for connection to a centralized grid"

ON MINI-GRIDS WITH SPARE CAPACITY AT PEAK TIMES, OFF-THE-SHELF BATTERYLESS AC APPLIANCES CAN SIMPLY BE PLUGGED IN DIRECTLY.

4.5.2.2 What is the state of the mini-grid sector?

"Tanzania is a regional leader in mini-grid development. In 2008, it adopted a ground-breaking mini-grid policy and regulatory framework to encourage investment in the sector. Since then, the number of mini-grids in the country has doubled. The national utility (TANESCO), private businesses, faith-based organizations, and local communities now own and operate more than 100 mini-grid systems."

TANZANIA IS A REGIONAL LEADER IN MINI-GRID DEVELOPMENT, CREATING A KEY OPPORTUNITY: MINI-GRID-ECOOK.

"Tanzania has at least 109 mini-grids, with installed capacity of 157.7 MW (exact figures are not known, because some small systems may not have registered). They serve about 184,000 customers. Sixteen of these plants are connected to the national grid; the remaining 93 operate as isolated mini-grids. Not all the installed capacity goes to customer connections; some is sold to the national utility, the Tanzania Electric Supply Company (TANESCO)."

"Hydro is the most common technology (49 mini-grids), although the 19 fossil fuel systems account for 93 percent of customer connections and almost half of total installed capacity. Tanzania has 25 biomass mini-grids, and 13 solar mini-grids (10 of them small donor-funded, community-owned demonstration projects). There are no wind mini-grids in Tanzania (Figure ES-1)."

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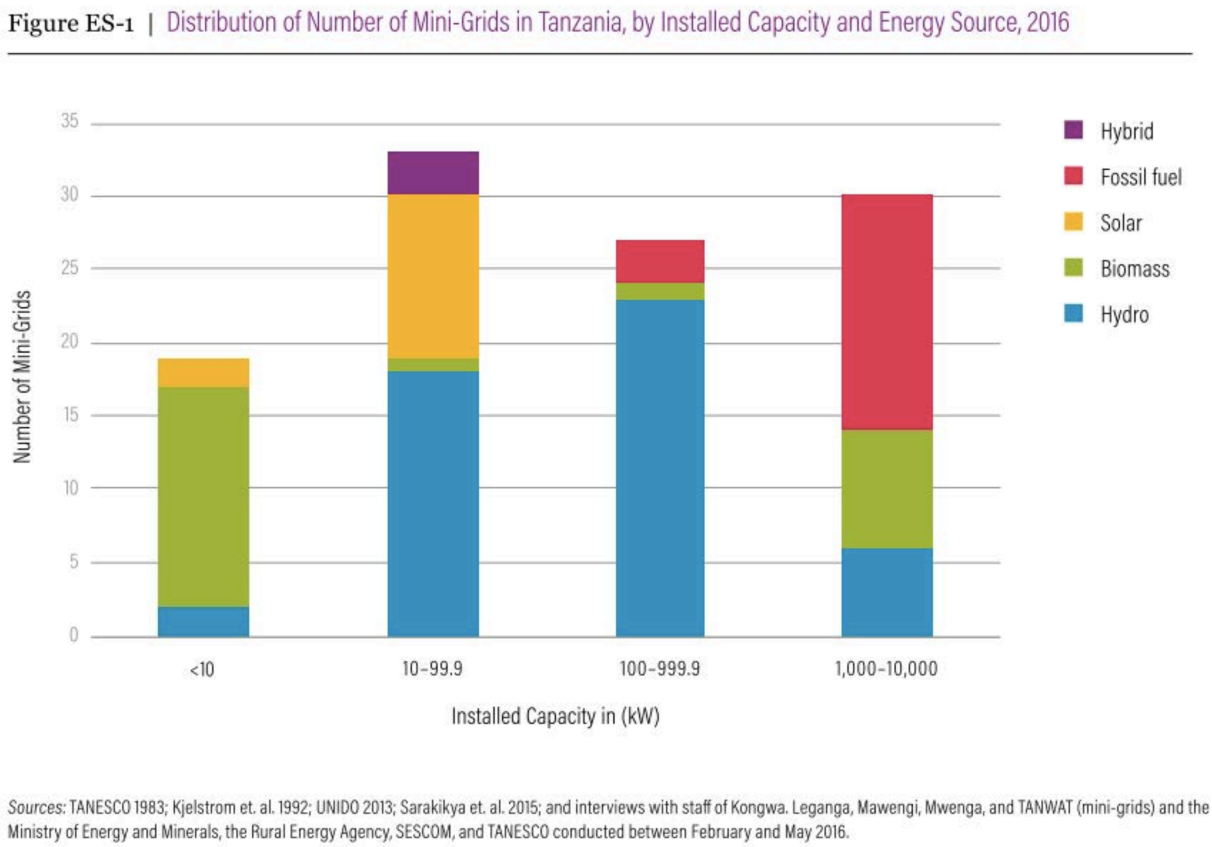

Figure 17: Distribution and number of mini-grids in Tanzania in 2016 by installed capacity and energy source (Odarno *et al.*, 2017).

"Mini-grids provided the first electricity in Tanzania (in colonial days) and continue to supply many rural enterprises and isolated communities. Developers have favoured technologies that have proven to be robust and cost-effective.

- Hydro mini-grids are the most common type of mini-grids, but fossil fuel and biomass systems dominate installed capacity. Hydro is expected to remain the dominant technology if current financing support is maintained.
- Diesel and natural gas mini-grids (all owned by the Tanzania Electric Supply Company [TANESCO]) account for the vast majority of mini-grid customers. They are large (average 3.8 MW) and relatively inexpensive to install, but they need frequent maintenance and spare parts that are not readily available in rural areas.
- Numerous small, informal diesel mini- grids exist. They supply small clusters of households all over the country and are not captured in formal records.
- Diesel systems can also be quickly started and stopped, which is useful for meeting fluctuations in demand, as is common in commercial applications. In contrast, solid biomass

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plants, such as steam turbines, take a long time to cool down after stopping and require a long time to restart.

- Most biomass plants (average 2.1 MW) are commercially owned units powering wood or sugar mills and supplying other users in the vicinity. They are moderately inexpensive to build and maintain, but fuel supply and preparation can be challenging.
- Hydro mini-grids are smaller (average 672 kW), and most of them are run-of-river installations. They are expensive to build but long-lived and relatively inexpensive to operate. Most hydro mini-grids in Tanzania are perennial, although generation during the dry season is usually lower than in the wet season.
- Consumers are familiar with stand-alone solar home systems; they are less familiar with larger solar mini-grid systems that provide services to a cluster of users. Solar mini-grids remain mostly at the demonstration stage.
- Although the cost of solar is falling, solar mini-grids in Tanzania remain largely at the demonstration stage, funded by donor governments and participating developers"

RUN-OF-THE-RIVER HYDRO AND SOLID BIOMASS WOULD BOTH BENEFIT FROM DISTRIBUTED HH STORAGE TO BALANCE THE RELATIVELY CONSTANT AVAILABLE POWER WITH VARIABLE DEMAND.

SOLAR & WIND MINI-GRIDS USUALLY INCLUDE CENTRALISED ENERGY STORAGE, HOWEVER THERE IS STILL A PEAK LOA LIMIT IMPOSED BY THE INVERTER CAPACITY & DISTRIBUTION NETWORK.

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Table 9: a) Installed capacity and no. connections (top right) and installed capacity and no. plants (bottom right) of Tanzania's mini-grids in 2016 (Odarno *et al.*, 2017).

INSTALLED CAPACITY	HYDRO	BIOMASS	FOSSIL FUELS	SOLAR	HYBRID	TOTAL	SHARE OF TOTAL (PERCENT)
Less than 10	2	15	0	2	0	19	17.4
10-99.9	18	1	0	11	3	33	30.3
100-999.9	23	1	3	0	0	27	24.8
1,000-10,000	6	8	16	0	0	30	27.5
All	49	25	19	13	3	109	100.0
Share of total (percent)	45.0	22.9	17.4	11.9	2.8	100.0	

Sources: TANESCO 1983; Kjelstrom et. al. 1992; UNIDO 2013; Sarakikya et. al. 2015; and interviews with staff of Kongwa. Leganga, Mawengi, Mwenga, and TANWAT (mini-grids) and the Ministry of Energy and Minerals, the Rural Energy Agency, SESCOM, and TANESCO conducted between February and May 2016.

ENERGY SOURCE	NUMBER OF PLANTS			INSTALLED CAPACITY (KW)		
	GRID-CONNECTED	ISOLATED	TOTAL	TOTAL	MEAN	NUMBER OF CONNECTIONS
Fossil fuels	0	19	19	72,700	3,826	170,065
Hydro	9	40	49	32,921	672	11,925
Solar	0	13	13	234	18	1,153
Biomass	7	18	25	51,714	2,069	562
Wind	0	0	0	0	0	0
Hybrid[a]	0	3	3	177	59	–
All	16	93	109	157,746	1,447	183,705

Sources: TANESCO 1983; Kjelstrom et. al. 1992; UNIDO 2013; Sarakikya et. al. 2015; and interviews with staff of Kongwa. Leganga, Mawengi, Mwenga, and TANWAT (mini-grids) and the Ministry of Energy and Minerals, the Rural Energy Agency, SESCOM, and TANESCO conducted between February and May 2016.

Note: a. Hybrid systems serve more than 300 people.
— Not available.

Source: World Resources Institute and TANESCO, National Grid System Map (2015).
Note: Map shows only 107 mini-grids; geographic coordinates of 2 mini-grids could not be obtained. Data are accurate as of February 2016.

Figure 18: Location of mini-grids in Tanzania (Odarno *et al.*, 2017).

SOLAR MINI-GRIDS ARE OPENING UP NEW OPPORTUNITIES FOR RENEWABLE GENERATION IN REGIONS WITHOUT HYDRO OR BIOMASS RESOURCES.

IN WET AND HILLY TOPOGRAPGY, SUCH AS KILIMANJARO, MBEYA OR NJOMBE, HYDROPOWER IS STILL THE MOST COST-EFFECTIVE OPTION.

THE RESOURCES AVAILABLE IN EACH PART OF T HE COUNTRY VARY SIGNIFICANTLY, CREATING DIFFERENT OPPORTUNITIES FOR MINI-GRID-ECOOK.

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TECHNOLOGY	COST		LIFESPAN	OUTLOOK
	CAPITAL	OPERATIONS AND MAINTENANCE		
Fossil fuels	Low	High (fuel and spare parts)	Short	Diesel likely to continue as technology of choice in larger mini-grid installations over short term, because of familiarity with technology and availability of spare parts, at least near townships. Where available, natural gas is less expensive than other fossil fuels; advanced steam turbines running on biomass represent attractive alternative option in isolated areas where it is available.
Hydro	High to very high	Low	Long	Likely to remain very attractive option for isolated locations where water resources are suitable. Currently preferred technology among mini-grids under construction or planned, a trend that is likely to continue as long as financing is available for initial installation.
Biomass	High	Moderate (because of cost of feedstock)	Long	Steam engine and turbine systems, including combined heat and power cogeneration, are robust and commercially proven technologies. Advanced technology steam turbines are proving attractive for larger industrial applications in isolated areas. Gasifier and biogas technologies are still at demonstration stage; outlook for small biomass plants depends on continued improvements in these technologies. Biofuel outlook uncertain because of lack of track record; may have application as hybrid plants in combination with solar.
Solar	High but falling rapidly	Very low	Moderate	Likely to become more widespread among small users in isolated areas if costs continue to fall. Feed-in tariff structure has failed to attract development of large scale solar mini-grids. Not yet clear whether new competitive bidding structure will be sufficient to encourage development.
Wind	High but falling	Moderate	Moderate	Falling prices not yet sufficient to attract investors. Specific site requirements may also limit appeal. Outlook unclear.
Hybrid	Moderate	Moderate	Moderate to long	Outlook unclear because of small number of hybrids operating (three) and short track record. Good option as back-up for intermittent renewable systems. More demonstration plants necessary.

Source: Authors' compilation.

Table 10: Costs, lifespans and outlooks for each mini-grid technology in Tanzania (Odarno *et al.*, 2017).

4.5.2.3 Which business models have proven to be most scalable?

FROM A USER PERSPECTIVE, THERE WILL BE LITTLE DIFFERENCE BETWEEN MINI-GRID-ECOOK ON TANESCO'S FOSSIL FUEL MINI-GRIDS & GRID-ECOOK ON TANESCO'S MAIN GRID.

"Mini-grids in Tanzania operate under four models: community, private, utility, and faith- based ownership and operation.

- Fossil fuel mini-grids owned and run by TANESCO all operate on the utility model. The same nationwide tariffs that TANESCO charges its grid-connected customers apply to its mini-grid customers. Operations and maintenance costs of rural mini-grid networks run by TANESCO are high, but the utility is allowed to charge only a low "lifeline" tariff to rural customers. The lifeline tariff is cross-subsidized by tariffs to larger users, but they, too, fail to fully reflect costs.

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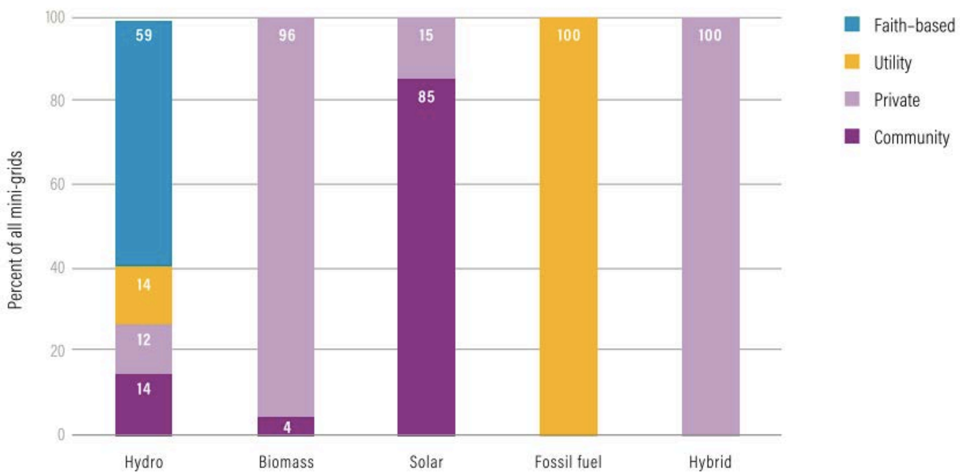
- Community-based models have experienced mixed success with management, service delivery, and revenue collection. Community ownership and participation in project development and operations appears to be a key factor for sustainability.
- Private entities usually sell power to TANESCO and to retail customers. Larger privately owned mini-grids that are grid connected experience difficulties with delayed payment for bulk sales to the national utility. Household customers pay on time, but retail tariffs need to be high to cover long-term costs.
- Mini-grids owned by faith-based organizations have operated for many years but are usually not financially self-sufficient."

"Mini-grids can price retail energy based on consumption (kWh), power demand magnitude (kVA per month), the number of appliances, a monthly service charge, or a combination of different methods. SPPs may charge a cost- reflective tariff that incorporates a reasonable return on capital. Mini-grids can choose from various options regarding when and how consumers can pay. Table 11 summarizes some of these options.

MINI-GRID-ECOOK CAN ENABLE MINI-GRID USERS WITH LOAD-LIMITED CONNECTIONS TO USE APPLIANCES WITH MUCH GREATER POWER RATINGS BY TRICKLE CHARGING THE BATTERY.

Hydro, biomass, and hybrid systems sell electricity on credit via credit-metering systems. Most solar mini-grids use load limiters, although a few use prepayment metering and pay-as-you-go payment systems. The utility model uses both prepayment and credit metering (Table 11 and Figure 19)."

Figure 19: Ownership of mini-grids in Tanzania in 2016 by energy source (Odarno *et al.*, 2017).



Sources: TANESCO 1983; Kjelstrom et. al. 1992; Sarakikya et. al. 2015; UNIDO 2013; interviews with staff of Kongwa, Leganga, Mawengi, Mwenga, and TANWAT (mini-grids) and Husk Power, the Ministry of Energy and Minerals, the REA, SESCOM, and TANESCO conducted between February and May 2016.

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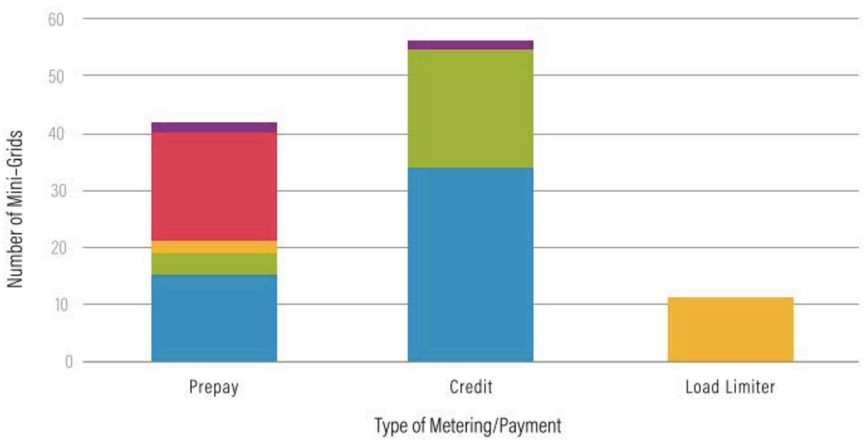
Table 11: Mini-grid retail tariff, measurement and payment options in Tanzania in 2016 (Odarno *et al.*, 2017).

ITEM	OPTION
Tariff structure	■ Flat-rate tariffs or subscription tariffs: Fixed monthly fee regardless of amount of energy used, as long as maximum demand at any given time (load) does not exceed level set in subscription amount (e.g., price per month). ■ Energy tariff: Price per unit of energy consumed (price/kWh). ■ Service charge: Typically a flat monthly rate to cover costs incurred by electricity supplier for meter reading, billing, and related costs. ■ Demand charge: Often expressed as price per kVA/month. Demand charges typically used for consumers that consume large amounts of electricity (e.g., commercial entities).
Financing and payment	■ Credit: Customer consumes energy and then pays for it. Bill usually issued at end of month based on meter readings. Billed amount varies monthly. ■ Prepaid: Customer purchases energy units in advance (e.g., at beginning of each month), via scratch cards, card tokens, cash at retail location with payment printouts, or mobile money. ■ Pay-as-you-go: Customer purchases small amounts of prepaid electricity on ongoing basis. ■ Prepaid and pay-as-you-go systems can be turned on and off remotely as electricity is purchased or used up.

Source: Tenenbaum et al. (2014) and Deshmukh et al. (2013).



Sources: TANESCO 1983; Kjelstrom et. al. 1992; Sarakikya et. al. 2015; UNIDO 2013; interviews with staff of Kongwa, Leganga, Mawengi, Mwenga, and TAI Husk Power, the Ministry of Energy and Minerals, the REA, SESCOM, and TANESCO conducted between February and May 2016.

Figure 20: Mini-grid metering and payment options in Tanzania in 2016 by energy source (Odarno *et al.*, 2017).

"Many practical difficulties stand in the way of the development and scale-up of mini-grids. Mini-grids are often located in rural areas, where technical and managerial capacity is often limited, spare parts are not available, and electricity customers have limited ability to pay, making it hard to collect revenues that match short-term and long-term operating costs."

MINI-GRIDS IN PERI-URBAN AREAS ARE LIKELY TO BE MORE ATTRACTIVE FOR MINI-GRID-ECOOK, AS PEOPLE ARE MORE LIKELY TO BE PAYING FOR COOKING FUEL THAN IN RURAL AREAS.

THE EVIDENCE FROM THE COOKING DIARIES SUGGESTS THAT MINI-GRID-ECOOK USERS ARE LIKELY TO USE 50-100KWH/MONTH. THIS WORKS OUT AT A VERY AFFORDABLE 0.01-0.16USD/KWH OR 5-16USD/MONTH ON THE 4 MINI-GRIDS STUDIED BY ODARNO ET AL. (2017).

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"Retail tariffs charged by mini-grids and TANESCO vary widely. Based on tariff schedule data collected in February 2016, the authors calculated electricity expenditures at five levels of consumption (Table 12). Mwenga, followed by TANESCO, appears to have charged the lowest lifeline rates for electricity consumption up to 75 kWh per month. The LUMAMA tariff was very high for a similar level of consumption. TANESCO was the most expensive for consumption of 100–250 kWh per month. At 1,000 kWh, the LUMAMA tariff was the most expensive. The Leganga tariff appears low for consumption of 50–1,000 kWh, but the containerized solar plant of 15 kWp (or net 13.5 kWp) is capable of providing 1,000 kWh to only three consumers, which would result in electricity being denied to all other consumers for the entire month. The plant is capable of supplying about 50–100 kWh per month to 60 customers in the village."

Table 12: Retail tariffs for electricity purchased from TANESCO, LUMAMA, Mwenga and Leganga (TSh/kWh) (Odarno et al., 2017).

CASE STUDY/ MODEL	KWH PURCHASED PER MONTH				
	20	50	100	250	1,000
TANESCO (utility)	100	100	361	328	312
LUMAMA (community)	400	310	280	312	506
Leganga (community)	150	60	30	20	5
Mwenga (private)	60	60	234	234	234

Source: Interviews with TANESCO, LUMAMA, Leganga, and Mwenga staff.

Note: Tariffs are as of February 2016.

4.5.2.4 What has the impact of mini-grids been on rural development?

IN COMMUNITIES WHERE MANY HHS ARE ALREADY PAYING FOR COOKING FUEL, ECOOK COULD GREATLY ENHANCE THE DEVELOPMENT IMPACT OF MINI-GRIDS.

"Anecdotal evidence from five case studies suggests that mini-grids are improving the lives of rural people. In one project, support from an Italian NGO, paired with electricity from the mini-grid, contributed to the start of several new enterprises, including sunflower oil pressing, mechanical workshops, poultry farming, and fruit processing. Financing from savings and credit cooperative societies (SACCOs) and village community banks enabled residents to develop small and medium-size enterprises, contributing to sustained demand for electricity and rural development. Improved lighting and electricity services helped rural residents start small businesses,

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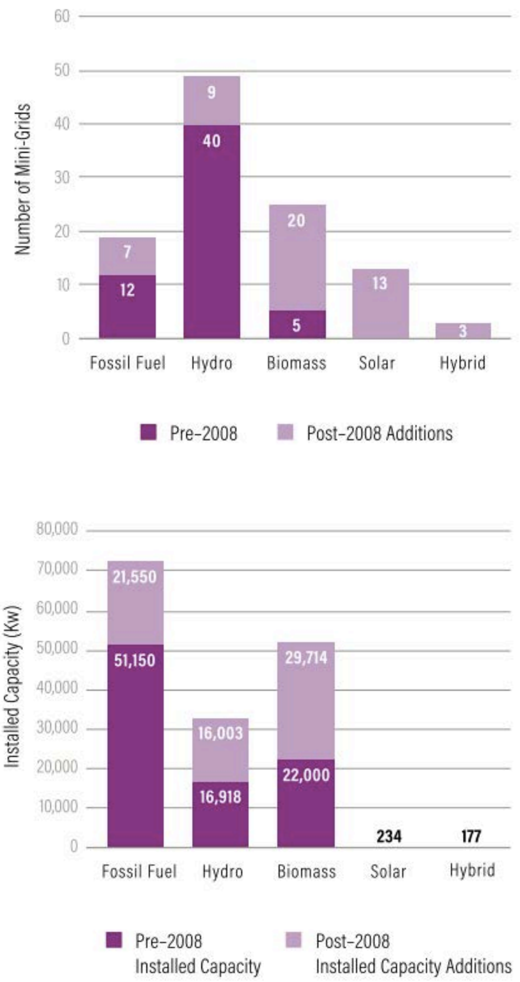
increased access to information (including market prices) via information and communication technologies, and improved social services"

4.5.2.5 What policies currently enable/inhibit mini-grid/off-grid electrification?

"The number and installed capacity of mini- grids in Tanzania has nearly doubled since 2008, when the government introduced the small power producers (SPP) framework. Fifty-two mini-grids were commissioned between 2008 and 2016, and more than 67 MW of new capacity was installed (Figure 21: Number and installed capacity of mini-grids installed in Tanzania since the 2008 policy reform *(Odarno* et al.*, 2017)*.)."

AS THE REVISED SPPT RECOGNISED, NOT ALL MINI-GRIDS ARE CREATED EQUAL. THUS MINI-GRID-ECOOK PRESENTS UNIQUE OPPORTUNIES FOR EACH TECH.:

- ALL: INCREASE LOAD FACTOR
- SOLAR: INCREASE STORAGE CAPACITY IN SMALLER INCREMENTS
- HYDRO: HH STORAGE ENABLES USE OF OTHERWISE WASTED ENERGY ON RUN-OF-THE-RIVER SYSTEMS
- GENERATORS: INCREASE FUEL EFFICIENCY WITH HIGHER LOAD FACTOR, & ENABLE 24H POWER ON FIXED SCHEDULE SYSTEMS



Sources: TANESCO 1983; Kjelstrom et. al. 1992; UNIDO 2013; Sarakikya et. al. 2015; and interviews with staff of Kongwa, Leganga, Mawengi, Mwenga, and TANWAT (mini-grids) and the Ministry of Energy and Minerals, the Rural Energy Agency, SESCOM, and TANESCO conducted between February and May 2016.

Figure 21: Number and installed capacity of mini-grids installed in Tanzania since the 2008 policy reform (Odarno *et al.*, 2017).

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"The first-generation feed-in tariff favoured hydro and biomass plants, because it failed to recognize cost differences of different technologies. Some investors signed agreements with TANESCO to build solar and wind mini- grids, but they were not built, because the feed-in tariffs did not reflect the costs of solar and wind generation. Revisions to the SPPTs made in 2015 took into account different renewable technologies, plant sizes, and site-specific characteristics, providing a more accurate reflection of the cost differences of different technologies."

"Public and private sector funding for rural electrification remains inadequate, but financial mechanisms have stimulated investor activity and led to further commitments of funds from development partners. Financial support to small power providers (SPPs) through the Tanzania Energy Development and Access Project (TEDAP) and the Rural Energy Fund (REF) (matching grants, performance grants, TEDAP credit line through commercial banks) has financed the completion or initiation of 17 mini-grid projects in Tanzania since 2008. Using financing facilities outside the SPP framework, donors have funded another 35 mini-grids."

4.5.3 Off-grid systems

IED's (2013) GIS analysis of Tanzania found that 33% of the population could be most economically electrified using standalone systems, such as solar home systems or solar lanterns. IRENA (2016b) note the low population density and poverty levels in rural areas as significant barriers to the scaling up of energy access solutions in rural Tanzania, which has an average population density of just 49 people/km^2. The rural regions of Lindi, Katavi and Ruvuma are even lower at 13, 15 and 22 people/km^2 respectively.

SOLAR LIGHTING IN TANZANIA IS BOOMING - IN 2014 THE INDUSTRY WAS REPORTEDLY WORTH 9 MILLION USD.

However, Lighting Africa (2018) add that "technological advancements and innovative business models in off-grid lighting and energy position these products as a rapidly scalable, credible alternative to the grid, at affordable costs." Accordingly, the Tanzanian off-grid industry is growing rapidly in order to meet this huge demand, which Lighting Africa estimated at USD 9,150,000 in 2014 (GreenMax Capital Advisors, 2013). GOGLA et al. (2016) report 185,000 SHS and pico-solar products sold in the second half of 2016 and Lighting Africa (2018) report total sales of 1.7 million quality-verified SHS and pico-solar products. Table 13 highlights the key players are the larger end of this market, i.e. those whose existing products are closest to PV-eCook.

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Table 13: Key players in Tanzania's solar home system market (GAP, 2017).

1 Solar Segments

Segment	Size	Companies Operating in that Space
Household Solar	<1kW	Zola, Mobisol, M-Kopa, Devergy
Village Solar (mini-grid)	1kW to 100kW	JUMEME, Rafiki
Industrial/Commercial Scale Solar	>100kW	Hecate

2 Market Segmentation

Segment	Size	Leading Companies in the Space	Trailing Companies in the Space
Small Household Solar	<10W	M-Kopa	
Medium Household Solar	12W to 80W	Zola	SimuSolar, SolarGrid Tanzania
Large Household or Small Business Solar	80W to 200W	Mobisol	SimuSolar, Sikubora, Devergy
Village Solar (mini-grid)	1kW to 100kW	Rafiki	JUMEME
Industrial/Commercial Scale Solar	>100kW	Hecate	

3 Present Installed User Base

Company Name	# of Systems Installed	Geographic Focus Area(s)	Comments
M-Kopa	>7,000,000	TBD, country headquarters in Dar Es Salaam.	Most installations are in Kenya, expanded to Tanzania in late-2016.
Zola	>50,000	Northern Tanzania, but aggressively expanding to other regions.	Likely first mover in Tanzania, expanded into Uganda in 2016 or 2017. Set-up a JV with EDF to expand into the Ivory Coast.
SimuSolar	>5,000	Lakes Region, other NGOs have brought their system elsewhere.	Partnered with We Care Solar NGO
Sikubora	Unknown	Likely Arusha, but unknown	Found them online, limited awareness among competitors when asked.
SolarGrid Tanzania	>5,000	Morogoro & Dar Es Salaam	
Mobisol	>84,000	Northern Tanzania, but aggressively expanding to other regions.	Started in Rwanda, but expanded to Tanzania. 50,000+ units sold in Tanzania.
Devergy	~20	Morogoro & Mbeya	Executed a strategic market shift in February 2017 to reposition themselves hoping for growth acceleration.
Rafiki	8	Iringa and Arusha	No information available regarding how many grids are still operable, although based on our findings it is likely at least some are now inoperable.
JUMEME	1	Next phase will stay around Lake Victoria	

M-KOPA, ZOLA & MOBISOL SEEM TO BE THE MARKET LEADERS IN TANZANIA'S SOLAR HOME SYSTEM MARKET. WORKING WITH THEM TO DEVELOP A COOKING UPGRADE FOR THEIR EXISTING CUSTOMERS WILL BE AN OBVIOUS ROUTE TO SCALE FOR PV-ECOOK.

Tanzania's solar resources range from 4kWh/m^2/day at the foot of Mount Kilimanjaro to 6kWh/m^2/day in the semi-arid plains surrounding Dodoma (World Bank, 2018). This is roughly equivalent to between 3 and 5kWh/kWp. However, few places in Tanzania are as cloudy as Kilimanjaro. Broadly speaking, PV output in the cloudier Eastern, Southern and North Western regions is approximately 4kWh/kWp, meaning that a 500W PV array would be able to produce 2kWh/day for a PV-eCook system. In the sunnier central region, PV output is closer to 5kWh/kWp, meaning that a 400W PV array should also produce 2kWh/day. Figure 23 shows that the solar resource is relatively stable throughout the year across the country. Seasonal variation is within +/-15%, which means that a PV-eCook system

PV-ECOOK SYSTEMS AT THE FOOT OF KILIMANJARO WOULD NEED ALMOST TWICE AS MUCH PV AS IN DODOMA. FORTUNATELY, MOST OF TANZANIA IS MUCH LESS CLOUDY. HOWEVER, PV IS NO LONGER THE MAJOR COST IN OFF-GRID SOLAR SYSTEMS, IT IS BATTERY STORAGE, WHICH WOULD BE EQUAL IN BOTH CASES.

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designed to meet demand in the cloudiest season would offer users up to 30% extra energy in the sunniest season.

Figure 24 shows that Tanzania presents relatively favourable environmental conditions for PV-eCook. Excluding mountain tops, annual average temperatures range from 14-26C, implying that extreme temperatures that could significantly affect battery lifetimes are rare. However, temperatures in the drier central region vary more between day and night. Temperatures are also notably lower in higher altitude regions such as Iringa, Njombe and Kilimanjaro. In these regions, people are more likely to be using stoves for the dual purpose of space heating, which makes highly efficient electric stoves less attractive as by design, they retain heat. It should also be noted that the majority of the country is over 1000m above sea level, meaning that water boils below 97C, significantly lengthening cooking times in unpressurised appliances.

THE SOALR RESOURCE IS HIGH & STEADY THROUGHOUT THE YEAR IN ALMOST ALL OF TANZANIA, SO PV-ECOOK SYSTEMS CAN BE COST-EFFECTIVELY DESIGNED FOR YEAR-ROUND USE.

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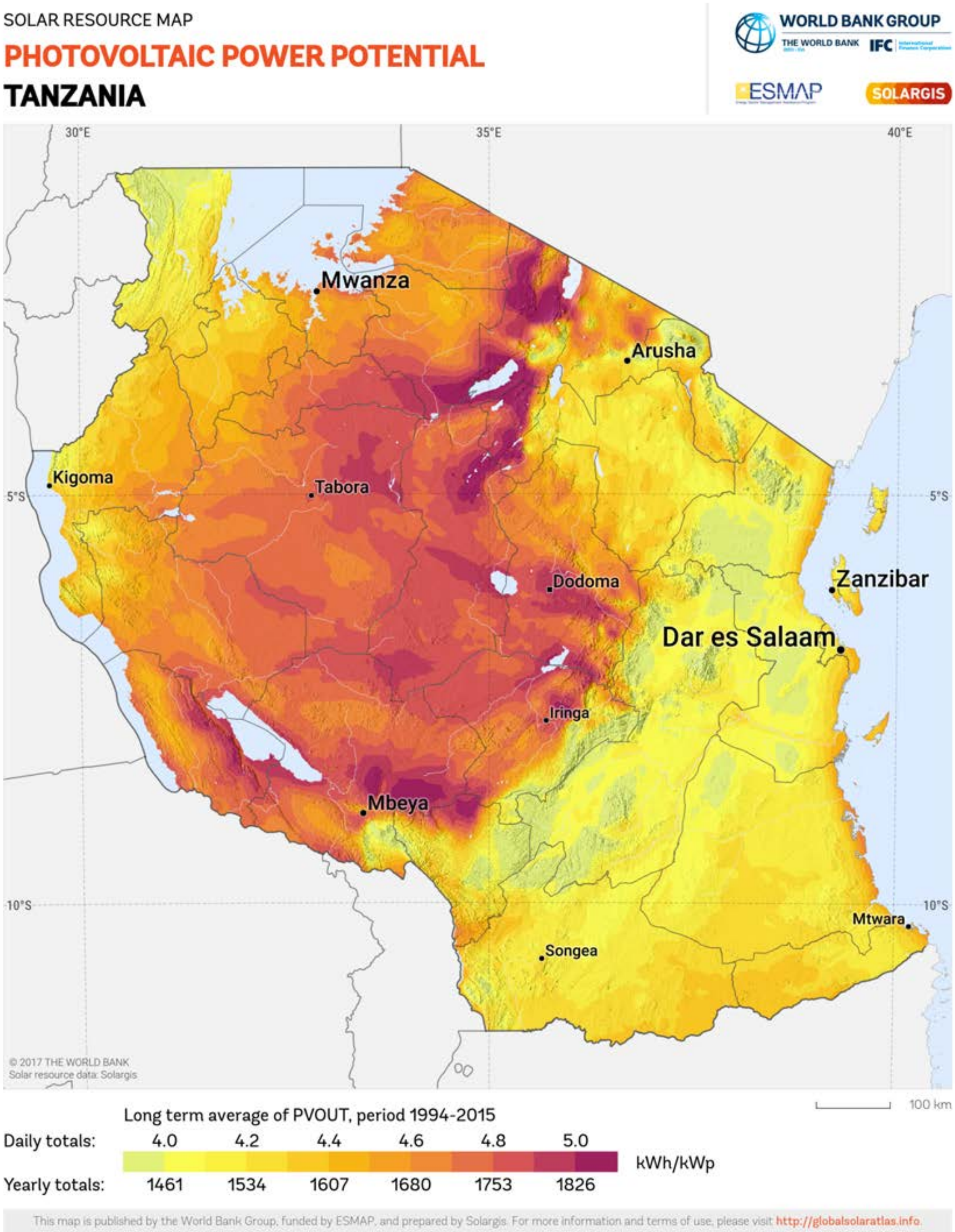

Figure 22: Global solar irradiation in Tanzania (World Bank, 2018).

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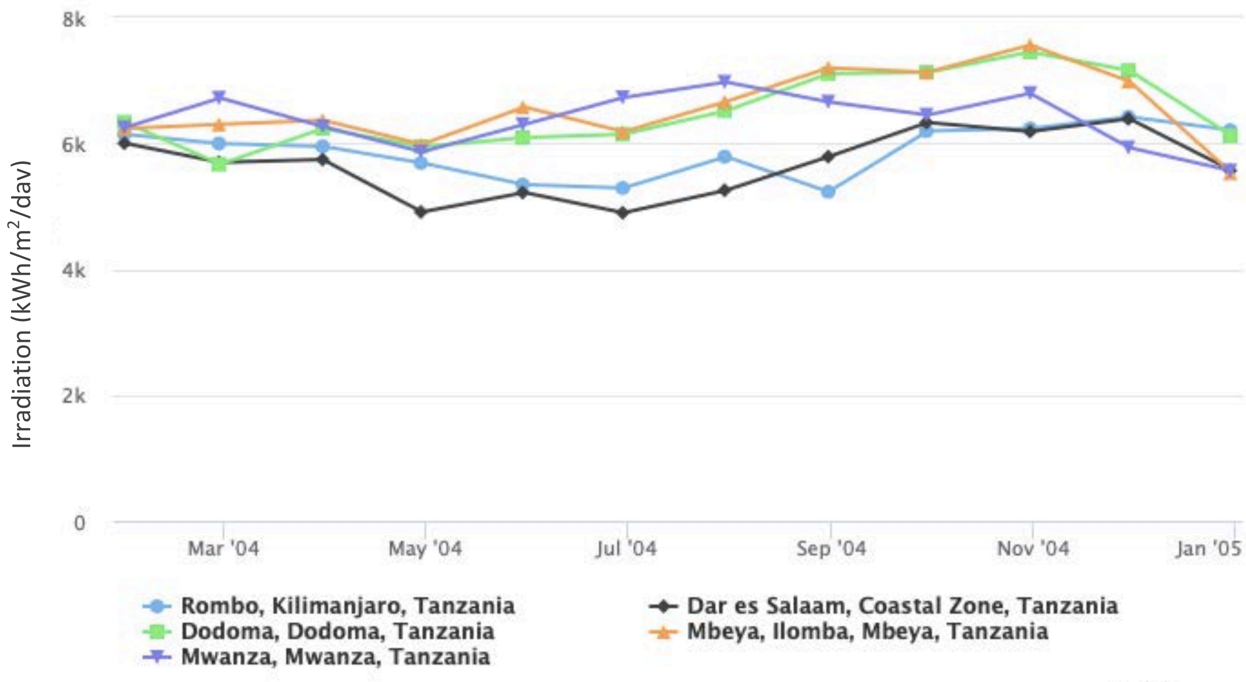

Figure 23: Seasonal variation in solar radiation in selected locations in Tanzania from HelioClim-1 dataset (IRENA, 2016a)

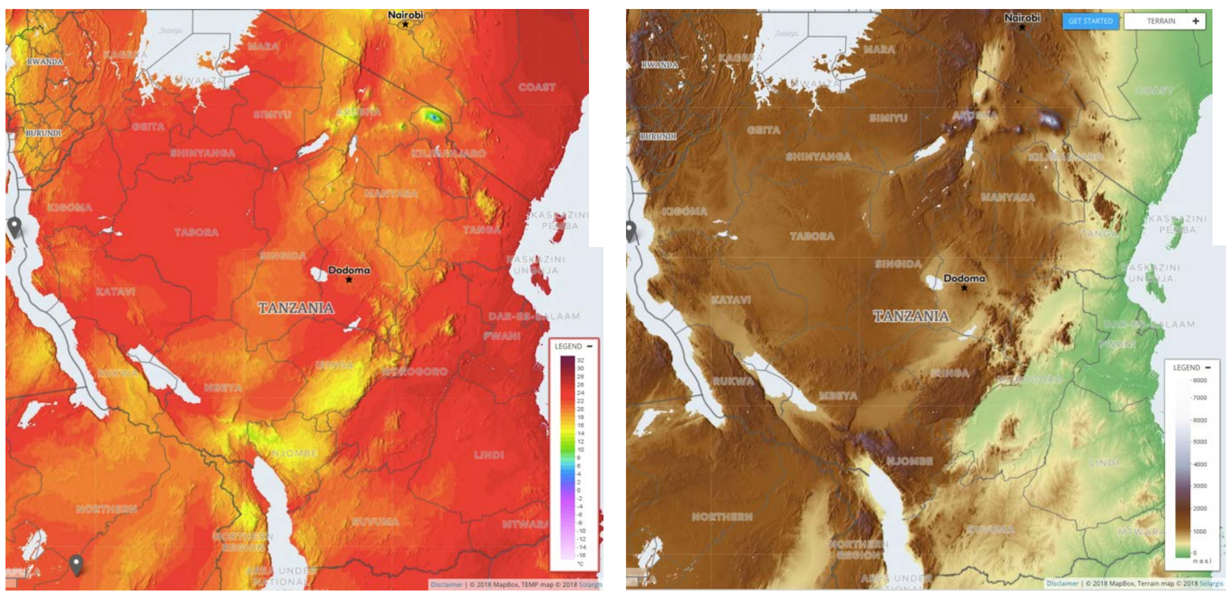

Figure 24: a) Average temperatures (left) and b) elevation (right) (World Bank, 2018).

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4.5.3.1 Key learning points from Lighting Africa

The following section presents key insights from GreenMax Capital Advisors (2013) Tanzania Market Intelligence Report, providing a commentary on the implications for PV-eCook. The report was commissioned by Lighting Africa and carried out in partnership with Tanzania's Rural Energy Agency.

"Major solar system markets are located in Dar es Salaam, Arusha and Mwanza, these are also the areas where of a majority of the solar lighting suppliers are located, and where BOP energy consumers have access to modern lighting technologies. Markets in those three regions have evolved based on needs and opportunities. For example, Dar es Salaam is a commercial centre where solar technologies are marketed and all business operations are governed, while Arusha is the tourism region where education is highly valued and technology adoption is linked to access through neighbouring countries like Kenya. In Mwanza, however, solar market penetration has been mainly through government sponsored projects in partnership with NGO development partners; NGOs continue to play a critical role in planning and delivering off grid lighting to BOP consumers using a more programmatic approach;

> SCHOOLS COULD FORM A VAUABLE PART OF A MARKETING STRATEGY FOR PV-ECOOK, FOR EXAMPLE BY PROVIDING DEMOSTRATION SYSTEMS FOR CLASSES & TO HEADTEACHERS.

Several distribution models have emerged which systematically target different market sub-segments. These are mostly delivered by NGOs, but some of the large private distributors are now also bringing novel ideas. While all of the models have some shortcomings, in totality they represent a variety of innovative approaches which may be improved upon and expanded. Some of these models are:

- Using middle schools as marketing centres; selling first to school headmasters with follow-on promotions to students, who in turn convince their parents to make the purchase; the school serves as the local stocking, distribution and sales centre.
- Well organized campaigns that feature music and entertainment targeted for youth and women — using mobile shops inside trucks that travel to remote areas while carrying many diverse products.
- Using community-based organizations such as Savings and Credit Cooperative Organizations (SACCOS), Care International, and JUKULIA (a district association in the Ilala district, Dar es Salaam) to reach each member of the association. The dealer supplies the products and the promotion materials to the SACCOS, or village/community agents who supply to their members.

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- Use of mobile payment systems such as MPESA which are already used in the banking system to pay for services such as water and food, for lighting products as well.
- NGO awareness campaigns, through mass media.
- Business networking, skills training, and building capacity for solar entrepreneurs.
- While some of these organizations have partnered with Microfinance Institutions (MFIs), most dealers and distributors indicated that lack of a simple and affordable financing plan was one of several key obstacles to rapid expansion.
- A large number of distributors cite poor product quality and shipments of defective merchandise as a second key obstacle. The problem seems to lie at three distinct levels – poor product designs offered by manufacturers, insufficient technical expertise at the distribution level to select quality devices, and manufacturers dumping the defective units on the Tanzanian market with insufficient enforcement and control at importation by the Tanzania Bureau of Standards (TBS).
- High costs of establishing proper logistics and poor transport infrastructure were cited as additional key obstacles by distributors.
- Provision of after sales service is uneven amongst distributors and along with poor product quality is a major source of concern. NGOs are often the biggest culprit of lack of follow-up and product servicing due to poor technical capabilities and the transient nature of many NGO distribution efforts, which provide a flurry of promotion and distribution without any permanent presence in the community.

THE PREVELANCE OF MOBILE MONEY SYSTEMS IN RURAL AREAS WILL BE A KEY ENABLER FOR THE INNOVATIVE BUSINESS MODELS THAT PV-ECOOK WILL REQUIRE.

TARGETED EXCHANGE PROGRAMS FOR, IN PARTICULAR, FEMALE SOLAR ENTREPRENEURS IN THE CLEAN COOKING INDUSTRY COULD HELP PREPARETHEM FOR PV-ECOOK.

DEVELOPING A SERVICE NETWORK TO ENSURE ACCESS TO SPARE PARTS & TECHNICAL ASSISTANCE WILL BE ESSENTIAL. THIS A KEY LIVELIHOOD OPPORTUNIY FOR WOMEN IN RURAL AREAS.

Import duties and value added taxes are exempted for all solar products according to the government officials interviewed for this study. However, the concerns of the supply chain survey respondents were that, although tax exemptions for solar products are well structured, the implementation is poorly managed by the Tanzania Revenue Authority and by the TBS. The survey respondents indicated that the system lacks technical capacity and knowledge at all levels from import, to storage, to the product inspection, to the clearance process.

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- TAREA (the Tanzania Renewable Energy Association), an NGO involved in solar suppliers' accreditation is spearheading the prevention of counterfeit products entry, which is prohibited by the law.
- Some amount of financing for lighting supplies in rural and peri-urban areas is provided in form of credits and microloans through Village community Banks (VIKOBAs); Savings and Credit Societies (SACCOS); and Trust Funds ("Mfuko wa HISA").
- Only a few MFI's offer specific loan products for household or business sustainable energy purchases.
- The BOP's income base, especially in rural areas, often does not enable borrowing from MFIs. In peri- urban areas, incomes are higher but there is often no asset base to support lending since many peri- urban BOP consumers live in rented homes and have no agricultural assets. MFIs prefer lending to SMEs since the enterprise cash flows and assets can serve as collateral.
- Across the full range of potential expenditure levels for solar lighting products, BOP participants in the study Focus Groups indicated the need for some form of financing to cover up front costs."

ENGAGING WITH TBS & TAREA TO ENSURE GOOD QUALITY PV-ECOOK PRODUCTS & COMPONENTS CAN BE IMPORTED WITHOUT TAXES & POOR-QUALITY ITEMS ARE KEPT OUT WILL BE KEY.

CREATING AWARENESS OF PV-ECOOK AMONGST VIKOBAS, SACCOS, TRUST FUNDS & MFIS WILL BE KEY TO UNLOCKING THE FINANCING THAT RURAL PEOPLE WILL NEED.

4.6 Cross-cutting issues

4.6.1 Social and Gender Issues

THE LACK OF COLLATERAL IS ALSO LIKELY TO BE AN ISSUE FOR PERI-URBAN POTENTIAL PV-ECOOK CUSTOMERS LIVING IN RENTED HOMES & WITH NO AGRIGULTURAL ASSETS.

The role of men is to lead and manage their households and families as providers of household services and requirements including foods, shelters, etc. Women are supporting their families and households through cooking, cleaning, collecting woodfuels, etc. Men are decision makers in households. The education in Tanzania is availed to both men and women. Women used to be favoured in order to go to the high learning institutions. The current situation shows that there is balance in urban areas between men and women for being enrolled in the education services. The situation for rural areas is a bit different because men in rural areas have high chances of going to schools compared to women. Roles of men and women are changing according to development of new technologies and income generating activities. Most of incomes generating initiatives in the households are controlled by men and women support men in doing those activities.

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There are uneven efforts of empowering women through different sectors such as energy, forestry, agriculture, and business undertakings. In the energy sector, some of them have been trained to use different clean cooking technologies such as improved cook stoves, solar cookers, fireless cookers, biogas, briquettes, etc.

Access to cooking energy and electricity is closely linked to gender equality and child-protection. Lack of reliable and safe access to energy and water forces rural women and children to spend most of their day performing basic domestic activities, including time-consuming and physically draining tasks of collecting biomass fuels. The Energy Access Survey (2017) reveals that share of male-headed households connected to electricity in rural areas is 18.3%, while of female-headed only 11.7% are connected. This is particularly pronounced in certain regions, notably Dodoma (3.9 vs. 20.9%), Singida (4.3 vs. 16.8%) and Kagera (4.3 vs. 19.2%). Both factors reduce the opportunities of attending education, employment, and other income-generating and livelihood enhancing activities. For households using charcoal, the cost consumes a large part of the disposable income of rural households.

Women are disproportionally affected by indoor air pollution. It is estimated that with women in Tanzania spending 3-7 hours a day cooking, they are exposed to respiratory track diseases, eye diseases ("red eye disease").

Modern or improved cooking stoves and sustainably produced charcoal can reduce the workload of women and improve health conditions and reduce environmental and climatic impact.

WHILE THE BURDEN OF BIOMASS COOKING HAS MAINLY BEEN A PROBLEM FOR WOMEN, IN MANY CONTEXTS, HI-TECH ELECTRONICS HAS TRADITIONALLY BEEN THE DOMAIN OF MEN. IN THE FOCUS GROUPS THE WOMEN SPECULATE THAT A 'HI-TECH' APPLIANCE LIKE A MULTICOOKER MIGHT ATTRACT MORE MEN TO COOK. HOWEVER, THE FIRST HURDLE WILL BE – WILL MEN 'AUTHORISE' THEIR HOUSEHOLD TO PURCHASE 'TECHNOLOGY' WHEN ITS MAINLY A DEVICE FOR THE WOMEN TO USE?!

4.6.2 Business and Finance

Business is seen as a central pillar in the attainment of the mission of the economic sectors towards higher efficiency and productivity in the country. The SMEs policy is intending to foster job creation and income generation through promoting the creation of new SMEs and improving the performance and competitiveness of the existing ones to increase their participation and contribution to the economy in the country.

THERE ARE TWO DOMAINS OF FINANCE.: SUPPLIERS NEED MAJOR CAPITAL TO SET UP & EXPAND THEIR BUSINESS., WHILST HOUSEHOLDS WILL ALSO NEED FINANCE TO REPAY THE HIGH UPFRONT COST OF THE INDIVIDUAL SYSTEMS. BOTH MUST BE IN PLACE FOR ECOOK TO SUCCEED.

Finding locally available financing at competitive rates is a significant

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challenge. Interest rates from a commercial bank are around 16-18% at good rate and are more likely to be around 20-21%. The government is creating grants for off-grid energy, but these seem to be exclusively targeted at mini-grid developers. Therefore, while it is possible to get finance, this is often prohibitively expensive. Currency stability also has a significant influence on cash flow as stocks have to be purchased in dollars but sold in shillings. Fluctuations in exchange rates can quickly undermine small operators.

HIGH INTEREST RATES COULD BE A SIGNIFICANT PROBLEM FOR ECOOK. THE DISCOUNT RATES IN LEACH AND ODURO'S MODEL ARE AT 5% AND 20%, AND EVEN AT 20% ECOOK CAN WORK. HOWEVER, IT MAY NOT BE THE INTEREST PER SE THAT CREATES CHALLENGES SO MUCH AS IDENTIFYING FINANCE THAT IS WILLING TO TAKE THE RISK & FINDING THE FINANCE IN THE FIRST PLACE!

In Tanzania, traditional microfinance loans are quite localised. In rural areas, small localised credit facilities can be used to provide finance but as these microfinance institutions need to buy their own capital locally at high interest rates, adding operational costs and default risk, this sets interest rates at between 40% and 100% per annum. However, there are different financial mechanisms for supporting cleaner cookstoves and off –grid systems such as village community banks, (VICOBA), Savings and Credit Cooperatives Society (SACCOS), Micro Financial Institutions (e.g. PRIDE SEFAFU and FINCA), etc. SEFAFU is only microfinance designed for sustainable energy services. The entity is still at the infancy stages and could be boosted in order to provide credit services for electricity cooking.

Tanzania is one of the world leaders in mobile money transfers (mobile phone-based money transfer), with 44% of adults having access to it and a total of 16m subscribers. There are 4 mobile money providers in Tanzania: Vodacom with M-Pesa (42% market share), Tigo with Tigo Pesa (31%), Airtel with Airtel Money (24%), and Zantel with Ezy Pesa (3%). In addition to mobile money, mobile operators in Tanzania offer other mobile financial services such as financing and micro financing services, and mobile insurance. (https://www.tanzaniainvest.com/mobile-money). To help address this, pay-as-you-go financing schemes are now becoming available for solar home systems, including mobile-enabled pay-as-you-go. However, there is no any organization that is using it to allow the customers to make payments on clean cookstoves but some companies e.g. SESCOM, ENSOL, etc, are using it for payments on off-grid systems. The GSMA indicates that mobile money providers will continue to strengthen the customer experience and improve the quality of agent networks, in turn attracting more customers and encouraging greater usage of mobile money. Solar pay-as-you-go companies

USERS MAY SHY AWAY FROM 4-5YR PAYBACK (SOLAR LIGHTING TYPICALLY 1YR). UTILITY MODELS ADDRESS THIS - USERS NEVER OWN EQUIPMENT, INSTEAD PURCHASING COOKING SERVICES.

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are lobbying mobile phone companies to improve connectivity in areas where this is impeding operations.

Tanzania has mix of international and local manufacturing industries. The survey is required to understand strength, capability and forms of products that could be manufactured by international and local industries. However, capacity development will be required to make sure that eCook clean cooking system is manufactured by local companies like SEECO and similar companies. The supply chain for products from outside the country depending on different business models of the companies and shops which are selling them. Big stores and supermarkets are importing direct from outside the country. Some local shops are acquiring them from whole sellers in Dar es Salaam and continue to distribute them in different areas of the mainland. Solar PV systems are also imported from China, South Africa and Europe. Importing a consignment of solar PV system equipment from manufacturers may take one to three months.

IN EITHER CASE, THE ABILITY TO ACCEPT PAYMENTS (AND TO MONITOR USAGE) THROUGH THE MOBILE PHONE NETWORK WILL BE CRITICAL, AND TANZANIA HAS AN INTERESTING BALANCED MARKET FOR 4 DOMINANT PLAYERS. PLUS, THE VIETNAMESE MNO HALO HAS RECENTLY STARTED WITH RELATIVELY IMAGINATIVE & ENTREPRENEURIAL VALUE-ADDED SERVICES.

Nevertheless, several steps have been taken which support the sector. VAT and tariff exemptions have been applied to imports of **small solar products**. However, **batteries** are not exempted from VAT, which causes particular issues for operators selling solar home systems where component parts of the product are separate. The previous Tanzanian President lent his voice to Off Grid: Electric's high-profile plans to create 1 million solar homes, and two projects to promote and raise awareness have been implemented. Moreover, the National Electrification Program Prospectus notes that, even if all of the interventions outlined in it are realised, it will not meet targets unless "access to electricity" is re-defined. This would need to be extended to encompass those who do not have electricity within their own home (i.e. by including those who have access to central services, such as a dispensary with a fridge). This suggests that solar home systems could fill significant gaps in off-grid areas.

THE SEPARATION OF BATTERIES FROM SOLAR SYSTEMS AND APPLYING VAT TO BATTERIES SEEMS TO BE COMMON TO A NUMBER OF COUNTRIES. THIS MAY BE ONE OF THE MORE IMPORTANT POLICY CHANGES REQUIRED TO MAKE ECOOK AFFORDABLE.

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4.6.3 Demographics

According to Census 2012 (www.nbs.go.tz), the population of Tanzania showed that there were 44,928,923 people living in the country with an annual growth rate of 2.9%. The population is now estimated at over 59.09 million, as Tanzania has one of the highest birth rates in the world and more than 44% of the population is under the age of 15. The total fertility rate is 5.01 children born per woman, which is the 17th highest of any country. Odarno *et al.*, (2017) note that "given the country's young demographic profile, Tanzania will experience rapid population growth in coming years. The United Nations' median population projection is more than 82 million by 2030 (UN 2015b)."

TANZANIA'S RAPID POPULATION GROWTH IS LIKLEY TO ACCENTUATE THE PROBLEM OF DEFORESTATION EVEN FURTHER, PUSHING UP THE PRICE OF WOOD FUELS TO EVEN HIGHER LEVELS. THIS WILL ONLY AMPLIFY THE ECONOMIC ARGUMENT FOR ECOOK, AS THE EXISTING EXPENDITURES ON BIOMASS FUELS WILL BE EVEN GREATER & BROADER.

Odarno *et al.*, (2017) state that "continued economic and population growth will create strong demand for electricity. According to the International Energy Agency (IEA 2014b), demand in Tanzania could rise by an annual average rate of 6.6 percent between 2012 and 2040." Access to grid electricity has increased to more than 36% with rural electricity access of 17 % while urban 65%. Based on Energy Access Situation Report 2016, a total of 3,753,615 households on Mainland Tanzania are electrified with any form of electricity out of 11,454,818 households.

Tanzania has a very uneven population distribution. In the arid regions, population density is as low as 1 person per square kilometre, about 53 people per square kilometre in the water-rich mainland highlands and up to 134 people per square kilometre. About 80% of the population lives in rural areas. Of this total population, 1.3 million reside on the islands of Zanzibar. This equates to a population density of 47.5 people per square kilometre (123.1 people per square mile).

4.6.4 Environment and Climate Change

4.6.4.1 Climate in Tanzania

The Tanzania climate statistics describe the average temperature and the total rainfall during a typical year. There are four main climatic zones: (1) the coastal area and immediate hinterland, where conditions are tropical, with temperatures averaging about 27° C (81° F), (2) the central plateau, which is hot and dry, with considerable daily and seasonal temperature variations; (3) the semi-temperate highland areas, where the climate is healthy and bracing; and (4) the high, moist lake regions. There are two rainy seasons in the north, from November to December and from March through May. In the south there is one rainy season, from November to March.

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Solar insolation values for Tanzania are at least twice that of those available in Europe because of the longer solar window available at equatorial latitudes, making solar power an attractive long-term investment option for companies and individuals seeking a robust, reliable and independent power supply. The country has high levels of solar energy, ranging between 2,800-3,500 hours of sunshine per year, and a global horizontal radiation of 4–7 kWh per m2 per day. Solar resources are especially good in the central region of the country, and it is being developed both for off-grid and grid-connected solutions. In the elevated areas around Moshi and Arusha, and in Iringa and southwards, however, insolation is considerably reduced (i.e. below 4 kWh/m2/day) during the cloudy season between May and August. Solar PV electricity has been installed countrywide for various applications in schools, hospitals, health centres, police posts, small telecommunications enterprises and households, as well as for street lighting. More than half of this capacity is utilised by households in peri-urban and rural areas.

STRONG SOLAR IRRADIATION & A HOT, BUT NOT EXTREME CLIMATE MAKE THE TANZANIAN CLIMATE VIRTUALLY IDEAL, AS PV PANELS WILL PRODUCE MORE, BATTERIES ARE UNLIKLEY TO BE DAMAGED BY EXTREME TEMPERATURES & STOVES ARE NOT EXPECTED TO PERFORM THE DUAL FUNCTION OF SPACE HEATING, GREATLY REDUCING ENERGY DEMAND & THEREFORE BATTERY SIZE/COST.

Cookstoves are used for space heating in elevated areas which are cool parts in the country. However, whenever people are using charcoal stoves are advised to use them in open air areas due to toxic gases like carbon monoxide. There is no history of damaging batteries by extreme heat or cold.

The assessed potential of small hydropower resources (up to 10 MW) is 480 MW (Odarno *et al.*, 2017). Installed, grid-connected, small-hydro projects contribute only about 16 MW. Most of the developed small-hydro projects are owned by private entities and are not connected to the national electricity grid. Five sites in the 300 kW–8,000 kW range are owned by TANESCO. Faith-based groups own more than 1617 with 15 kW-800 kW capacity and an aggregate capacity of 2 MW.

Several small hydro projects e.g. Mawengi, Mwenga, Lupali, Ikondo, etc. were developed as isolated mini grids. The Ministry of Energy is conducting small hydro feasibility studies in eight regions: Morogoro, Iringa, Njombe, Mbeya, Ruvuma, Rukwa, Katavi and Kagera. Development partners are supporting several mini-micro grid projects throughout the country.

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4.6.5 Environmental Effects

Energy access and climate issues can be positively linked. For instance, non-polluting and highly efficient cook stoves and other advanced biomass systems for cooking reduce the need for woody and other biomass by more than 50 per cent compared to traditional cook stoves. This would avoid major emissions of black carbon from inefficient biomass burning, responsible for indoor pollution, additional global warming and ice-melting in particular.

Energy poverty is one of the most important obstacles to social and economic development for the poor, next to lack of access to clean water and food. Our current energy system leaves a major portion of the world's population behind. In some poor energy importing countries, the high costs of fossil fuels now eats up more than 10 per cent of the GDP and makes conventional energy increasingly unaffordable for many.

Clean, affordable and reliable energy access is one of the most important requisites for decent livelihoods, next to water and food. Unfortunately, our current energy system excludes a major portion of world's population from this fundamental right.

Climate change is affecting people around the planet, but is particularly wreaking havoc on developing nations and poorest communities. Improving the well-being of these people is the best way to help them adapt to climate change and be resilient.

Energy access and climate issues in Tanzania can be positively linked. For instance, non-polluting and highly efficient cook stoves and other advanced biomass systems for cooking reduce the need for woody and other biomass by more than 50 per cent compared to traditional cook stoves. This would avoid major emissions of black carbon from inefficient biomass burning, responsible for indoor pollution, additional global warming and ice-melting in particular.

Energy poverty is one of the most important obstacles to social and economic development for the poor, next to lack of access to clean water and food. Our current energy system leaves a major portion of the world's population behind. In some poor energy importing countries, the high costs of fossil fuels now eats up more than 10 per cent of the GDP and makes conventional energy increasingly unaffordable for many. Girls and women are particularly affected since in many developing countries they spend lots of time collecting regionally available bioenergy sources — time they cannot use for education or jobs.

Clean, highly efficient renewable energy is one key pillar to better livelihoods and health, improved education and gender balance and better learning conditions, which in turn can facilitate environmental protection. Sustainable energy access, through the adoption of renewable energy, sustainable practices and energy efficiency, will help the conservation of ecosystems, the adaptation

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of communities to climate change, and in the global effort to lower emissions. Not only are people who suffer most from climate change often energy-poor, but the way billions of people will access modern sources of energy will have a long-lasting impact on the energy sector and climate as well. Access to renewable and sustainable energy will benefit energy-poor people and reduce effects of climate change.

To help accelerate the process of achieving a world powered by 100 per cent renewable energy by 2050, WWF Tanzania is engaging with key governments to encourage them to agree to take steps to end energy poverty by 2030. The essence of this strategy is to demonstrate that there are viable, sustainable energy access solutions for energy-poor people in the country and to encourage these solutions to be replicated and scaled up in different areas.

THIS SECTION ENDS ON A POSITIVE NOTE, AND ONE THAT ECOOK CAN HARMONISE WITH.

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5 Recommendations

The following section presents a list of recommendations for policy actors and other key decision makers who would like to incentivise the development of a market for eCook products and services in Tanzania.

5.1 Electric pressure cookers in urban grid-connected areas

- Time of use tariffs
- Begin by encouraging suppliers to import efficient electrical cooking appliances
    - Reduce the import tariff and VAT
    - Developing a results-based financing program
        - e.g. 50% refund for every unit sold
    - Test and certify best quality products
        - Price, durability, energy-efficiency, service delivery
        - Supported by TBS & CLASP
- Once market has developed, incentivise local manufacture
    - Begin with assembly, building up to manufacture
    - Support innovation hubs to incubate start-ups, e.g. TaTEDO spin-out SESCOM
- Support establishment of service networks
    - Spare parts and expertise for repairs must be available locally
    - Package electric pressure cookers with spare parts such as rubber sealing rings
- Support consumers to understand the benefits and lower behavioural change barriers:
    - Package (or repackage international models) with:
    - Advice on how to cook local foods
    - E.g. stickers on appliance indicating cooking time for maharage, makande, wali, etc.
    - Advice on energy efficient cooking practices
    - E.g. recipe book, community cooking demonstrations
    - Include electricity (in particular efficient electrical cooking appliances) in clean cooking social marketing, focusing on:
    - Cost – cheaper than charcoal and even gas
    - Convenience – more time to do other things
    - How to save even more time and money by cooking efficiently
- Support consumers to repay high initial cost through micro-finance
    - Longer repayment options with low interest to reach poorer households
    - Flexible repayment schemes
    - Urban/peri-urban - in tune with how people currently pay for biomass

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  - Rural – in tune with harvests

5.2 Battery-supported cooking in peri-urban weak-grid areas and rural off-grid areas

- Widen access to consumers in weak-grid (frequent blackouts & unstable voltage) and off-grid regions by supporting importation of lithium ion batteries:
  - Reduce the import tariff and VAT
  - Developing a results-based financing program
  - Test and certify best quality products

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6 Conclusion

This review has confirmed that there is a strong market for eCook products and services in Tanzania. Electrification and clean cooking are currently seen as two separate domains, however eCook has the potential to unite the two. To date, progress in electrification has been relatively rapid, whilst clean cooking has lagged behind. Tanzania has a world leading mini-grid sector and the market for solar home systems is developing rapidly. eCook presents a transformative opportunity to leverage this encouraging progress to drive forward the equally important goal of ensuring universal access to clean cooking by 2030, in line with SDG 7.

The findings from this review will be combined with those from the other activities that have been carried under the eCook Tanzania Market Assessment. Together they will build a more complete picture of the opportunities and challenges that await this emerging concept. Further outputs will be available from https://elstove.com/innovate-reports/ and www.MECS.org.uk.

This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

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This research is funded by DfID/UK Aid and Gamos through the Innovate UK Energy Catalyst and the MECS programme.

8 Appendices

8.1 Appendix A: Problem statement and background to Innovate eCook project

8.1.1 Beyond business as usual

The use of biomass and solid fuels for cooking is the everyday experience of nearly 3 Billion people. This pervasive use of solid fuels—including wood, coal, straw, and dung—and traditional cookstoves results in high levels of household air pollution, extensive daily drudgery required to collect fuels, and serious health impacts. It is well known that open fires and primitive stoves are inefficient ways of converting energy into heat for cooking. The average amount of biomass cooking fuel used by a typical family can be as high as two tons per year. Indoor biomass cooking smoke also is associated with a number of diseases, including acute respiratory illnesses, cataracts, heart disease and even cancer. Women and children in particular are exposed to indoor cooking smoke in the form of small particulates up to 20 times higher than the maximum recommended levels of the World Health Organization. It is estimated that smoke from cooking fuels accounts for nearly 4 million premature deaths annually worldwide –more than the deaths from malaria and tuberculosis combined.

While there has been considerable investment in improving the use of energy for cooking, the emphasis so far has been on improving the energy conversion efficiency of biomass. Indeed in a recent overview of the state of the art in Improved Cookstoves (ICS), ESMAP & GACC (2015), World Bank (2014), note that the use of biomass for cooking is likely to continue to dominate through to 2030.

"Consider, for a moment, the simple act of cooking. Imagine if we could change the way nearly five hundred million families cook their food each day. It could slow climate change, drive gender equality, and reduce poverty. The health benefits would be enormous." ESMAP & GACC (2015)

The main report goes on to say that "The "business-as-usual" scenario for the sector is encouraging but will fall far short of potential." (ibid,) It notes that without major new interventions, over 180 million households globally will gain access to, at least, minimally improved[4] cooking solutions by the end of the decade. However, they state that this business-as-usual scenario will still leave over one-half (57%) of the developing world's population without access to clean cooking in 2020, and 38%

[4] A minimally improved stove does not significantly change the health impacts of kitchen emissions. "For biomass cooking, pending further evidence from the field, significant health benefits are possible only with the highest quality fan gasifier stoves; more moderate health impacts may be realized with natural draft gasifiers and vented intermediate ICS" (ibid)

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without even minimally improved cooking solutions. The report also states that 'cleaner' stoves are barely affecting the health issues, and that only those with forced gasification make a significant improvement to health. Against this backdrop, there is a need for a different approach aimed at accelerating the uptake of truly 'clean' cooking.

Even though improved cooking solutions are expected to reach an increasing proportion of the poor, the absolute numbers of people without access to even 'cleaner' energy, let alone 'clean' energy, will increase due to population growth. The new Sustainable Development Goal 7 calls for the world to "ensure access to affordable, reliable, sustainable and modern energy for all". Modern energy (electricity or LPG) would indeed be 'clean' energy for cooking, with virtually no kitchen emissions (other than those from the pot). However, in the past, modern energy has tended to mean access to electricity (mainly light) and cooking was often left off the agenda for sustainable energy for all.

Even in relation to electricity access, key papers emphasise the need for a step change in investment finance, a change from 'business as usual'. IEG World Bank Group (2015) note that 22 countries in the Africa Region have less than 25 percent access, and of those, 7 have less than 10 percent access. Their tone is pessimistic in line with much of the recent literature on access to modern energy, albeit in contrast to the stated SDG7. They discuss how population growth is likely to outstrip new supplies and they argue that "unless there is a big break from recent trends the population without electricity access in Sub-Saharan Africa is projected to increase by 58 percent, from 591 million in 2010 to 935 million in 2030." They lament that about 40% of Sub-Saharan Africa's population is under 14 years old and conclude that if the current level of investment in access continues, yet another generation of children will be denied the benefits of modern service delivery facilitated by the provision of electricity (IEG World Bank Group, 2015).

> "Achieving universal access within 15 years for the low-access countries (those with under 50 percent coverage) requires a quantum leap from their present pace of 1.6 million connections per year to 14.6 million per year until 2030." (ibid)

Once again, the language is a call for a something other than business as usual. The World Bank conceives of this as a step change in investment. It estimates that the investment needed to really address global electricity access targets would be about $37 billion per year, including erasing generation deficits and additional electrical infrastructure to meet demand from economic growth. "By comparison, in recent years, low-access countries received an average of $3.6 billion per year for their electricity sectors from public and private sources" (ibid). The document calls for the Bank Group's energy practice to adopt a new and transformative strategy to help country clients orchestrate a national, sustained, sector-level engagement for universal access.

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In the following paragraphs, we explore how increasing access to electricity could include the use of solar electric cooking systems, meeting the needs of both supplying electricity and clean cooking to a number of households in developing countries with sufficient income.

8.1.2 Building on previous research

Gamos first noted the trends in PV and battery prices in May 2013. We asked ourselves the question, is it now cost effective to cook with solar photovoltaics? The answer in 2013 was 'no', but the trends suggested that by 2020 the answer would be yes. We published a concept note and started to present the idea to industry and government. Considerable interest was shown but uncertainty about the cost model held back significant support. Gamos has since used its own funds to undertake many of the activities, as well as IP protection (a defensive patent application has been made for the battery/cooker combination) with the intention is to make all learning and technology developed in this project open access, and awareness raising amongst the electrification and clean cooking communities (e.g. creation of the infographic shown in Figure 25 to communicate the concept quickly to busy research and policy actors).

Gamos has made a number of strategic alliances, in particular with the University of Surrey (the Centre for Environmental Strategy) and Loughborough University Department of Geography and seat of the Low Carbon Energy for Development Network). In October 2015, DFID commissioned these actors to explore assumptions surrounding solar electric cooking[5] (Batchelor, 2015b; Brown and Sumanik-Leary, 2015; Leach and Oduro, 2015; Slade, 2015). The commission arose from discussions between consortium members, DFID, and a number of other entities with an interest in technological options for cleaner cooking e.g. Shell Foundation and the Global Alliance for Clean Cookstoves.

Drawing on evidence from the literature, the papers show that the concept is technically feasible and could increase household access to a clean and reliable modern source of energy. Using a bespoke economic model, the Leach and Oduro paper also confirm that by 2020 a solar based cooking system could be comparable in terms of monthly repayments to the most common alternative fuels, charcoal and LPG. Drawing on published and grey literatures, many variables were considered (e.g. cooking energy needs, technology performance, component costs). There is uncertainty in many of the parameter values, including in the assumptions about future cost reductions for PV and batteries, but the cost ranges for the solar system and for the alternatives

[5] The project has been commissioned through the PEAKS framework agreement held by DAI Europe Ltd.

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overlap considerably. The model includes both a conservative 5% discount rate representing government and donor involvement, and a 25% discount rate representing a private sector led initiative with a viable return. In both cases, the solar system shows cost effectiveness in 2020.

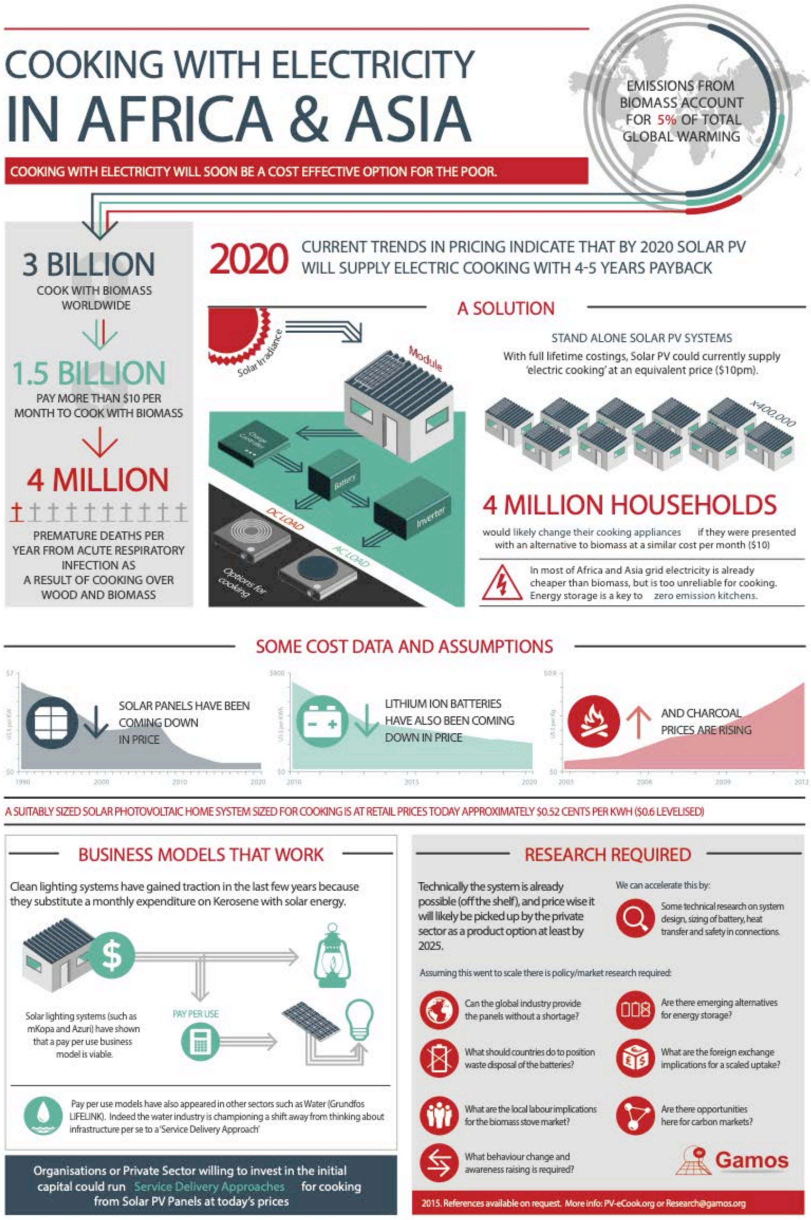

Figure 25 Infographic summarising the concept in order to lobby research and policy actors.

The Brown and Sumanik-Leary paper in the series examines the lessons learned from four transitions – the uptake of electric cooking in South Africa, the roll out of Improved Cookstoves (ICS), the use of LPG and the uptake of Solar Home Systems (SHS). They present many behavioural concerns, none of which preclude the proposition as such, but all of which suggest that any action to create a scaled use of solar electric cooking would need in depth market analysis; products that are modular and

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paired with locally appropriate appliances; the creation of new, or upgrading of existing, service networks; consumer awareness raising; and room for participatory development of the products and associated equipment.

A synthesis paper summarising the above concludes by emphasising that the proposition is not a single product – it is a new genre of action and is potentially transformative. Whether solar energy is utilised within household systems or as part of a mini, micro or nano grid, linking descending solar PV and battery costs with the role of cooking in African households (and the Global South more broadly) creates a significant potential contribution to SDG7. Cooking is a major expenditure of 500 million households. It is a major consumer of time and health. Where households pay for their fuelwood and charcoal (approximately 300 Million) this is a significant cash expense. Solar electric cooking holds the potential to turn this (fuelwood and charcoal) cash into investment in modern energy. This "consumer expenditure" is of an order of magnitude more than current investment in modern energy in Africa and to harness it might fulfil the calls for a step change in investment in electrical infrastructure.

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8.1.3 Summary of related projects

A series of inter-related projects have led to and will follow on from the research presented in this report:

- Gamos Ltd.'s early conceptual work on eCook (Batchelor, 2013).
    - The key **CONCEPT NOTE** can be found here.
    - An early infographic and a 2018 infographic can be found here.
- Initial technical, economic and behavioural feasibility studies on eCook commissioned by DfID (UK Aid) through the CEIL-PEAKS Evidence on Demand service and implemented by Gamos Ltd., Loughborough University and University of Surrey.
    - The key **FINAL REPORTS** can be found here.
- Conceptual development, stakeholder engagement & prototyping in Kenya & Bangladesh during the "*Low cost energy-efficient products for the bottom of the pyramid*" project from the USES programme funded by DfID (UK Aid), EPSRC & DECC (now part of BEIS) & implemented by University of Sussex, Gamos Ltd., ACTS (Kenya), ITT & UIU (Bangladesh).
    - The key **PRELIMINARY RESULTS** (Q1 2019) can be found here.
- A series of global & local market assessments in Myanmar, Zambia and Tanzania under the "*eCook - a transformational household solar battery-electric cooker for poverty alleviation*" project funded by DfID (UK Aid) & Gamos Ltd. through Innovate UK's Energy Catalyst Round 4, implemented by Loughborough University, University of Surrey, Gamos Ltd., REAM (Myanmar), CEEEZ (Zambia) & TaTEDO (Tanzania).
    - The key **PRELIMINARY RESULTS** (Q1 2019) can be found here.
- At time of publication (Q1 2019), a new DfID (UK Aid) funded research programme '*Modern Energy Cooking Services*' (MECS) lead by Prof. Ed Brown at Loughborough University is just beginning and will take forward these ideas & collaborations.

This data and material have been funded by UK AID from the UK government; however, the views expressed do not necessarily reflect the UK government's official policies.

8.1.4 About the Modern Energy Cooking Services (MECS) Programme.

Sparking a cooking revolution: catalysing Africa's transition to clean electric/gas cooking.

www.mecs.org.uk | mecs@lboro.ac.uk

Modern Energy Cooking Services (MECS) is a five-year research and innovation programme funded by UK Aid (DFID). MECS hopes to leverage investment in renewable energies (both grid and off-grid) to address the clean cooking challenge by integrating modern energy cooking services into the planning for access to affordable, reliable and sustainable electricity.

Existing strategies are struggling to solve the problem of unsustainable, unhealthy but enduring cooking practices which place a particular burden on women. After decades of investments in improving biomass cooking, focused largely on increasing the efficiency of biomass use in domestic stoves, the technologies developed are said to have had limited impact on development outcomes. The Modern Energy Cooking Services (MECS) programme aims to break out of this "business-as-usual" cycle by investigating how to rapidly accelerate a transition from biomass to genuinely 'clean' cooking (i.e. with electricity or gas).

Worldwide, nearly three billion people rely on traditional solid fuels (such as wood or coal) and technologies for cooking and heating[6]. This has severe implications for health, gender relations, economic livelihoods, environmental quality and global and local climates. According to the World Health Organization (WHO), household air pollution from cooking with traditional solid fuels causes to 3.8 million premature deaths every year – more than HIV, malaria and tuberculosis combined[7]. Women and children are disproportionally affected by health impacts and bear much of the burden of collecting firewood or other traditional fuels.

Greenhouse gas emissions from non-renewable wood fuels alone total a gigaton of CO_2e per year (1.9-2.3% of global emissions)[8]. The short-lived climate pollutant black carbon, which results from incomplete combustion, is estimated to contribute the equivalent of 25 to 50 percent of carbon dioxide warming globally – residential solid fuel burning accounts for up to 25 percent of global black

[6] http://www.who.int/indoorair/health_impacts/he_database/en/

[7] https://www.who.int/en/news-room/fact-sheets/detail/household-air-pollution-and-health https://www.who.int/gho/hiv/epidemic_status/deaths_text/en/, https://www.who.int/en/news-room/fact-sheets/detail/malaria, https://www.who.int/en/news-room/fact-sheets/detail/tuberculosis

[8] Nature Climate Change 5, 266–272 (2015) doi:10.1038/nclimate2491

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carbon emissions[9]. Up to 34% of woodfuel harvested is unsustainable, contributing to climate change and local forest degradation. In addition, approximately 275 million people live in woodfuel depletion 'hotspots' – concentrated in South Asia and East Africa – where most demand is unsustainable[10].

Africa's cities are growing – another Nigeria will be added to the continent's total urban population by 2025[11] which is set to double in size over the next 25 years, reaching 1 billion people by 2040. Within urban and peri-urban locations, much of Sub Saharan Africa continues to use purchased traditional biomass and kerosene for their cooking. Liquid Petroleum Gas (LPG) has achieved some penetration within urban conurbations, however, the supply chain is often weak resulting in strategies of fuel stacking with traditional fuels. Even where electricity is used for lighting and other amenities, it is rarely used for cooking (with the exception of South Africa). The same is true for parts of Asia and Latin America. Global commitments to rapidly increasing access to reliable and quality modern energy need to much more explicitly include cooking services or else household and localized pollution will continue to significantly erode the well-being of communities.

Where traditional biomass fuels are used, either collected in rural areas or purchased in peri urban and urban conurbations, they are a significant economic burden on households either in the form of time or expenditure. The McKinsey Global Institute outlines that much of women's unpaid work hours are spent on fuel collection and cooking[12]. The report shows that if the global gender gap embodied in such activities were to be closed, as much as $28 trillion, or 26 percent, could be added to the global annual GDP in 2025. Access to modern energy services for cooking could redress some of this imbalance by releasing women's time into the labour market.

To address this global issue and increase access to clean cooking services on a large scale, investment needs are estimated to be at least US$4.4 billion annually[13]. Despite some improvements

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[9] http://cleancookstoves.org/impact-areas/environment/

[10] Nature Climate Change 5, 266–272 (2015) doi:10.1038/nclimate2491

[11] https://openknowledge.worldbank.org/handle/10986/25896

[12] McKinsey Global Institute. *The Power of Parity: How Advancing Women's Equality can add $12 Trillion to Global Growth*; McKinsey Global Institute: New York, NY, USA, 2015.

[13] The SE4ALL Global Tracking Report shows that the investment needed for universal access to modern cooking (not including heating) by 2030 is about $4.4 billion annually. In 2012 investment

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in recent years, this cross-cutting sector continues to struggle to reach scale and remains the least likely SE4All target to be achieved by 2030[14], hindering the achievement of the UN's Sustainable Development Goal (SDG) 7 on access to affordable, reliable, sustainable and modern energy for all.

Against this backdrop, MECS draws on the UK's world-leading universities and innovators with the aim of sparking a revolution in this sector. A key driver is the cost trajectories that show that cooking with (clean, renewable) electricity has the potential to reach a price point of affordability with associated reliability and sustainability within a few years, which will open completely new possibilities and markets. Beyond the technologies, by engaging with the World Bank (ESMAP), MECS will also identify and generate evidence on other drivers for transition including understanding and optimisation of multi-fuel use (fuel stacking); cooking demand and behaviour change; and establishing the evidence base to support policy enabling environments that can underpin a pathway to scale and support well understood markets and enterprises.

The five-year programme combines creating a stronger evidence base for transitions to modern energy cooking services in DFID priority countries with socio-economic technological innovations that will drive the transition forward. It is managed as an integrated whole; however, the programme is contracted via two complementary workstream arrangements as follows:

- An Accountable Grant with Loughborough University (LU) as leader of the UK University Partnership.
- An amendment to the existing Administrative Arrangement underlying DFID's contribution to the ESMAP Trust Fund managed by the World Bank.

The intended outcome of MECS is a market-ready range of innovations (technology and business models) which lead to improved choice of affordable and reliable modern energy cooking services for consumers. Figure 26 shows how the key components of the programme fit together. We will seek to have the MECS principles adopted in the SDG 7.1 global tracking framework and hope that participating countries will incorporate modern energy cooking services in energy policies and planning.

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was in cooking was just $0.1 billion. Progress toward Sustainable Energy: Global Tracking Report 2015, World Bank.

[14] The 2017 SE4All Global Tracking Framework Report laments that, "Relative to electricity, only a small handful of countries are showing encouraging progress on access to clean cooking, most notably Indonesia, as well as Peru and Vietnam."

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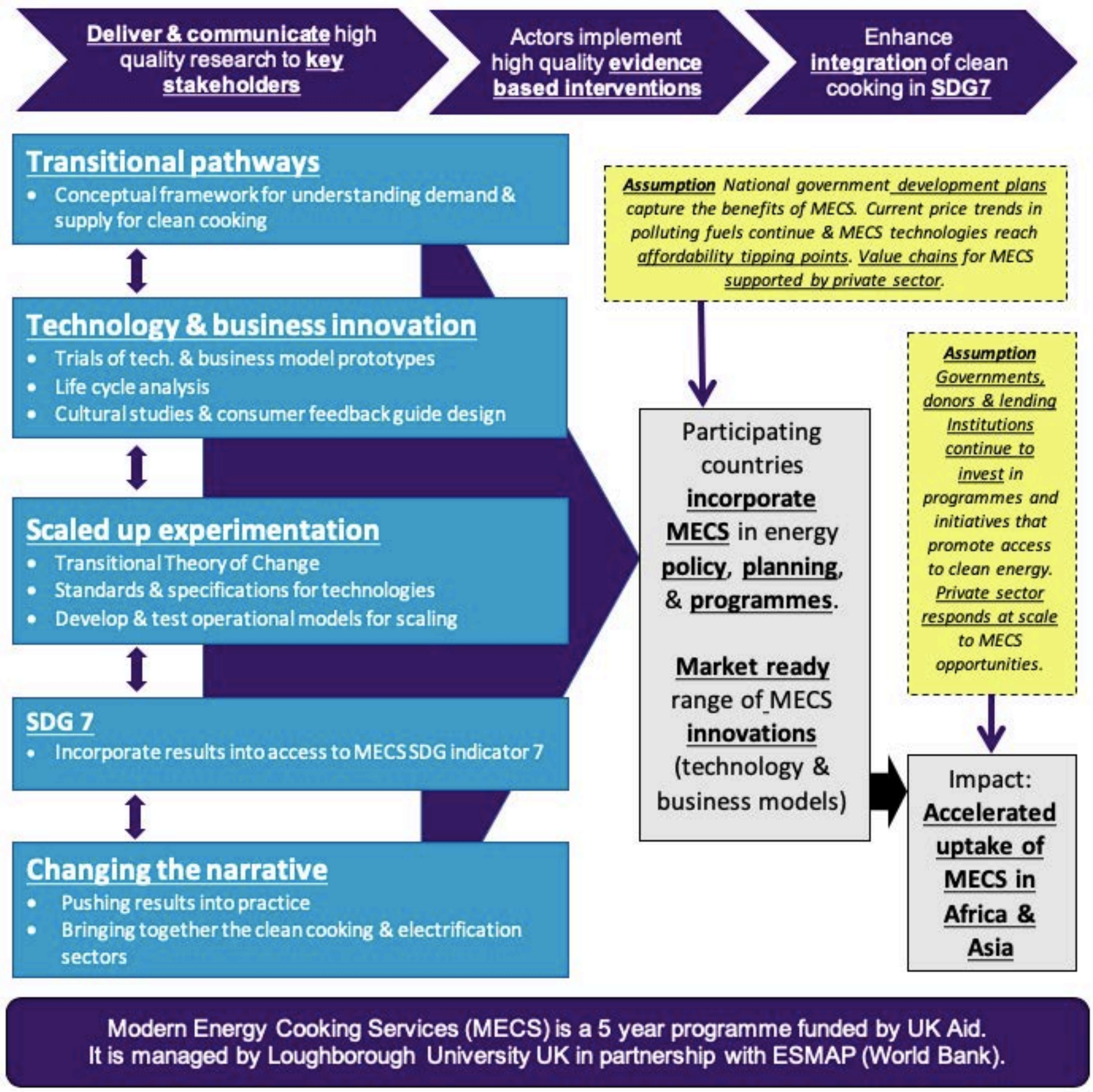

Figure 26: Overview of the MECS programme.

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8.2 Appendix B: Policy/markets review framework

For all factors, what is their current status and what is the likely future direction?

How do trends vary across the country, particularly from urban to rural areas?

8.3 Clean cooking

What is the state of the clean cooking sector?

- Who are the key government, NGO, research & private sector actors in the clean cooking sphere and what are their roles?
- What is the national cooking energy mix (i.e. how many people primarily cook with firewood, charcoal, kerosene, LPG & electricity)?
    - How is this changing?
        - Which successful interventions have facilitated transitions to cleaner cooking solutions? Which have failed and why?
        - How many biomass users have adopted improved stoves?
        - How and where are improved stoves manufactured?
    - What are the most popular cooking appliances?
        - How compatible are the popular electrical appliances with battery-supported electricity?
    - Are there national fossil fuel reserves? If so, how significant are they and how are they exploited?
- What do people cook and how do they cook it?
    - How does this vary across the country?
    - Is this changing?
- How many people are suffering from acute respiratory illnesses due to cooking on polluting fuels?
    - What initiatives have addressed this? How successful have they been?
- How severe is deforestation?
    - What initiatives have addressed this? How successful have they been?

Which policies currently enable or constrain the roll out of cleaner cooking solutions?

- Are there any specific targets for the quality of clean cooking solutions and the number of people who should gain access to them by a certain date?
    - If so, what policies have been developed to enable this and is there a government budget assigned to it?
- Is there a national biomass energy or cleaner cooking strategy?
    - Is charcoal production/transportation/wholesale/retail legal? If so, is it taxed and by how much? If not, how does the sector get around the law?
- Are there national targets to reduce the incidence of acute respiratory infections?
    - If so, which policies have been developed to enable this and is there a government budget assigned to it?
    - Does cooking contribute towards national targets for nutrition, maternal health, etc.?
- Are there national carbon emissions reductions targets?

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    - If so, which policies have been developed to enable this and is there a government budget assigned to it? Do they specifically mention cookstoves?
- Is kerosene or LPG use for cooking encouraged or discouraged by current national policy?
    - Is the retail price of kerosene and LPG fixed? If so, why and to what?

8.4 Electrification, renewable energy and energy efficiency

8.4.1 Grid electrification

What is the state of the national grid?

- Who has access and who does not, what are the key generation sources, how efficient is the transmission & distribution infrastructure, how frequent are blackouts/load shedding, does peak time demand exceed supply?
- Is there a single state-owned electrical utility or is there competition from the private sector?

What policies currently enable/inhibit sustainable grid electrification?

- Electricity access
    - Are there national targets for electricity access?
        - If so, which policies have been developed to enable this and is there a government budget assigned to it?
        - Do the targets specify a service level (hours of availability, maximum power/energy, etc.)?
    - What is the connection fee?
        - Are subsidies, tax exemptions, utility loans/on-bill financing or micro-loans available to support connection fees for poorer/rural households?
    - Is there a standard tariff structure for residential customers (e.g. fixed rate, rising block, declining block)?
        - Is there a cross-subsidised/social/lifeline tariff for poorer households?
        - Are grid connections pre-paid, post-paid or a mixture of the two?
- Renewable energy
    - What is the current energy mix for the national grid?
    - Are there national targets for increasing the proportion of renewable energy?
        - If so, which policies have been developed to enable this and is there a government budget assigned to it?
    - Is there a feed-in-tariff that is applicable to residential-scale generation?
- Energy efficiency
    - Are there national targets for energy efficiency?
        - If so, which policies have been developed to enable this and is there a government budget assigned to it?
    - Do/es the national utility/ies have a demand side management department/s? If so, what is their mandate and what activities have they carried out?
    - Are there time of use tariffs?
    - Are subsidies, tax exemptions, utility loans/on-bill financing or micro-loans available to support consumer purchasing of energy efficient appliances (especially cooking appliances)?

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8.4.2 Mini-grid & off-grid systems

What is the state of the mini-grid and off-grid electrification sectors?

- How many mini-grids/standalone systems are in operation, what are the key generation sources, who developed/operates them, how many people do they serve, what level of service do they offer, what tariffs do they charge?
- Which successful interventions have facilitated uptake of mini-grid and off-grid systems? Which have failed and why?
    - Which business models have proven to be most scalable?

What policies currently enable/inhibit mini-grid/off-grid electrification?

- Are mini-grids legally allowed to operate? If so, can they be privately owned and are they allowed to charge a different tariff to the national grid?
- Are there national targets for mini-grid/off-grid electrification?
    - If so, which policies have been developed to enable this and is there a government budget assigned to it?
    - Do the targets specify a service level (hours of availability, maximum power/energy, specific energy services, etc.)?
    - Do subsidies or tax exemptions exist for mini-grids/off-grid systems or key components (solar panels, batteries, controllers, inverters, chargers etc.)?

8.5 Cross cutting issues

- Electrification/clean cooking crossover
    - Is there any overlap between the clean cooking and electrification sectors (e.g. SHS suppliers also selling improved cookstoves, energy efficiency programs targeting electric cooking)?
- Gender
    - What role do women and men typically play in society?
        - Who are the main household decision makers?
        - How well educated are women and how does this compare to men?
        - How are these roles changing?
    - Have there been any initiatives to empower women? If so, how successful have they been?
        - Have any electrification or clean cooking initiatives specifically targeted women as entrepreneurs, as well as end users?
    - Are there national gender equity targets?
        - If so, which policies have been developed to enable this and is there a government budget assigned to it?
- Business & finance
    - What are the key contextual factors that enable and constrain the development of new and existing businesses?
    - Are there specific government or market-based financing facilities designed to support developers of mini-grids/off-grid systems and/or manufacturers/retailers of cleaner cookstoves?
    - Are there specific government or market-based financing facilities designed to support consumers of cleaner cookstoves/mini-grids/off-grid systems (e.g. village

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banking systems, community revolving funds, pay-as-you-go solutions, nationally subsidy programmes)?
    - How developed is the mobile money industry?
        - Which organisations are using it to allow their customers to make repayments on cleaner cookstoves/mini-grids/off-grid systems?
    - What interest rate would a) private sector and b) utility actors would use when developing their business models?
    - International trade and domestic manufacturing
        - How strong are local manufacturing industries?
        - How established are supply chains for importing equipment from China?
            - How much extra does it cost and how long does it take to import $10, $100, $1000, $10,000 or $100,000 of solar panels and batteries from China (including shipping and/or road transport, import duties and VAT)?
- Demographics
    - How many people live in urban/rural areas and how is this balance changing?
        - How many people live in urban slums and rural grid connected areas?
        - How many people live in rural off-grid areas?
- Climate
    - What are the monthly average temperatures and how do they vary across the country?
        - Are cookstoves also used for space heating?
        - Are batteries likely to be damaged by extreme heat or cold?
    - What is the monthly average solar resource and how does it vary across the country?
        - Are there extended cloudy periods?
    - Where are the key hydropower resources located?
        - What is the potential for micro-hydro powered mini-grids and what are the limitations due to seasonality?

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