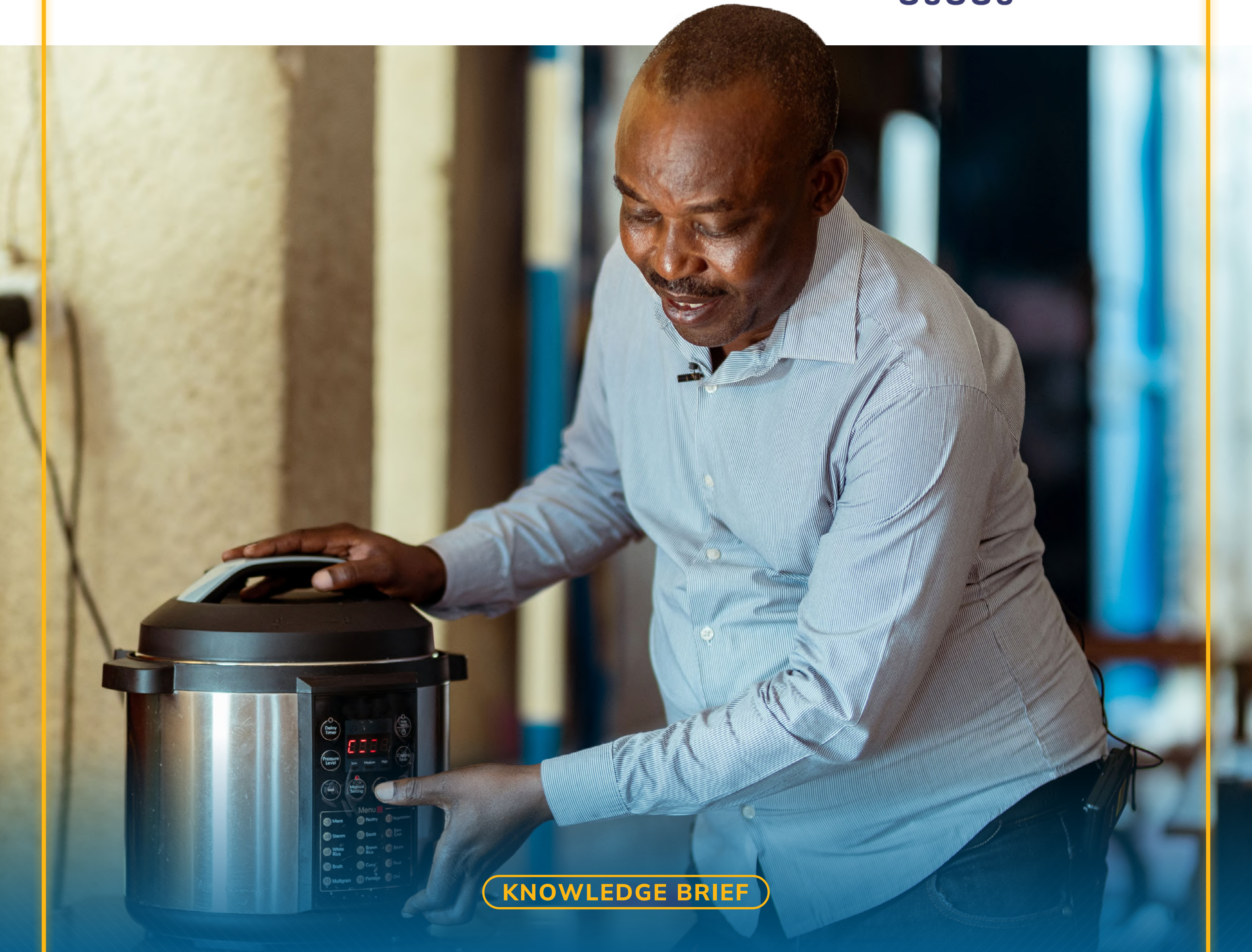

KNOWLEDGE BRIEF

Integrating Clean Cooking into National Energy Access Planning

Tools and Considerations for Planning and Implementing eCooking

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ABBREVIATIONS

AC	Alternate current
ADALYs	Averted Disability Adjusted Life Years
ADB	Asian Development Bank
BGFA	Beyond the Grid Fund for Africa
CCA	Clean Cooking Alliance
CCAC	Climate and Clean Air Coalition
CCG	Climate Compatible Growth
CCPT	Clean Cooking Planning Tool
CDM	Clean Development Mechanism
CLASP	Collaborative Labeling and Appliance Standards Program
CO	Carbon monoxide
DC	Direct current
(d)MRV	(digital) Monitoring, Reporting and Verification
EAQIP	Rwanda Energy Access and Quality Improvement Project
EnDev	Energising Development
EPC	Electric Pressure Cooker
EPR	Extended Producer Responsibility
EPRA	Energy and Petroleum Regulatory Authority
ERA	Electricity Regulatory Authority
ESMAP	Energy Sector Management Assistance Program of the World Bank
ETP	Energy Technology Perspectives
GEAPP	Global Energy Alliance for the People and Planet
GEC	Global Energy and Climate model
GeCCo	Global Electric Cooking Coalition
GHG	Greenhouse gas
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoR	Government of Rwanda
GSM	Global System for Mobile Communications
IAEA	International Atomic Energy Agency
ICCPT	Integrated Clean Cooking Plan Tool
IEA	International Energy Agency
IEAP	Integrated Energy Access Plan
IEC	International Electrotechnical Commission
IEP	Integrated Energy Plan
IIASA	International Institute for Applied Systems Analysis
IIED	International Institute for Environment and Development
IoT	Internet of Things
IRENA	International Renewable Energy Agency
ISO	International Organization for Standardization
KPLC	Kenya Power and Lighting Company
LCEM	Least-cost electrification model
LMIC	Low- and Middle-Income Country
LNG	Liquid Natural Gas
LPG	Liquified Petroleum Gas
M-LED	Multi-sectoral Latent Electricity Demand
MAED	Model for Analysis of Energy Demand
MCFA	Modern Cooking Facility for Africa
MECS	Modern Energy Cooking Services
MEDEE2	Model for Long-Term Energy Demand Evaluation
MEPS	Minimum Energy Performance Standards
MESSAGE	Model for Energy Supply System Alternatives and General Environmental Impacts
MITEI	Massachusetts Institute of Technology Energy Initiative
MTF	Multi-Tier Framework
NDC	Nationally Determined Contribution
NICCP	National Integrated Clean Cooking Plan
OnSSET	Open Source Spatial Electrification Tool
OnStove	Open Source Spatial Clean Cooking Tool
OSeMOSYS	Open Source Energy Modelling System
PAYGO	Pay-as-You-Go
PV	Photovoltaic
RBF	Results-based financing
RE	Renewable energy
REM	Reference Electrification Model
R&D	Research and development
RURA	Rwanda Utilities Regulatory Authority
SDG	Sustainable Development Goal
SEA	Southeast Asia
SEforALL	Sustainable Energy for All
SHS	Solar home system
SME	Small- and Medium-Sized Enterprise
SOLCO	Solar-Electric Cooking Partnership
SPLAT	System Planning Test
SSA	Sub-Saharan Africa
SUM	Stove Use Monitoring
UCL	University College London
UIEP	Universal Integrated Energy Planning
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
USD	United States Dollar
VAT	Value-added tax
VCM	Voluntary Carbon Market
WEM	World Energy Model
WEO	World Energy Outlook
WFP	World Food Programme
WHO	World Health Organization
WRI	World Resources Institute

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EXECUTIVE SUMMARY

This Knowledge Brief aims to inform approaches to energy access planning in low- and middle-income countries (LMICs) that simultaneously address access to electrification and clean cooking. It focuses on electric cooking (eCooking), which is at the heart of this integration. The Knowledge Brief provides a review of relevant tools and methodologies for integrated energy access planning and gives an overview of policy, finance and knowledge initiatives that help create enabling conditions for these plans to be implemented and drive clean cooking transitions.

Access to clean energy is essential for improving lives and livelihoods, boosting gender equity and reducing greenhouse gas (GHG) emissions. However, meeting Sustainable Development Goal 7 (SDG7) – access to affordable, reliable, sustainable and modern energy for all – by 2030 is currently off track, with 685 million people lacking access to electricity and over 2.1 billion having no access to any form of clean cooking (IEA et al. 2024). Given the faster progress on electrification, eCooking has increasingly received recognition as a feasible clean cooking alternative for households in LMICs.

Yet, universal electrification initiatives have considered linkages with clean cooking too rarely and inconsistently. This may be due to a lack of awareness amongst the stakeholders involved, absence of supporting strategies and plans bridging the two, and limited opportunity (and ability) to deploy available funding to both electrification and clean cooking access simultaneously. Integrated energy planning has increasingly been considered as a key solution to tackling this sectoral divide. A well-designed integrated energy plan can help achieve energy access goals more efficiently, as it considers all resources and mechanisms needed for the provision of all energy needs, including electrification and access to clean cooking in a joint manner, leveraging the synergies between the two and considering the challenges from the start. In contexts where energy access is not yet universal, energy plans must consider its extension, ensuring that all individuals and communities have reliable and affordable access to clean and sustainable energy sources. Adequate mechanisms and strategies are then needed to operationalize and implement those plans.

Energy planning is the process of developing long-term strategies to help guide the future development of an energy system (IAEA 2018) in a way that strikes a balance between competing objectives, including energy security, access, availability, affordability, efficiency and environmental concerns, and economic development. Acknowledging that the scope of integrating energy planning may include all sub-sectors meaningfully contributing to energy demand (e.g., cold chains, transportation, industry, etc.), this Knowledge Brief, however, focuses on the electricity and clean cooking sub-sectors and refers to planning exercises that account for both as integrated energy planning. It reviews the traditional segmentation of planning exercises in two broad categories:

- Energy system or sub-sector planning, which focuses on identifying the technological options and infrastructure investments required to meet an aggregate demand, and
- Energy access planning, which generally adopts a geospatial angle and considers the investments and infrastructure required to deliver energy services to end users.

Integrating cooking and electricity considerations in planning exercises and increasing the linkages between energy system and access planning is critical to: facilitate faster and more efficient transition pathways towards universal access to energy; unlock the potential of eCooking; and build more integrated and resilient energy systems that meet local demand reliably and affordably.

While energy planning has historically not focused on clean cooking as much as on electricity, clean cooking has nevertheless been incorporated in relatively ad hoc ways, driven by the specific requirements of each planning exercise. This Knowledge Brief finds that, overall, energy access planning approaches focused on clean cooking are still at an early stage of development and that comprehensive, integrated energy planning tools that tackle electrification and clean cooking holistically from system to access planning are still mostly aspirational. However, some of the latest efforts have produced methodologies and tools that look promising. The development of the Integrated Clean Cooking Plan Tool (ICCPT) in Rwanda possibly constitutes the most significant methodological advance to date as it achieves a full methodological integration of clean cooking and electrification for energy access planning and captures the impact of the demand for eCooking on the electricity system through feedback loops. Another approach being explored is the combination of open-source tools with a holistic energy modelling analytical workflow, such as the soft-linking of the Open Source Energy Modelling System (OSeMOSYS), the Open Source Spatial Electrification Tool (OnSSET) and the Open Source Spatial Clean Cooking Tool (OnStove), which are presented in more detail in Section 2.

Enhancing these approaches with linkages to other open-source tools could generate additional financial, technical and climate insights, critical for implementing energy access plans and informing political and financial decisions. As data ultimately underpin any energy modelling exercise and the resulting energy plans, it is critical that access to quality datasets covering all required dimensions is facilitated. Current practices promoted by international organizations and academic professionals, including open access to energy datasets often linked with open-source modelling tools, might help speed up progress on developing more robust energy plans and policies. Robust data would lead to enhanced market knowledge and unlock opportunities to improve the design of support mechanisms such as on-bill appliance financing and results-based financing (RBF) to promote affordability for end users and product availability. It is also indispensable for the private sector to access the required capital through lending and equity instruments – the monetization of impact. The democratization of digital monitoring, reporting and verification platforms and Internet-of-Things (IoT) cooking devices presents an unprecedented opportunity to both enhance market knowledge through improved data generation and collection, and leverage emerging carbon methodologies relying on digitalization.

Achieving integrated energy plans will also require collaborative efforts across sectors and stakeholders, along with effective resource allocation to address the most pressing socioeconomic needs at local and national levels. This coordination among government entities is especially vital for clean cooking planning, which involves complex cross-sectoral considerations, including the implications of eCooking, and requires transcending electrification versus clean cooking silos to integrate energy considerations into broader policy domains such as finance, labour, taxation, transport and industry. Moreover, addressing the complexity of demand for clean cooking services requires interventions that account for existing cooking practices and the need for competitive pricing and sustainability of clean cooking solutions. Hence, research will require continued support to empower the whole range of different stakeholders with adequate knowledge and evidence.

CHAPTER ONE

INTRODUCTION

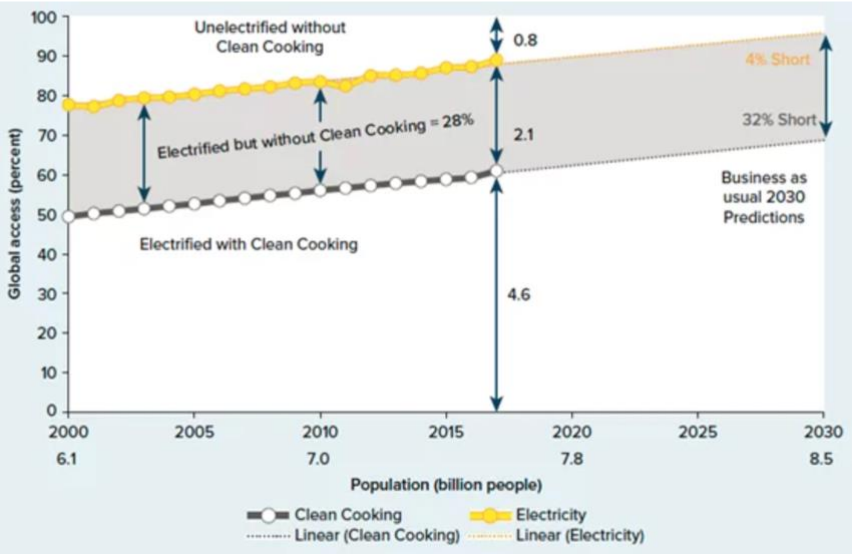
Access to clean energy is essential for improving lives and livelihoods, boosting gender equity and reducing greenhouse gas (GHG) emissions that contribute to climate change and its impacts. However, the world is currently off track to achieving Sustainable Development Goal (SDG) 7 by 2030, with 685 million people lacking access to electricity and over 2.1 billion having no access to any form of clean cooking[1] (IEA et al. 2024). Recent projections show that at the current rate of progress approximately 1.8 billion people will lack access to clean cooking in 2030, while over 600 million will still lack access to electricity. To close these gaps over the next decade, meet rising energy needs and align with the climate goals set out in the Paris Agreement, annual clean energy investments in emerging and developing economies will need to more than triple from USD 770 billion in 2022 to as much as USD 2.8 trillion by the early 2030s (IEA & IFC 2023).

Despite progress made on electrification, there has been relatively little action taken to leverage that progress to tackle the lack of access to clean cooking. Given that less than 10 percent of the global population do not have access to electricity and over 30 percent do not have access to any form of clean cooking, there is a vast opportunity to explore electric cooking (eCooking) as one

[1] The World Health Organization's (WHO) definition of clean, transitional and polluting fuels and technologies used for cooking, heating and lighting is accessible here.

viable solution.[2] Figure 1 shows the historical gap between electrification and access to clean cooking and the projections under two scenarios: business as usual (BAU) where still over 30 percent of the global population will lack access, and a scenario where electricity is leveraged for faster transition to cleaner cooking, leaving the world with a much smaller gap in the levels of access to clean cooking of 4 percent.

FIGURE 1: The gap between electricity access and clean cooking



Source: ESMAP (2020)

Over the last 10 years, eCooking, which encompasses electric pressure cookers (EPCs), electric hot plates, infrared or induction hobs, and other appliances (e.g., rice cookers, air fryers, electric ovens, etc.), has received increasing recognition as a feasible clean cooking alternative for electrified households in low- and middle-income countries (LMICs) (Brown et al. 2017; Batchelor et al. 2019; ESMAP 2020; Batchelor et al. 2022; Sánchez-Jacob et al. 2021). This growing recognition has been in parallel with the strong push towards more power generation through renewable energy (RE) sources, such as solar, wind, geothermal energy or hydropower. Progress in recent years has seen added renewables-based capacity reaching historical highs, with the share of renewables in total capacity expansion standing at 83 percent in 2022, up from 78 percent in 2021 (IRENA 2023a). Where power predominantly comes from renewable sources, eCooking becomes one of the cleanest low-carbon cooking solutions available (IRENA 2023b). The market of eCooking solutions and technologies in LMICs has also been growing steadily, offering an ever-wider range of eCooking appliances at decreasing costs, making it more affordable for households to transition away from harmful and polluting cooking that largely relies on biomass. As demonstrated by the World Bank's Energy Sector Management Assistance Program (ESMAP) and the Modern Energy Cooking Services (MECS) programme (2020), the use of energy efficient eCooking appliances in LMICs can be cost-competitive with more common alternatives such as charcoal or liquefied petroleum gas (LPG), challenging the widespread perception of electricity being too expensive to cook with.

[2] eCooking is considered clean for end users regardless of the mix of primary energy sources used for electricity generation, in line with WHO's definition of clean cooking. However, it is widely recognized that renewables-powered eCooking offers the most environmental benefits (IRENA 2024).

The opportunity to benefit from the improved cost competitiveness of eCooking is particularly relevant for urban areas in Sub-Saharan Africa (SSA) and South-/Southeast Asia (SEA) that have higher electrification rates than rural areas and where cooking with charcoal or other forms of biomass is still prevalent and frequently (and increasingly) expensive (Rose et al. 2022). Cost competitiveness against the most common cooking fuels is one important aspect, with availability, cleanliness, convenience and time saving benefits important eCooking co-benefits to consider.

In addition, access to electricity services offers more than just eCooking opportunities. It can also be leveraged as an anchor for the extension, or provision, of other, non-electric, clean and modern cooking services, such as LPG, ethanol, biogas or liquid natural gas (LNG). This could be through last-mile delivery networks that already exist for different modes of electrification (whether via the grid or off-grid systems), customer relations, better understanding of household needs and ability to pay for energy services.

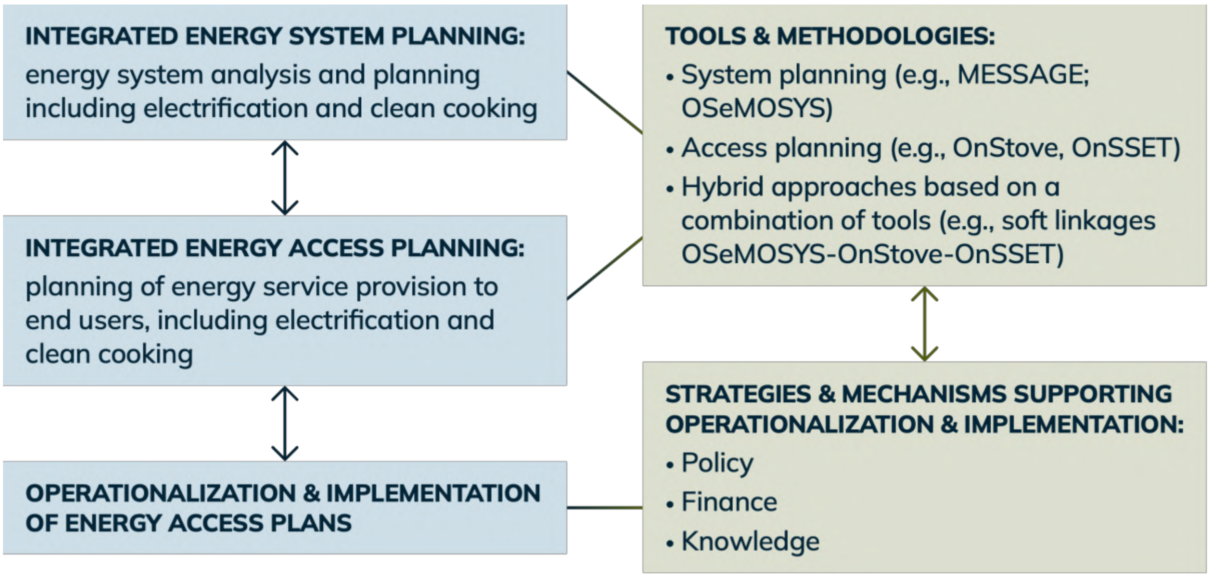
Yet, universal electrification initiatives rarely consider linkages with clean cooking due to lack of awareness amongst the stakeholders involved, absence of supporting strategies and plans bridging the two, and limited opportunity (and ability) to deploy available funding to both electrification and clean cooking access simultaneously. This carries an inherent risk where an electricity system (generation and network infrastructure) may become unable to support the growing electrification of the economy, locking out socially desirable energy services (including eCooking as well as others, such as electric vehicle charging) and important components of long-term net-zero energy transitions (Batchelor et al. 2022). Similarly, clean cooking planners and advocates often leave out electrification from their initiatives, which hinders progress in meeting cooking needs through electrification. Hence, despite the fact that common objectives of providing universal energy access under SDG7, including electricity and clean cooking, are intertwined and provide overlapping health, economic and environmental benefits, energy policy around these goals remains disconnected (Newell & Daley 2022).

Energy planning integrating electricity and clean cooking considerations has increasingly been considered as a key solution to tackling this sectoral divide. Energy planning is the process of developing long-term strategies to help guide the future development of an energy system (IAEA 2018) in a way that strikes a balance between competing objectives, including energy security, access, availability, affordability, efficiency and environmental concerns, and economic development. In contexts where energy access (encompassing electricity, cooking and other energy needs like heating and cooling) is not yet universal, energy plans must consider its extension, ensuring that all individuals and communities have reliable and affordable access to clean and sustainable energy sources. Finally, adequate mechanisms and strategies must be put in place to operationalize and implement those plans. Figure 2 presents the flow of this overarching process, specifically for integrated energy planning approaches covering both electrification and clean cooking. Acknowledging that the scope of integrating energy planning may include all sub-sectors meaningfully contributing to energy demand (e.g., cold chains, transportation, industry, etc.), this Knowledge Brief, however, focuses on the electricity and clean cooking sub-sectors and refers to planning exercises that account for both as integrated energy planning.

However, as there have been relatively few initiatives that have explicitly included clean cooking, and particularly eCooking, into energy planning in LMICs, there is a need to better understand how the integration of clean and modern cooking into energy planning can be facilitated and enhanced.

Further, there is a need to better understand what policies and strategies, and other mechanisms, are needed to operationalize such integrated energy plans to facilitate energy access for end users.

FIGURE 2: Process flow for integrated energy planning, including supporting tools, methodologies and implementation considerations



Source: Authors.

This Knowledge Brief aims to inform approaches to integrated energy planning in LMICs that simultaneously address access to electricity and clean cooking, with specific considerations for eCooking. It provides a review of relevant tools and methodologies and gives an overview of policy, finance and knowledge initiatives and considerations that can help create enabling conditions for these plans to be operationalized and implemented to drive clean cooking transitions. The Knowledge Brief focuses on eCooking, which is at the heart of this integration, while acknowledging that eCooking makes up a part of a wider set of clean cooking solutions.

1.1 Shifting Narratives: Electrification and Clean Cooking

Historically, electrification and cooking have been categorized as two separate sectors characterized by different needs, modes of provision, funders, value chains, policy actors and planning tools, among others. As opposed to access to clean cooking, which has received much less attention and significantly fewer resources (World Bank 2021), electricity has historically been seen as a strategic question and one of infrastructural and economic development. That, in turn, has driven both the approaches to energy planning and the institutions, policy instruments, and resources that have been mobilized in support of electrification access objectives. These objectives, however, have rarely included an explicit capacity of electricity systems to cover cooking needs (in the form of eCooking), in particular in LMICs where cooking with electricity has commonly been perceived by both policymakers and end users as too expensive and challenging given the issues related to grid instability (Lee et al. 2022).

In addition, lack of people-centricity in energy planning and path dependencies created by early electricity policy choices (largely exclusive of eCooking) in much of SSA and SEA has led to cooking with electricity suffering from poor, if any, institutional and policy support, even in contexts where it could play an important role in clean cooking transitions, such as highly urbanized and electrified areas. Historic lack of data and evidence on eCooking, especially considering the rapidly improving efficiency levels of electric appliances, including eCooking ones, has also hindered progress on bringing the electrification and clean cooking agendas closer together (Sokona et al. 2023).

However, thanks to the work carried out over the last decade, including by programmes, organizations and initiatives such as MECS, Sustainable Energy for All (SEforALL), the Collaborative Labeling and Appliance Standards Program (CLASP), GIZ-Energising Development (EnDev), the International Institute for Environment and Development (IIED), Climate Compatible Growth (CCG), ESMAP, the Asian Development Bank (ADB), the International Renewable Energy Agency (IRENA) and the International Energy Agency (IEA), among others, the bridging of the electricity-clean cooking divide has started taking shape and the energy sector has observed a growing awareness of the urgency to seek solutions that will not only speed up the full achievement of SDG7.1, but ones that will also help address the enormous health and environmental challenges associated with continued reliance on biomass. Among them, eCooking has been gaining prominence and recognition as an increasingly viable option for extending access to clean cooking. In Kenya and Uganda, where there are rapid levels of grid electrification and high shares of renewable power generation, eCooking has been embraced as a way to boost electricity consumption while also tackling clean cooking transitions, and has received policy and regulatory support, with eCooking tariffs already in place and eCooking strategies currently under development (CCAC 2023).

A growing body of research and evidence has also been produced and demonstrates the potential and multi-faceted benefits of eCooking, especially where households already have access to electricity, whether through the grid or through decentralized, off-grid energy systems. The latter, having become an integral component of electrification efforts in LMICs, and most notably in SSA, has also shifted the focus from electrification as infrastructure development to energy service delivery. New business models for mini-grids and standalone solar home systems have emerged to address the constraints of delivering energy services in more rural and often remote settings. This has opened an opportunity for clean cooking delivery through decentralized, off-grid solutions (e.g. Sánchez-Jacob et al. 2021), allowing clean cooking to benefit from the strategic labelling and policy support that electrification has historically received (ESMAP 2020).

eCooking remains an opportunity yet to be fully tapped into, as to date relatively few countries have fully embraced policies and strategies to promote it in both grid and off-grid settings. This is reflective of the wider landscape of clean cooking access still lagging behind electrification efforts in LMICs. Integrated approaches to energy planning offer one way forward to tackle this challenge.

1.2 Opportunities for Integrated Energy Planning and eCooking

Integrated energy planning takes a holistic look at a country's energy system when planning for household, institutional and industrial access to electricity and clean cooking (SEforALL 2023). It moves beyond simply evaluating the least-cost electrification options (grid, mini-grid or standalone systems), which has been a common approach in the energy sector (e.g., the Reference Electrification Model (REM)).

Integrated energy plans can help achieve energy access goals more efficiently, as long as they consider all resources and mechanisms needed for the provision of all energy needs, including electrification and access to clean cooking in a joint manner, leveraging the synergies between the two and considering the challenges from the start (see Table 1 for examples). As opposed to standalone electrification or clean cooking plans, an integrated energy planning approach can provide policymakers, funders and the private sector with valuable data and insights to enable them to make decisions about extending energy access more holistically, covering all different energy services, including cooking. Such an approach can also guide governments, funders and other development partners in prioritizing certain research and innovation areas, to continue developing breakthrough solutions and associated human capital that can further help address the key barriers to the uptake of clean cooking.

Among the various clean cooking solutions, integrating eCooking into electricity planning holds the greatest promise, given the numerous synergies between them. Table 1 below presents the benefits and challenges associated with integrating eCooking into electricity planning. To provide a comparative perspective, these benefits and challenges are also examined using LPG as an example of an alternative clean cooking solution.

TABLE 1: Benefits and challenges of integrating eCooking and LPG with electricity planning

	BENEFITS	CHALLENGES
E-Cooking	• Is integral to electricity generation and distribution planning by including eCooking loads for different customer segments, hence requiring no additional planning processes • Avoids lock-ins whereby a greater share of eCooking cannot be adopted due to limitations in infrastructure planned without eCooking considerations • Can benefit from dedicated tariffs, e.g., an eCooking tariff (see section 4, Box 6: eCooking tariffs in Kenya and Uganda, as examples), making cooking with electricity more affordable to end users • Electricity subsidies benefit end users for cooking and other electricity uses • Involves same group of policymakers and planners as for electrification (i.e., same ownership) • Relies directly on the electrical connection available and is immediately available to connected households (no or only small investments for end users[3]) • Price is decided by electricity service regulators and, as long as generation is local, is independent of international price volatilities	• Requires data and evidence on levels of electricity consumption for cooking and end users' cooking behaviours for planning purposes (i.e., adequate assessment of extra loads required to satisfy cooking needs) • Requires reinforcements of power generation and distribution networks, and careful electricity load management systems to ensure electricity networks do not get overloaded at any time, particularly at peak times (cooking in the mornings and evenings often coincides with a general peak in electricity use) • Requires creation of favourable environments for the private sector to grow the range of available (energy-efficient) eCooking appliances and measures such as tax and duty exemptions, campaigns to promote eCooking • Requires behaviour change campaigns to educate end users on cooking with electricity (whether changing from biomass or LPG cooking)

[3] In some instances, depending on the quality of internal electrical wiring in households or other contexts (e.g., institutions, commercial or industrial facilities), some additional wiring improvement or additions might be needed.

	BENEFITS	CHALLENGES
	• Leverages electrification (grid/off-grid) investment • Can be net zero in terms of emissions if electricity comes from renewable sources • Affordability barrier can be addressed by tailoring delivery models (for grid or off-grid electricity services) to end users' capacity to pay for electricity and electric appliances (e.g., on-bill financing, rent-to-own schemes)	
LPG	• Can benefit from existing oil products infrastructure (e.g., distribution chains for other oil uses) • Can benefit from the extension of the necessary infrastructure needed for electrification, e.g., roads (to enable easier operation of distribution networks) • Can be added as an add-on service by off-grid energy providers and leveraging existing distribution networks and understanding of customer needs	• Relies on the development of a separate value chain than electrification (from production or importation to bottling, distribution and servicing) • If crude oil is not available and processed locally, it is highly vulnerable to price fluctuations on international markets • Requires additional infrastructure for end users (cylinders, connection hoses, valves) • Typically, different political ownership than that of electrification, making integration and coordination more complex • Requires different investment streams than electrification • Requires creation of favourable environments for the private sector to build LPG distribution networks and provide LPG cooking equipment (stoves, cylinders, hoses, etc.) • Requires different subsidy and other policy incentives than electrification

Source: Authors.

In addition to recognizing the numerous synergies and benefits gained by integrating eCooking and electrification for integrated planning, it is also worth noting that many SSA countries, with much of their energy and other infrastructure yet to be built, have a unique opportunity to leapfrog towards RE systems, which can also form an integral, and core, part of integrated energy planning. They have the option to pursue energy measures that can leverage the decentralized nature of renewables to achieve universal access at the least cost, avoiding new investments into fossil fuel-based energy systems that threaten to generate stranded assets, and contribute to environmental degradation and climate change (Sokona et al. 2023). This can result in the provision of clean (grid or off-grid) electricity and truly clean cooking with it.

CHAPTER TWO

CLEAN COOKING IN ENERGY PLANNING IN LOW- AND MIDDLE-INCOME COUNTRIES

Energy planning is an important input into policy, regulatory, investment and management decisions that contribute to both the clean energy transition and the expansion of energy access. Systematic analysis of the energy sector and its various sub-components can not only contribute to setting policy or quantitative targets that support the efficient use of financial and energy resources, but also to improved coordination in decentralized, multi-actor market-based systems by generating a shared vision and common understanding of the main issues and trade-offs in achieving policy goals.

2.1 Overview of Energy Planning Approaches

As mentioned in Section 1, energy planning is the process of developing long-term strategies to help guide the future development of an energy system (IAEA 2018) in a way that achieves both energy access and reliable supply.

Energy planning is generally conducted in a centralized manner, and national authorities are responsible for developing or coordinating the various levels of planning.[4] Energy planning approaches have historically varied depending on the scope, scale and specific policy or strategic questions that the plans were intended to inform. It is crucial to emphasize that delineating the scope of an energy planning exercise in terms of sectors and technologies significantly influences the applicability of the model's outcomes and its ability to generate specific policy insights. Broadly, historical attempts to undertake energy planning can be categorized into three interrelated segments, which have informed each other and iteratively:

1. **Energy system planning** considers the energy sector, with particular focus on interactions between different sub-sectors including substitution possibilities between different primary energy sources, resource competition and constraints. For modelling energy systems, planners often account for considerations around energy security, access, availability, affordability, efficiency and sustainability, such as climate change and emissions mitigation strategies. Typically, models have used a time series optimization approach, returning a least-cost energy transition pathway under specified constraints, and have been used for the development of national targets and sectoral policies driving sub-sectoral planning exercises. For example, policy targets aimed at fuel switching from fossil fuels to electricity for the transport sector can inform the long-range demand forecast for the electricity sub-sector.

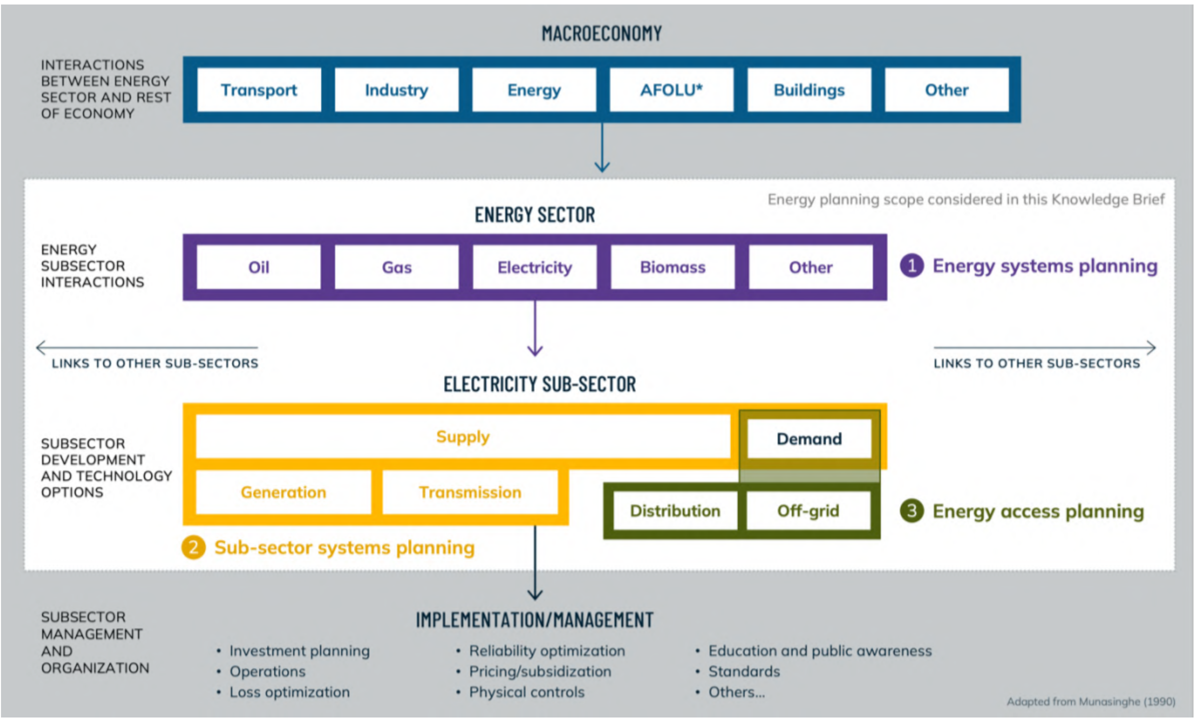
2. **Sub-sector system planning** considers planning within each of the energy sub-sectors (e.g., oil, liquefied petroleum gas (LPG), electricity, etc. as depicted in Figure 3), often with a focus on identifying the technological options and infrastructure investments required to meet aggregate demand. For the biomass sector, this may include detailed production and demand forecasts, with plans for reforestation and sustainable harvesting of wood, charcoal manufacturing, etc. For the electricity sub-sector these exercises are aimed at identifying the necessary generation and transmission investments required to meet aggregate demand and load, and balance energy supply and demand within certain cost, environmental and operational constraints. Since the focus is on aggregate demand for the full system or multiple nodes within the system, system and sub-sector system planning approaches may treat demand assumptions for specific user categories, service expansion and distribution investments, service delivery models, and/or off-grid electrification options in less detail than is generally the case in energy access planning approaches. Traditionally, sub-sector planning has been approached as a subset of energy system planning, relying on similar analytical frameworks and tools. This Knowledge Brief therefore presents both segments together.

3. **Energy access planning** targets specific segments of the population and hence modelling approaches have evolved to adopt location intelligence for more targeted interventions affected by the investments and infrastructure required to deliver energy services to end users, accounting for local factors related to population density, accessibility, specific demands and user types, local resources, etc. As a result, geospatial approaches to energy

[4] We use energy planning in the context of this Knowledge Brief to refer to government-affiliated or endorsed plans developed to specifically guide policy action. Energy modelling is used to refer to a broader set of similar activities, which can also encompass sectoral analysis and scenario development conducted by non-governmental organizations (NGOs), researchers or other actors. These activities may aim to influence policy decisions and drive methodological development, but they are not specifically commissioned by governments.

access planning have become prevalent. Energy access planning generally aims to identify the appropriate technological options to meet localized demands and to identify and prioritize corresponding distribution infrastructure investments. For the electricity sector, least-cost electricity planning is generally distinguished between areas to be served by decentralized renewable energy (RE) technologies such as mini-grids and standalone solar systems, and those for which traditional grid-based distribution systems are most cost-effective. Although energy access planning has traditionally focused on households' access to electricity, it increasingly includes considerations of specific energy end uses such as mechanical power for productive uses, cooling for agriculture or healthcare or cooking energy. At a minimum, energy access plans need to be informed by sectoral-level planning, such as assessing available energy in a given location or plans for grid extension, as well as the projected cost of grid-based energy supply. Elaborating these plans alongside broader sectoral planning efforts ensures comprehensive consistency throughout the planning process, improving demand estimations from the expansion of services to previously unserved or underserved areas, which may impact the energy system as a whole.

FIGURE 3: Traditional segmentation of energy planning



Source: Authors.

While, for the reasons given in Section 1, energy planning has historically not focused on clean cooking as much as on electricity, clean cooking has nevertheless been incorporated in relatively ad hoc ways, driven by the specific requirements of each planning exercise. This chapter describes how clean cooking has been treated in energy planning tools and methodologies, demonstrating the need to improve clean cooking integration in all segments, beginning with energy system modelling. Subsequent sections highlight the importance of expanding energy access planning approaches to include clean cooking and electric cooking (eCooking) and highlight the emerging tools and analytical approaches deconstructing the traditional segmentation of energy planning and leading the sector towards a more integrated approach.

2.2 Incorporating Clean Cooking in Energy System and Sub-Sector Planning

2.2.1 Clean Cooking Considerations in Energy System Planning Approaches

Widespread interest in energy planning emerged in the 1970s as a response to the global oil crisis and quickly spurred the development of bottom-up models for energy system analysis. These models aim to untangle the role of different technologies in delivering energy services. One notable approach to bottom-up energy modelling, based on the use of the Model for Long-Term Energy Demand Evaluation (MEDEE2) tool, was developed in the late 1970s and sponsored jointly by the United Nations Environment Programme (UNEP) and the International Institute for Applied Systems Analysis (IIASA) (Lapillonne 1978). In that time, access to clean cooking was framed as inter-fuel substitution and several relevant analyses were carried out (Munasinghe 1985; Fitzgerald et al. 1990; Floor et al. 1992). Since then, cooking has been treated both as a question of inter-fuel substitution (e.g., substituting fuelwood demand for LPG or electricity) and of efficiency gains (e.g., encouraging the uptake of improved cookstoves to reduce the overall energy intensity of cooking activities or adopting more efficient carbonization methods). Where eCooking is explicitly considered as a major contributor to the clean cooking transition, it also becomes relevant to establishing long-term electricity demand forecasts and load profiles that feed into the optimization of electricity supply in both energy system models and more specific power sub-sector modelling.

Multilateral agencies such as the International Energy Agency (IEA) and the International Atomic Energy Agency (IAEA) were early proponents of contextually appropriate energy system modelling, including considerations of clean cooking, through the development and promotion of dedicated tools and methods since the 1990s (IEA 2022; IAEA 2009; IAEA 2016). Figure 4 displays a selection of tools made available by the IAEA to its Member States, including numerous developing countries.

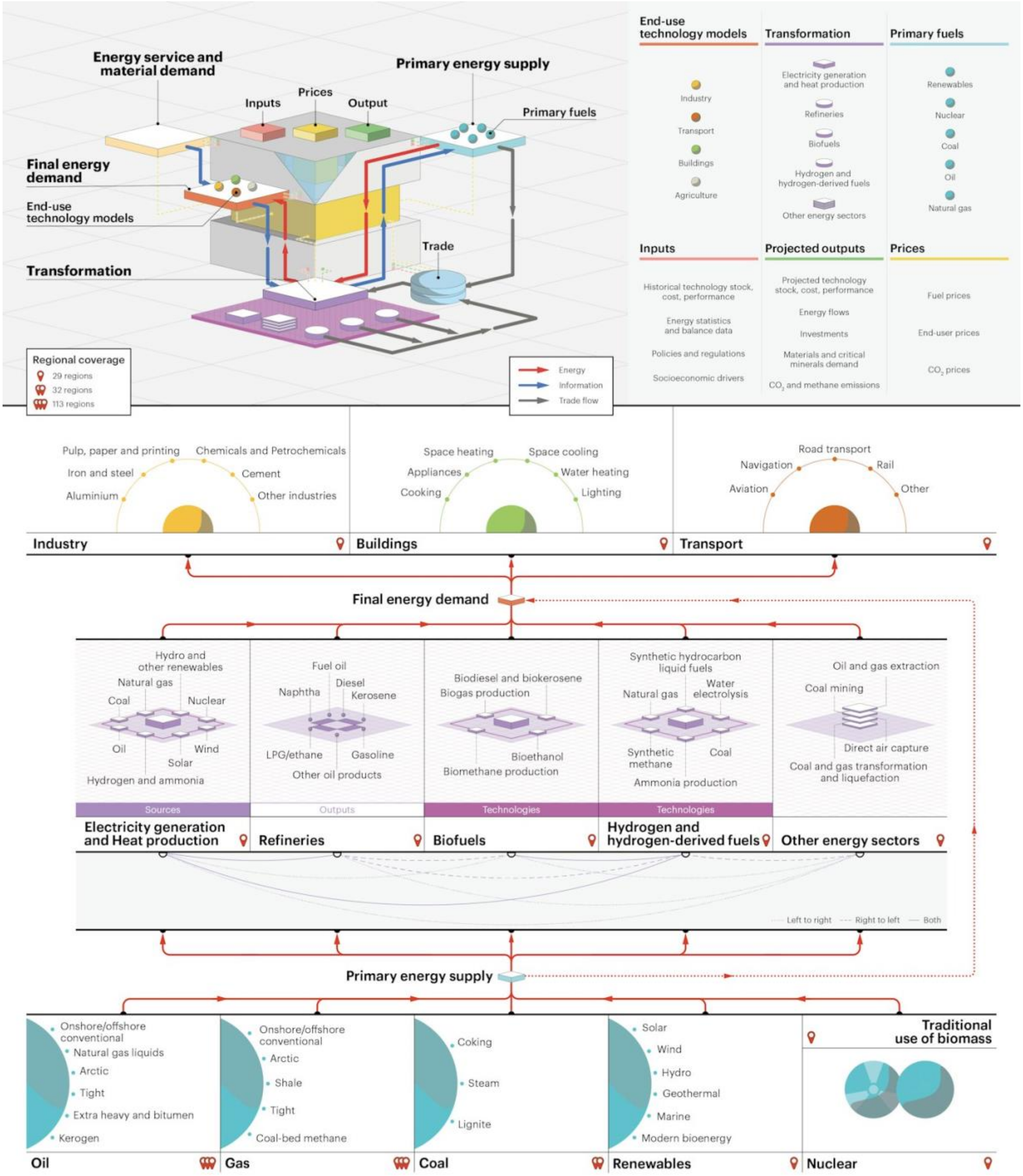
FIGURE 4: Energy system analysis and planning tools developed by the IAEA

Source: IAEA 2018.

Energy system planning based on modelling tools has historically concentrated on the main end-use sectors driving their national energy consumption and growth, such as transportation, buildings, industry, agriculture, healthcare, etc. To obtain a breakdown of relevant technologies for end-use services, e.g., cooking, heating (including water heating), etc., a combination of detailed data by consumption categories and robust assumptions for the future are required. Typically, energy needs for various cooking methods and other end uses are assessed with the help of bottom-up energy demand simulation models (e.g., the Model for Analysis of Energy Demand (MAED), as displayed in Figure 4), and their outputs feed into the energy supply analysis carried out using energy supply optimization models. The IAEA has used its Model for Energy Supply System Alternatives and General Environmental Impacts (MESSAGE) for energy system planning at national and sub-national levels in developing economies since the early 2000s. To reduce the upfront investment required for its application, an open-source simplified tool based on MESSAGE, the Open Source Energy Modelling System (OSeMOSYS), was released in the late 2000s by a coalition of stakeholders, including the IAEA, the United Nations Industrial Development Organization (UNIDO), the KTH Royal Institute of Technology, Stanford University, and University College London (UCL) (IAEA 2008). MESSAGE was also used by the International Renewable Energy Agency (IRENA) to create System Planning Test (SPLAT) capacity expansion models, to enhance the representation of national supply structures and regional interconnections, and allow national energy planners to assess a wide range of least-cost supply scenarios in 47 African countries (IRENA 2020).

Similar attempts to integrate clean cooking into energy planning for developing economies were led by the IEA in the framework driving the preparation of its 2017 World Energy Outlook (WEO) (IEA 2017), relying on its World Energy Model (WEM) and Energy Technology Perspectives (ETP) models for the electrification component. Clean cooking modelling was based on an extrapolation of a baseline scenario of clean cooking access and household cooking practices at urban and rural levels (IEA 2017). This process primarily occurred concurrently with electrification modelling exercises and considerations given to interdependency were minimized. In particular, the IEA assumed that eCooking could not be adopted at scale in contexts where the power supply was unreliable or in off-grid areas due to its relative high cost for both the end consumer and the implications on load management for mini-grid operators. As a result, eCooking was only included as a viable modern cooking technology in countries with well-developed electricity networks, such as China and South Africa (IEA 2017). Since then, the IEA has developed a new hybrid modelling approach, the Global Energy and Climate (GEC) model relying on the strengths of both the WEM and ETP models (see Figure 5). Today, this large-scale bottom-up partial-optimization modelling framework is the principal tool used to generate detailed long-term scenarios for different sectors (including cooking) across IEA's publications (IEA 2022, IEA 2023) and allows for a comprehensive modelling of the implications and opportunities to provide universal energy access at the supra-national or national scales. This includes an evaluation of additional energy demand, investments and related greenhouse gas (GHG) emissions arising from universal access to electricity and clean cooking services, as demonstrated in the IEA's most recent Net-Zero Emissions by 2050 Scenario (IEA 2023). Results are generated at the aggregate level and the analysis therefore may need to be complemented by other tools to identify implications at a local scale.

FIGURE 5: Detailed view of IEA's Global Energy and Climate model



Source: IEA (2023).

Achieving energy security whilst also minimizing carbon emissions has become a structuring objective for many countries, as climate action and adopting low-emissions or net-zero development trajectories have become more pressing. From both a clean cooking perspective and an emissions-reduction perspective, the identification of mechanisms to reduce the overall share of primary and/or traditional biomass in final energy consumption, driven in large part by household consumption for cooking and space heating[5], has become a key concern. This trend has been accelerated by the establishment of long-term low-emissions development strategies as a cornerstone of country commitments to reduce GHG emissions under the United Nations Framework Convention on Climate Change (UNFCCC) under the Paris Agreement[6], and the increasing prominence of national energy transition or net-zero plans in driving energy sector policy formation and public investment decisions. It has been facilitated by a number of initiatives and collaborations led by development partners, international agencies and academia, including significant capacity-building efforts deployed to support energy system planning both for governments and for the broader energy modelling community. The elaboration of Eswatini's 2034 Energy Masterplan, conducted by a national team of energy modellers using SPLAT, supported by training and software from IRENA and the IAEA[7], is a recent example of such multi-stakeholder collaboration. The plan includes a well-articulated clean cooking component that considers both efficiency gains through increased penetration of improved cookstoves and appliances, as well as gradual inter-fuel substitution from traditional biomass to electricity in line with improving household access to electricity. The exercise produced results at the system level and a follow-up analysis of geospatial elements is required to assess implications at the local level. Box 1 offers some additional considerations on the inclusion of eCooking in the electricity sub-sector planning.

BOX 1: Considering eCooking in electricity sub-sector planning

In general, electricity sub-sector planning requires detailed demand estimates, with significant granularity in terms of spatial decomposition and evolution over time (i.e., time series), in order to assess implications for power generation and transmission investment operations. In this context, modelling the impact of power demand linked to eCooking becomes particularly important, with attention to both the level of household adoption and related residential power consumption as well as specific use patterns and their impact on overall load shape, particularly at peak hours.

Ideally, eCooking demand scenarios in electricity sub-sector modelling exercises could be informed by a broader system optimization approach that would provide insights into the evolution of the cooking energy mix for households over time, considering various factors that may affect household preferences for different types of cooking technologies and fuels.

However, with clean cooking modelling still at a very early stage in many contexts, this type of analysis has generally not been available to modellers looking specifically at the power sector. ECooking demand has therefore often not been explicitly considered or has been incorporated based on simplified assumptions that fix a share of total cooking energy to be met with electricity in each modelled time step for specific categories of residential consumers (e.g. grid-connected households), without systematically considering if and how widespread adoption of eCooking would affect the overall load profile. Several tools reviewed in this Knowledge Brief have the functionality to deliver such an analysis (e.g., IAEA's suite of energy system analysis and planning tools, SPLAT and OSeMOSYS) and provide an opportunity to improve practices in this regard.

[5] Alongside residential use, traditional biomass fuels are also used in non-residential end uses, such as thermal processes in the industrial sector.

[6] First envisaged at COP15, Article 4, paragraph 19, of the Paris Agreement (COP21), indicates that all Parties to the UNFCCC (United Nations Framework Convention on Climate Change) should strive to formulate and communicate long-term low greenhouse gas (GHG) emission development strategies.

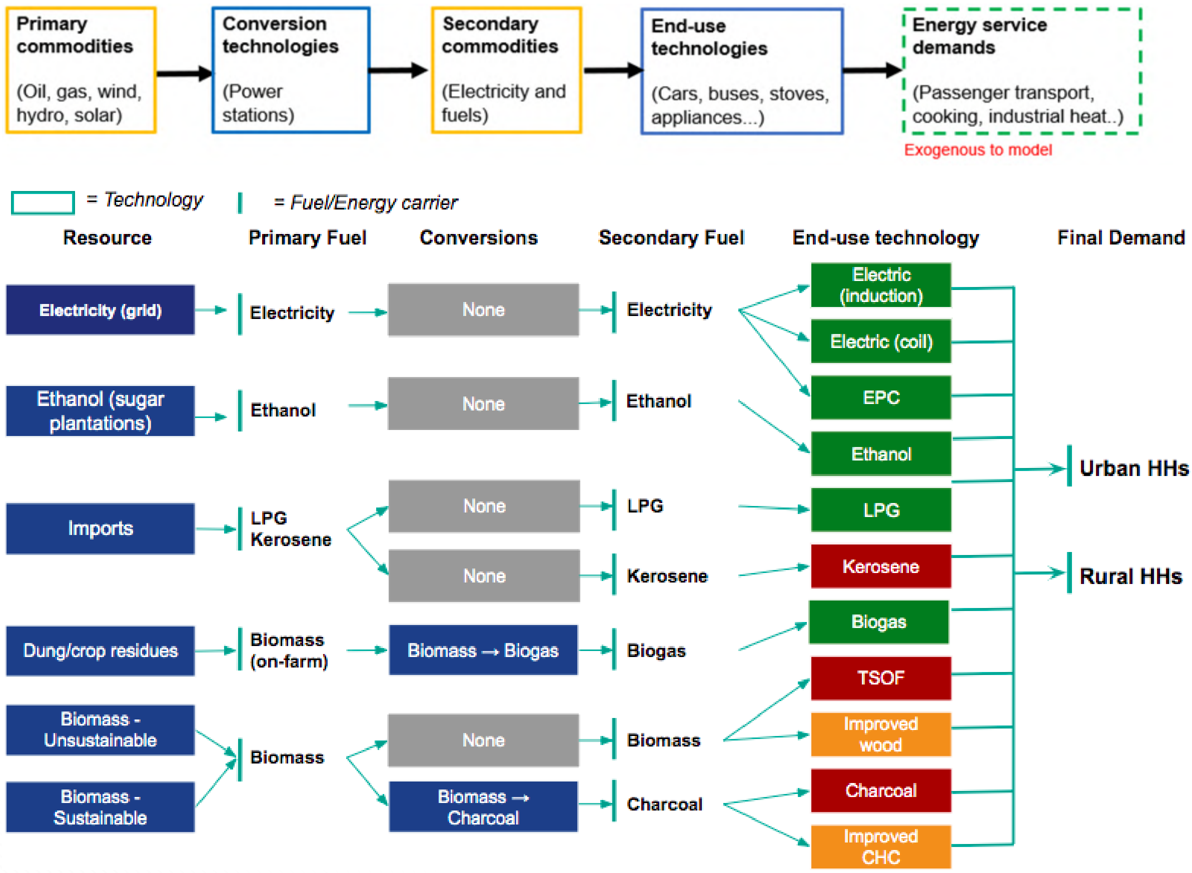
[7] The national modelling team was composed of members from the Ministry of Natural Resources and Energy and attached entities, as well as the Central Statistical Office and the University of Swaziland.

2.2.2 Methodologies for Modelling Clean Cooking in Energy System Approaches

At the heart of any integrated energy planning exercise is the definition of the energy system to be modelled. The definition of the boundaries of the system in terms of sectors to include, and technologies associated with end-user services, has a fundamental bearing on the scope, validity and relevance of the model outputs. An energy system is the value chain linking primary energy sources with the delivery of energy services to the end user. It can be understood as a flow of energy commodities between different technologies used in their transformation or conversion (see Figure 6):

- Upstream of this system is the energy supply sector, comprising of energy resources, commodities and endowments that can be transformed into secondary energy sources or commodities by conversion technologies.
- Downstream is the energy demand. It is characterized by end-use technologies that are delivering the energy services sought by end users.

FIGURE 6: Modelling the flow of energy from resources to clean cooking energy services using OSeMOSYS



Source: CCG (2023).

2.2.3 Optimizing an energy system pathway

While a wide variety of methodological approaches exist in energy system planning, many modern tools (e.g., MESSAGE, OSeMOSYS, SPLAT models) take an optimization approach. In the electricity sub-sector, planners have sought to identify a least-cost development pathway for the energy system under consideration, which minimizes the discounted total cost of meeting a future demand for given energy services within specified constraints, such as resource scarcity, available capacity, the rate of technological innovation and improvement in energy efficiency, environmental constraints, and climate objectives. Since the constraints can be amended to reflect different policy options, leading to variations of the model outputs, this approach makes it possible to assess the resulting impact of alternative scenarios on the whole energy system or sub-sector on the overall energy mix, as well as use of local resource availability, GHG emissions, investment needs and the final cost of energy to the end user.

With respect to clean cooking, identifying an optimal cooking mix[8] under specific constraints is of particular interest. Two different questions may underpin the optimization approach:

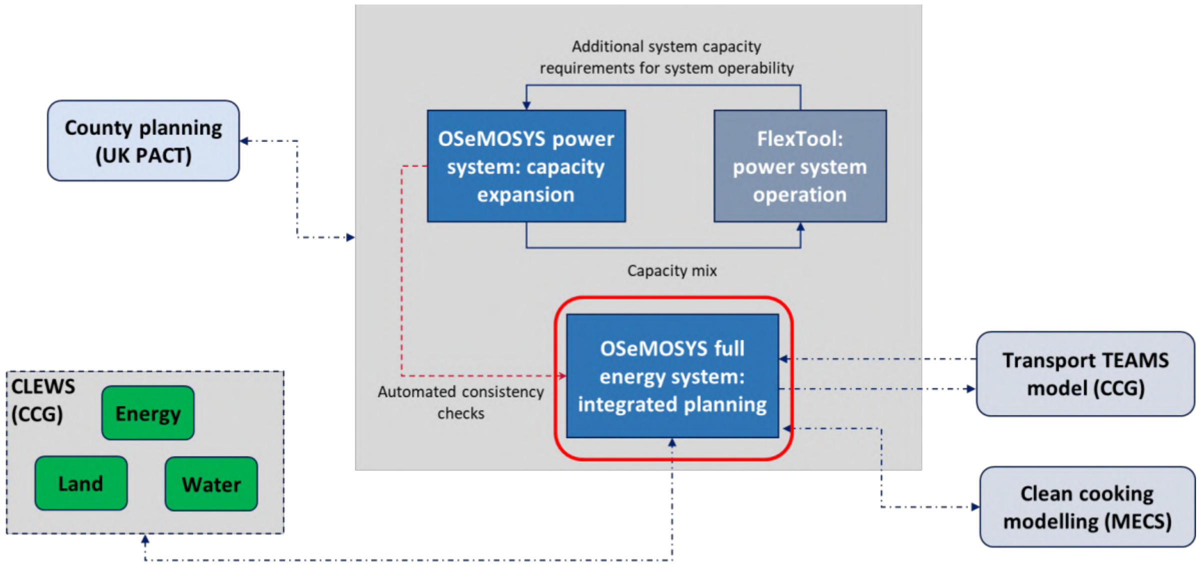
- What is the least-cost mix of cooking technologies under given constraints (e.g., non-renewable share of forest exploitation, carbon emissions, etc.)?
- What mix of technologies maximizes cost benefits under given constraints, including affordability vs. investment and recurring costs, health, environment, employment, etc.?

The results can feed back into electricity sub-system planning to generate policy-relevant insights. For example, integrating eCooking penetration into electricity-sector demand forecasts can help assess the implications of eCooking uptake on the optimal generation mix, required investments costs to meet additional eCooking demand, and ultimately implications for setting electricity tariffs.

This analysis can also be taken a step further with a comprehensive integration of inter-dependencies between eCooking uptake and electricity sector characteristics. A two-way relationship indeed exists, and an iterative approach can be used to feed changes in the tariff back into the supply-side optimization of the clean cooking mix. For example, such feedback loops have been incorporated in the Kenya modelling toolkit developed by a coalition of stakeholders under the lead of the Climate Compatible Growth (CCG) programme (see Figure 7 and Figure 8).

[8] A cooking mix fuels such as eCooking, improved biomass (i.e., pellets or briquettes), traditional biomass (i.e., firewood, charcoal or other biomass, e.g., agricultural waste), LPG, natural gas, biogas, ethanol and the corresponding stoves.

FIGURE 7: Kenya modelling toolkit



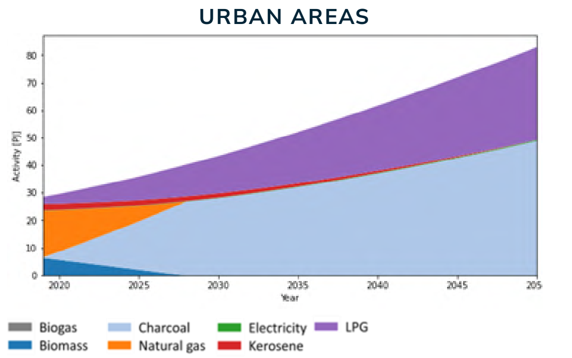
Source: CCG (2023).

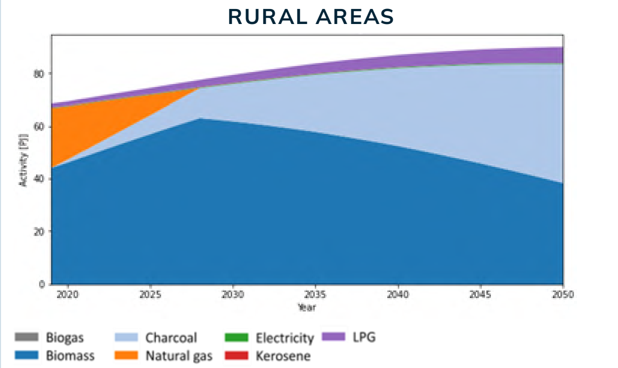
Optimization models are used at the macro-geographic levels, and most often for the purpose of informing national policy choices and strategies. Local-level analysis provides better insights for understanding of the respective adequacy and relevance of different energy sources and related technologies in particular settings. The link between the outcomes of these models and geospatial planning has been trialled in the electricity sector, leading to the development of detailed least-cost electrification plans (Moksnes et al. 2017). For clean cooking, however, the linkage between a modelling exercise featuring a two-way relationship between electrification and eCooking has only recently been explored in a study by Khavari, using the Open Source Spatial Electrification Tool (OnSSET) and the Open Source Spatial Clean Cooking Tool (OnStove) (2024). As illustrated in Figure 8, it is possible to generate a subset of results for relatively large sub-national units (here urban and rural areas), and, in theory, it is also possible to generate such results for multiple nodes, i.e. at a smaller geographical unit (e.g. village), using MESSAGE or OSeMOSYS, and aggregate these results at a national scale. These modelling tools have not been commonly used to generate such geospatial models, due to the limitations related to the significant computational resource requirements associated with such calculations and data availability at the local level. However, such analyses using OSeMOSYS have been recently carried out (Moksnes et al. 2024), which represents a significant development in the application of the tool.

In optimization approaches, the demand for end-use services and its evolution over time is generally defined exogenously. Energy-demand projections can be generated through specific tools and models, e.g., IAEA's MAED simulation tool (IAEA 2006), which provides a flexible framework for exploring the influence of social, economic, technological and policy changes in the long-term evolution of energy and electricity demand. These bottom-up demand estimates are then fed into supply optimization models, such as MESSAGE or OSeMOSYS.

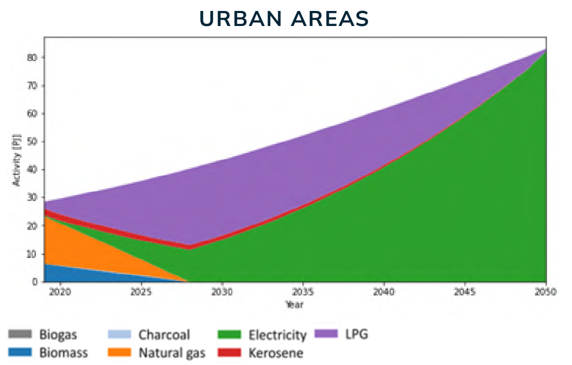
FIGURE 8: Examples of different scenarios used in the application of OSeMOSYS in Kenya and their impact on the clean cooking mix

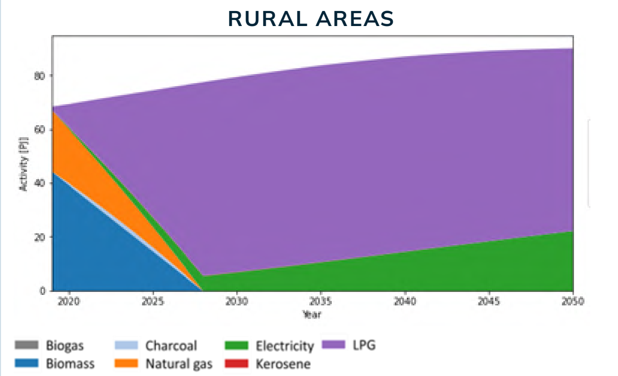
Business-as-usual (BAU) scenario: Continuation of historical trends and adjustment of baseline to the current use of technologies/fuels





High-electrification scenario: 100% of urban demand and 25% of rural demand is met by e-stoves





Source: CCG (2023).

While optimization models produce outputs that can be extremely useful as decision-support tools, they ultimately depend on the ability to quantify and model the constraints and relationships in the system under consideration. As illustrated in Figure 8, new tools have been developed to facilitate a more detailed representation of cooking demand and supply. More importantly, as demonstrated by IEA's GEC modelling work, there has been a surge in attention for clean cooking in energy system modelling, reflecting a shift in priorities towards net zero and universal access, and facilitated by a new generation of models and modellers.

2.2.4 Simulating policy scenarios

Simulations are particularly useful in contexts with high levels of informal activity and complex behavioural patterns that make quantification and modelling interdependencies difficult. For this reason, simulation approaches are well suited to clean cooking, since in many low- and middle-income country (LMIC) contexts, cooking energy supply is dominated by informal distribution or free collection/self-production of traditional biomass, and household-level cooking technology adoption and use patterns depend on a complex array of economic, behavioural and cultural factors.

Simulations project different scenarios from a baseline in self-consistent frameworks, subject to constraints (Munasinghe 1990). Questions such as "*What are the implications on investment* *requirements, and climate, economic or health benefits of the development of defined cooking technology(ies) to certain levels*?" underpin the analysis. Simulations rely on expert judgement to estimate trajectories depending on specific policy decisions or contrasting market development scenarios. A simulation enables, for example, a comparison of the implications of a high eCooking penetration scenario, targeting 60 percent of eCooking penetration within 10 years, with an alternative scenario where policy decisions have encouraged higher levels of adoption of LPG or biofuels.

For example, the Clean Cooking Planning Tool (CCPT), developed by the World Bank and MECS, has adopted a simulation approach to help visualize potential transition pathways to universal access to clean cooking solutions by 2030. For a selected country or region, users can view: (i) the 2020 state of access (baseline); (ii) the 2030 business-as-usual (BAU) scenario; (iii) the cost of inaction; (iv) the current policy/regulatory environment; (v) the estimated investment cost based on the user's selected transition pathway; and (vi) the estimated benefits of transition (World Bank & MECS 2022).

2.3 Clean Cooking from an Energy Access Perspective

Improved geospatial planning can support governments and donors in targeting their clean cooking programmes, as well as companies involved in the distribution of clean cooking technologies. These companies often lack visibility into the market potential of specific areas and access to basic data on available local infrastructure (e.g., road quality) or energy sources to build robust distribution strategies and networks. As a result, an increasing number of modelling approaches prioritizing the geospatial element over a two-way integration of the electricity and cooking components are under development. Like simulation and optimization energy modelling approaches, geospatial approaches require large sets of data, such as demographic and socioeconomic data, existing infrastructure, geographical and environmental data, energy resource data etc.

2.3.1 Clean Cooking Considerations in Energy Access Planning Approaches

Energy access modelling focuses on identifying technology options for specific end-user categories and locations, and therefore tends to limit its scope to the distribution segment of the overall supply chain. Within this scope, however, energy access planning considers both supply-side (e.g., technical constraints or component costs for specific technologies) and demand-side inputs (e.g., consumer use patterns, affordability, etc.) with a high level of technological and spatial granularity, thanks to the use of geospatial analytics and modelling tools.

For electrification, where these approaches are well established, this means that generation and transmission are treated with a low level of precision – these aspects of grid infrastructure are generally summarized with a simple cost of grid-based electricity supply parameter – while distribution infrastructure and decentralized systems are modelled based on spatialized demand estimations in sufficient detail to identify the quantity and types of specific components, including conductors, transformers, meters, and in the case of decentralized systems, system-sizing and component requirements. These analyses may further include load flow studies of the proposed system extensions to ensure the technical viability of the proposed options and obtain a clear and precise understanding of the relative capital expenditure or lifetime levelized costs of various technology options. Many proprietary and open-access tools have been developed for electrification planning (e.g. Network Planner, REM, OnSSET, GEOSIM Spatial Analyst, VIA Illustreets, VIDA). While these tools present some differences in approach and levels of spatial or technical granularity, most share a geospatial least-cost optimization approach, which identifies the least-cost technological options to meet electricity demand in each location.

Adopting an energy access planning approach to clean cooking implies identifying appropriate cooking technology options with a high level of spatial granularity, and a focus on the distribution infrastructure requirements for various cooking value chains, accounting for local characteristics including population distribution, affordability, available electrical infrastructure or local resource availability and accessibility. In the case of electrification, this involves identifying appropriate cooking technologies for each location and user type and quantifying the equipment and distribution infrastructure and investment requirements. However, the propensity of households to stack (i.e., use several) cooking technologies and fuels, depending on different local characteristics and traditional practices, tends to lead to the identification of a mix of cooking technologies rather than one single cooking technology.

BOX 2: Incorporating eCooking in geospatial least-cost electrification planning

The integration of clean cooking and electrification planning in geospatial energy access planning approaches provides valuable information to decision-makers about the constraints, costs and opportunities for expanding access to both electricity and eCooking, including insights on the impacts of eCooking adoption on electricity consumption and peak demand, system design, and even commercial viability or break-even tariffs for specific electrification technology options.

An immediate opportunity exists to incorporate eCooking uptake considerations more consistently into geospatial least-cost electrification planning and test the impact of different eCooking penetration scenarios to identify potential impacts on consumption and peak demand and their implications for system sizing and potentially least-cost technology options (grid, mini-grid, standalone systems). While, in theory, this can be performed using existing least-cost electrification tools, it has not been a common practice due to multiple factors. At the institutional level, energy access planning exercises tend to remain siloed in the power sector, and the development of multisectoral approaches that imply modelling specific end-use applications, including not only eCooking but also productive uses of energy and other energy services, is still underway and not yet sufficiently considered. Lack of available data and the complexity of eCooking market characteristics (e.g., early-stage market development, complex user behaviours and preferences) also make it difficult to develop robust demand estimations without substantial primary data collection efforts.

Given the distribution-level focus of energy access planning exercises, it is critical that the additional power generation and/or transmission capacity required to accommodate the potential changes in electricity demand levels and patterns, particularly at peak times, are carefully assessed. This can be done, for example, through soft linking electrification and clean cooking planning tools at the system and access levels.

Overall, energy access planning approaches focused on clean cooking are still at an early stage of development. The following sections review tools and methodologies that have attempted to integrate clean cooking into energy access planning.

2.3.2 SEforALL's Universal Integrated Energy Plans

In 2021, Sustainable Energy for All's (SEforALL's) Universal Integrated Energy Planning (UIEP) programme (SEforALL 2023) started to take a multisectoral simulation approach to energy access planning, encompassing both clean cooking and electrification, as well as critical energy services such as cooling for healthcare or agriculture. In SEforALL's integrated energy access planning exercises, cooking and electrification are considered simultaneously. In addition, from a visualization standpoint, geospatial results from the cooking and electrification exercises are jointly presented on an interactive data platform that allows users to superpose results and data in order to support further planning analyses and reinforce multisectoral approaches to service delivery for communities with high energy access deficits.

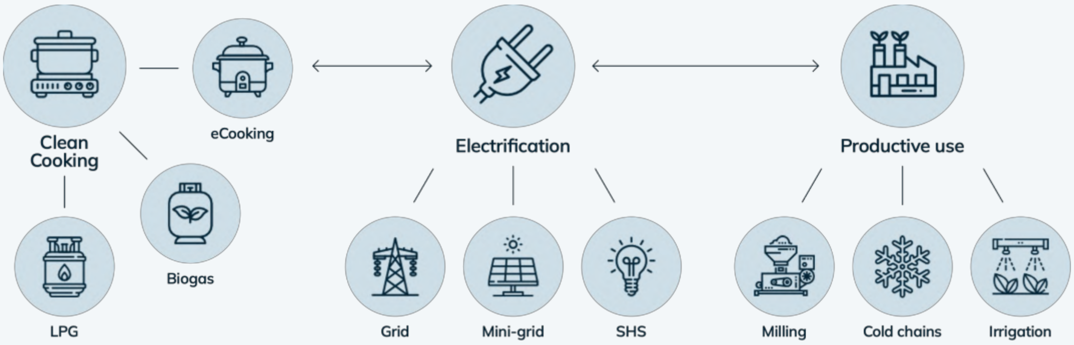
In the Integrated Energy Access Plans (IEAPs) delivered through SEforALL's UIEP programme completed to date in Madagascar, Malawi and Nigeria, the uptake of different cooking technologies over time is taken as an exogenous input parameter to the model and is calibrated based on specified policy scenarios. The geospatial component forecasts (i.e., through a simulation) energy access and fuel availability at the local level, including alternative biofuels and expanded access to electricity, and utilizes that expanded opportunity space of clean fuels to guide scenario analyses that describe pathways to reach established national clean cooking goals and universal access goals. In these exercises, the interface between the electrification and clean cooking model is limited. E-Cooking adoption is mainly restricted to grid-connected areas and is assumed to be accommodated within the spare capacity of the planned network. Box 3 and Box 4 below provide more details on the methodology and overarching results of the two existing Integrated Energy Plans (IEPs) for Malawi and Nigeria. Results from the analysis for both electrification and clean cooking are captured and displayed simultaneously on an interactive online platform, which may guide stakeholders in planning, coordinating, targeting and deploying their interventions more efficiently.

The methodology underpinning these IEP exercises is constantly evolving, based on lessons learnt from previous IEP exercises. For the ongoing Madagascar IEP, for example, the approach adopted for Malawi and Nigeria was extended through the definition of a minimal market size in geographical units of interest to better reflect market realities faced by clean cooking companies and the need for scale in operations. However, feedback loops that would assess the additional generation capacity required to accommodate the potential changes in electricity demand levels and patterns, particularly at peak times, and the investment needs returned by the model and required to sustain the transition towards universal access to clean cooking by 2030 are missing. To overcome this, SEforALL has supported a holistic IEP exercise in Rwanda through the development of the National Integrated Clean Cooking Plan (NICCP) and its underlying planning tool (the Integrated Clean Cooking Plan Tool (ICCPT)) (see next section and Box 5). This constitutes the largest methodological advance to date, with the possibility through the ICCPT to achieve full methodological integration of clean cooking and electrification for energy access planning.

BOX 3: SEforALL IEP in Nigeria

In 2019, the Federal Government of Nigeria, through the Rural Electrification Agency (REA), developed a geospatial model to determine the least-cost solution to achieving 100 percent electrification by 2024 and 2030 (SEforALL 2022). Building on that model, SEforALL supported the development of an IEP based on a simulation of the energy demand for electrification, clean cooking and productive use (see figure 9).

FIGURE 9: Scope of the Nigerian IEP



To determine the opportunity for different clean cooking solutions, including eCooking, a four-step analytical process was carried out:

1. Defining and identifying settlements with limited access to clean cooking defined as settlements where more than 50 percent of households use emission-intensive cooking technologies (e.g., firewood, charcoal, other biomass). E-Cooking (based on a two-burner electric stove) was assumed to be a viable option for households with existing or planned connections to the national grid or mini-grids.
2. Calculating a per capita cooking energy need based on a standard meal composition (rice and beef stew), a standard daily calorific intake per household, and a household cooking intensity defined as the product of household size and energy requirement (MJ) per meal per individual and the assumption that households have three cooked meals per day.
3. Estimating the opportunity for the expansion of clean cooking solutions: for each clean cooking solution, the total cost of ownership and the available spend on clean cooking across different consumer groups (based on the spend level) were calculated to determine the affordability of each solution; then, another filter of the likelihood of adoption using the female education level as a proxy was applied to assess how many of the households able to afford any given solution would likely adopt it.[9]
4. Limiting the pace of eCooking adoption to progress in electrification: the eCooking component of the model was informed by the least-cost electrification model (LCEM) and more specifically by the characteristics of areas that would be served by the grid or mini-grids. However, with the realization that a fifth of households to be served by eCooking by 2030 had to be first electrified, the pace of eCooking adoption had to reflect progress towards universal access to electrification.

A sensitivity analysis on the different electricity tariffs for both grid and mini-grid connections showed little impact on the numbers of households able to afford and likely to adopt eCooking.

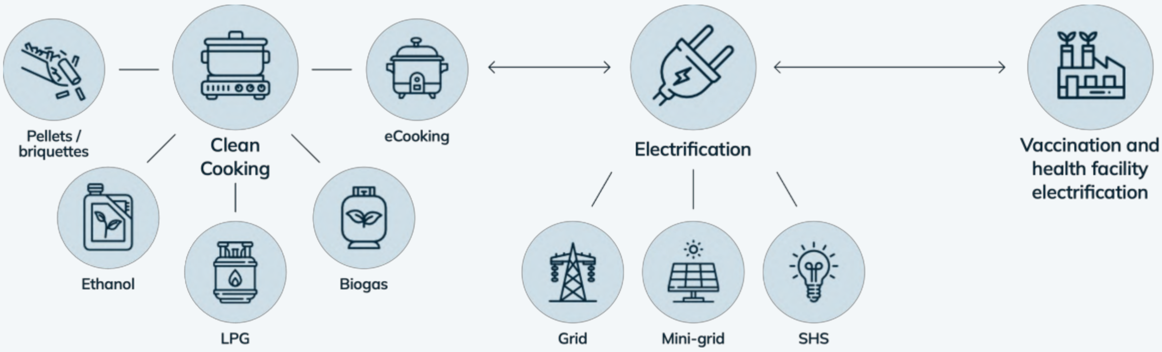
While the clean cooking model was informed by the LCEM, the LCEM was also impacted by the clean cooking model. The impact was for settlements where additional electricity supply was required to enable eCooking – switching from mini-grids to grid connection (600 settlements) or requiring an increased capacity of the existing mini-grid (112k settlements). These adjustments in the LCEM only marginally impacted the least-cost energy mix of the electrification component as the IEP did not assess the impact of the modelled eCooking uptake on the additional generation capacity required for the grid to meet such demand.

[9] Additional steps were applied to biogas, which requires an adequate level of feedstock to be viable.

BOX 4: SEforALL IEP in Malawi

The Malawi Integrated Energy Plan (IEP) was supported by SEforALL and developed in 2022. It consists of three components: electrification, clean cooking and medical cold chains (with a particular focus on COVID-19 vaccine distribution) and the three planning exercises were developed simultaneously (see figure 10).

FIGURE 10: Scope of the IEP in Malawi



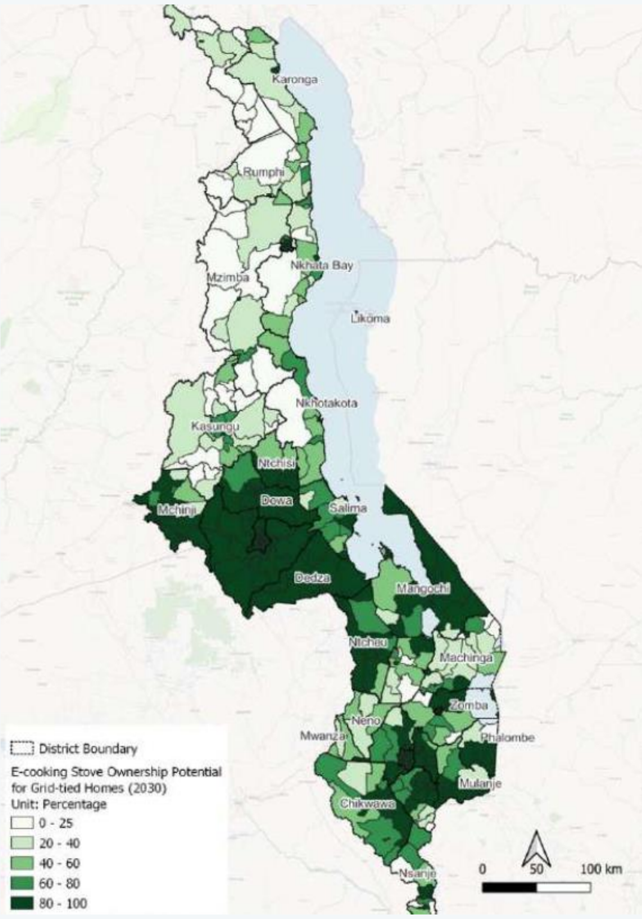
SCENARIO	2030 TARGET	E-COOKING PENETRATION BY 2030
Malawi SDG7 Cleaner Cooking Energy Compact	100% electrification	15% of urban households with a 2-burner induction stove 42% of urban households with improved charcoal and eCooking (a 2-burner hotplate[2]) 0% of rural households
SEforALL scenario	100% electrification and access to clean cooking	100% of grid-connected households with a 2-burner hotplate or a 2-burner induction stove, either as a sole solution or one used as part of a stack

Mini-grids and solar home systems (SHS) are assumed to have insufficient capacity to meet cooking loads under both scenarios, and the relatively high cost of electricity supplied by these systems is assumed to deter customers from adopting eCooking. Hence, off-grid households are assumed to adopt LPG in urban areas i.e., 10 percent of the urban population), and a mix of pellets/briquettes, biogas and bioethanol in rural areas. However, an acknowledgement that off-grid eCooking is becoming ever more viable has been made as part of the IEP development, to demonstrate that eCooking on mini-grids and SHS could be considered under medium- to long-term planning.

The model shows an increase in electricity demand due to the uptake of eCooking primarily in urban and peri-urban areas, which, in both scenarios, does not result in a substantial increase in investment needs into the grid, as:

- under the Compact scenario, the unused capacity of the planned distribution grid is expected to accommodate the simulated eCooking load.
- under the SEforALL scenario, minimal infrastructure upgrades to the planned distribution infrastructure stemming from the Compact scenario are necessary to accommodate the simulated eCooking load. In addition, the IEP acknowledges that eCooking adoption may lead to changes in daily and seasonal load profiles but does not investigate the implications of these potential changes on the required installed generation and storage capacity of the national grid, nor does it evaluate the capacity of the utility to fund these under the current tariff.

FIGURE 11: A geospatial visualization of the modelled eCooking adoption across Malawi under the SEforALL IEP scenario (100% access to electricity and clean cooking)



Source: SEforALL 2022

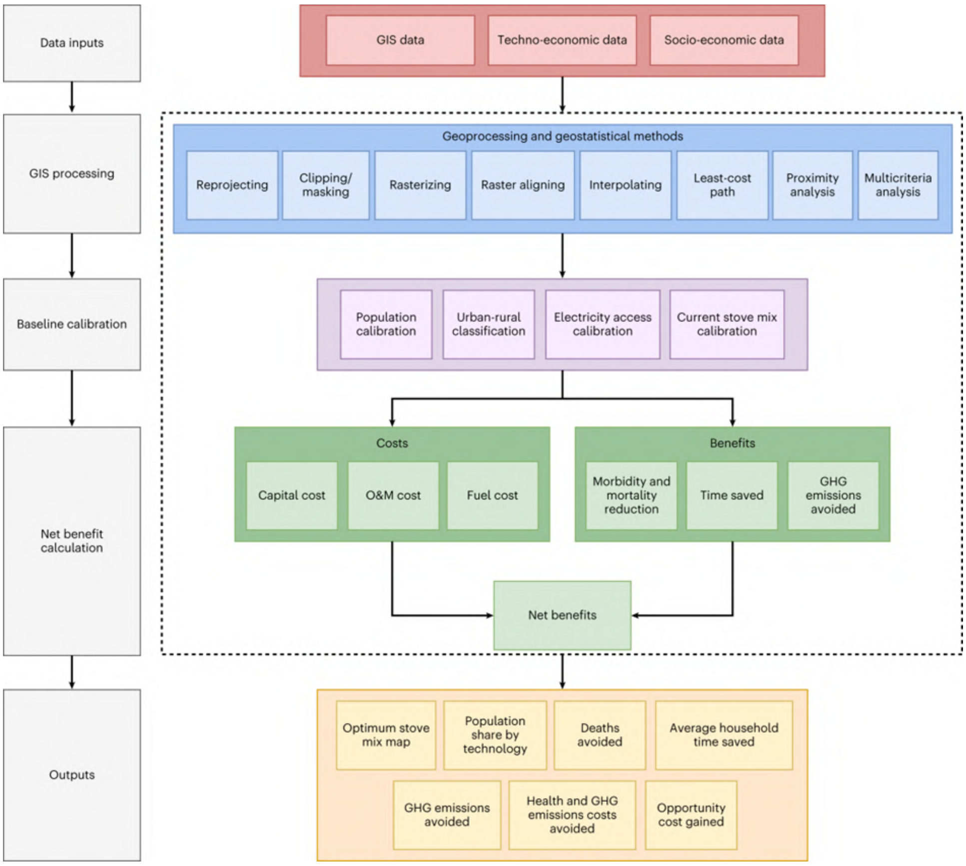
2.3.3 Dedicated Clean Cooking Geospatial Modelling Tools

Two dedicated geospatial clean cooking planning tools are the OnStove tool, developed by Sweden's KTH Royal Institute of Technology together with the Clean Cooking Alliance (CCA) and the World Resources Institute (WRI), and the Integrated Clean Cooking Planning Tool (ICCPT) developed by SEforALL, IIT-Comillas and the Massachusetts Institute of Technology Energy Initiative (MITEI). While electrification planning has converged toward a least-cost approach, the planning approaches adopted for clean cooking are heterogenous, with OnStove adopting a net-benefit approach that compares the transition costs of cookstoves and fuels with monetized benefits, and the ICCPT taking a multi-attribute least-cost approach, considering the economic, social and environmental costs. Despite the different objective functions, both tools aim to return the most appropriate localized technology and fuel mixes.

2.3.4 OnStove

OnStove is an open-source spatial tool that can be used to compare the relative potential of different cookstoves on the basis of their costs and benefits (Khavari et al. 2023). OnStove returns a clean cooking mix optimizing the outcome of a cost-benefit analysis, which considers geospatial variations of input parameters (e.g., fuel costs, resource endowment, etc.). The analysis relies on capturing direct costs associated with clean cooking (stove and fuel) and monetizing externalities arising from a transition to cleaner options, such as time saved, avoided emissions, and reduced morbidity and mortality (Khavari et al. 2023). Until recently, OnStove did not enable time-dynamic modelling and it was not possible to reflect changes from electrification programmes in the model's outputs. A study by Khavari (2024) marks some of the latest important developments of the tool. However, affordability and stove and fuel stacking considerations still have to be incorporated in the tool, as illustrated in Figure 12.

FIGURE 12: Simplified OnStove schematic describing the input data, processes and outputs



Source: Khavari et al. (2023).

2.3.5 Integrated Clean Cooking Planning Tool (ICCPT)

SEforALL and the Government of Rwanda (GoR) have established a collaboration to develop an NICCP approach applied to Rwanda in collaboration with the Institute for Research in Technology (IIT) Pontifical University of Comillas and the Energy Initiative of the Massachusetts Institute of Technology (MIT).

The methodology hinges on three main steps:

1. Incorporating base plans containing information on existing and future sub-sector supply chains (e.g., electricity and LPG), as well as other relevant parameters, into geospatial modelling tools for different cooking market segments (e.g., electricity, LPG, biogas, ethanol, pellets and ICS)
2. Modelling adoption, whilst modelling consumers' behaviour and reflecting the impact of specific interventions that may affect the pricing to the end consumer

3. Optimizing the transition towards cleaner forms of clean cooking by considering not only economic costs, but also social and environmental costs.

The ICCPT uses outputs from the Reference Electrification Model (REM) and the Reference Network Model (RNM). REM is an established electrification planning tool also developed by IIT-Comillas and MITEI. REM returns a geospatial design of the lowest-cost electrification infrastructure, while RNM, developed by the same institutions, is used to better allocate the electricity infrastructure upstream costs. Input parameters include building locations, solar irradiance, topography, grid coverage and reliability, expected consumer demand, fuel costs, and infrastructure costs (MIT Energy Initiative 2020). In the ICCPT, the REM is tailored for eCooking needs, based on geospatial data, such as road and base plans[10] to estimate the cooking needs and equipment catalogues for electric and LPG setups.

In parallel, an innovative optimization model for LPG infrastructure incorporates base plans, ensuring optimal accessibility. These base plans are established comprehensively and encompass electricity infrastructure, LPG supply chains, local business endeavours supporting alternative fuels (biogas, pellets, with the option to expand to other fuels as needed), and the promotion of improved cookstoves, especially where cleaner fuels are economically challenging to introduce. Another significant stream blends varied fuel sources (biogas, pellets, firewood, charcoal) with graded tiers of improved cookstoves to detail the costs associated with their local production and distribution. This lays the foundation for the adoption stage.

Beyond the electrical, LPG and other efficient appliances base-plan modelling, the adoption model of the ICCPT stands out as an important addition. For clean cooking, merely focusing on cost-based supply strategies without contemplating pricing structures that are key drivers for uptake can be counterproductive. The tool thus enables the flexible adjustment of pricing structures based on strategic policy interventions (e.g., subsidies, fiscal incentives, regulated tariffs) promoting affordability of certain cooking technologies, and within different timeframes. Consequently, the adoption model is discerningly non-neutral in technology selection: the enhanced adoption model is adept at projecting technology stacking landscapes across Rwanda, balancing supply costs with pricing policy allocations.

A multi-attribute optimization is then carried out iteratively in a complex structure of sub-problems, as illustrated in figure 13. Access and capacity of different technologies are adjusted by cost/benefit criteria, based on the local supply costs provided by the base plans, and the local adoption decisions derived from pricing and consumer behaviour. From an optimization lens, the analysis pivots on adding to previous economic costs the social and environmental costs, which are computed using weighted averages (or multipliers), incorporating emissions, deforestation, health factors, and gender/time metrics, particularly the time invested in fuel procurement and cooking. These economic, social and environmental costs create efficiency frontiers that are used to identify multi-criteria optimal solutions in which the social component can be progressively weighed.

[10] Cooking Diaries is an approach developed by the MECS programme to address a lack of data around how people cook, and how they might cook with electricity. It consists of data collection tools that aim to capture the detailed cooking practices, preferences and behaviours of households, with the option of adaptation for institutional or commercial contexts.

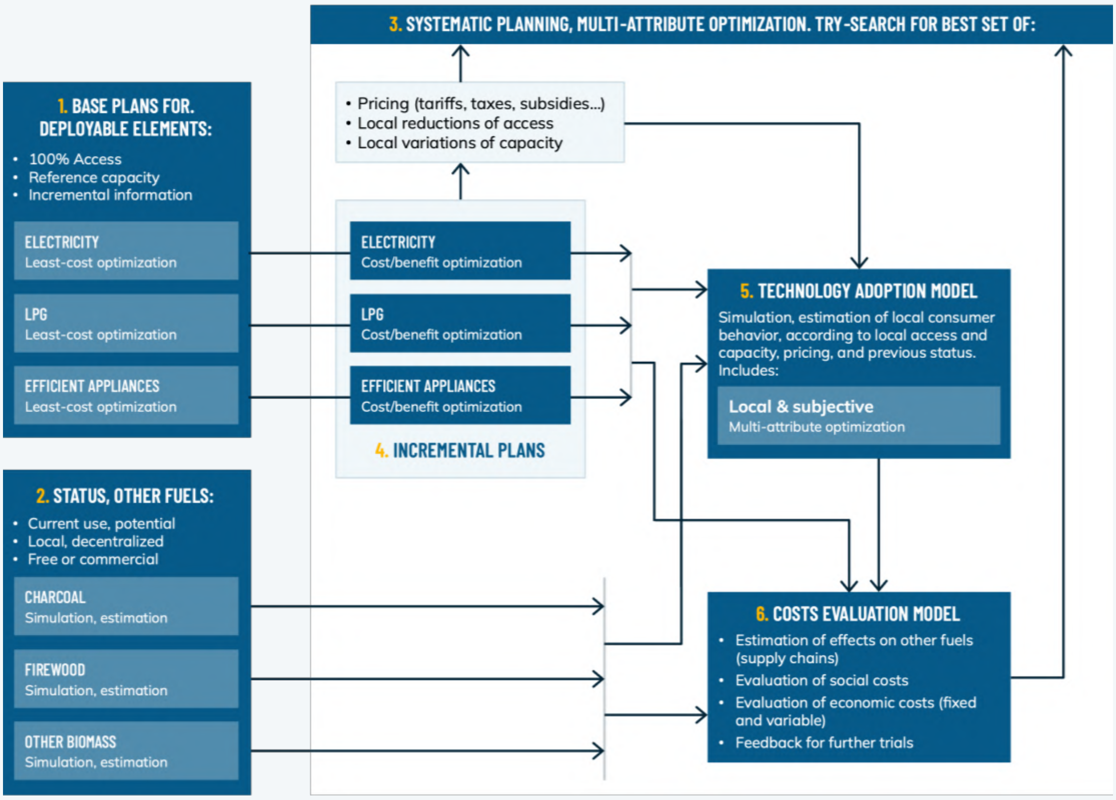
Finally, another significant innovation is the transition from the typically singular-agent, static techno-economic model prominent in today's landscape. A strategic financial planning paradigm is implemented in stages, considering financial implications for different stakeholders, including the private and public sectors, and development partners.

The ICCPT currently considers eight fuels (electricity, LPG, biogas, pellets, charcoal, commercial firewood, free firewood and free biomass) and does not include others, such as natural gas or ethanol, which is becoming more popular in Rwanda following the recent market entry of a major provider of ethanol-based clean cooking. The exclusion was driven by the lack of locally available data on ethanol-based clean cooking technologies at the time of the ICCPT development. As a result, the NICCP is limited in providing a comprehensive set of clean cooking scenarios for Rwanda but as mentioned above, the ICCPT can accommodate additional fuels and technologies as needed and depending on the changing policy priorities, market conditions or other factors that impact the availability and feasibility of different clean cooking technologies, and the availability of reliable data. In addition, the granularity of the present NICCP is limited due to data limitations on the demand side: supply areas have been aggregated into districts to match the granularity available for demand areas with the division into rural and urban consumers, although the design of the electrical networks can be shown at the household level and the LPG supply chain at the village level.

BOX 5: Detailed optimization mechanism for the electricity component in the ICCPT

Figure 13 represents the main blocks and interactions of the overall approach, in which optimization processes and data flows (yellow boxes and red arrows) are combined with complex simulation processes (in blue).

FIGURE 13: ICCPT's optimization mechanism for the electricity component



Source: Authors.

In the case of Rwanda, centralized/planned elements are the deployment of electricity, LPG and efficient appliances. Other fuels are managed locally, and their use is simulated, not optimally deployed. Base plans (block 1) are developed assuming 100 percent access of the population, but with incremental information to estimate reduced-access and lower-capacity scenarios. Biomass-based fuels (block 2) are modelled by their current use and their potential (local availability). Then, the systematic multi-attribute planning is applied (block 3), considering both economic and social costs as the main independent variables:

a. Prices of fuels and appliances (including tariffs, taxes and subsidies)
b. Local target reductions of access to clean fuels and appliances
c. Local reductions of supply capacities for clean fuels and appliances

The multi-attribute planning is further internally structured into three main blocks, as part of its optimization loop, in the following sequence:

1. Incremental plans for deployable elements (block 4). The access reductions are optimally applied, so that the cost/benefit ratio of deployments is minimized.
2. Technology adoption model (block 5). This process simulates the local response of different types of consumers to the pricing and availability of fuels and appliances. The response includes the subjective (optimal) balance between economic and social costs as well.
3. Costs evaluation model (block 6). This process estimates the final effects of pricing, deployments and adoption of technologies. The effects are economic costs and social costs, both conditioned by the actual adoption of technologies.

In summary, the expanded "integrated" concept encapsulates several layers for clean cooking planning:

- Diverse technology inclusion with an accent on 'stacking' strategies catering to both individual and aggregated consumption.
- Synthesis of techno-economic plans with financial trajectories.
- A fusion of advanced multi-attribute optimization with simulation paradigms for decision-making.

A strategy alignment that correlates supply blueprints with demand-driven adoption, distinctly partitioning supply (or access) costs from pricing and adoption models.

2.4 Pushing the Boundaries

To carry out a holistic energy planning exercise integrating energy system with access planning and reflecting the linkages between the clean cooking and the electrification sectors, a combination of tools to lead to a least-cost optimization under specified constraints can be used. Linking specialized electrification, clean cooking and energy system planning tools is particularly promising and could allow planners to conceptualize the interplay between infrastructure availability, eCooking viability and demand, and system sizing and technology options:

- Electrification-cooking feedback loops in access planning: through electrification analysis, clean cooking plans can enable a deeper grasp of the affordability and accessibility of eCooking as a viable option; and a dedicated clean cooking plan can provide robust eCooking input parameters that can feed back into the electrification model.
- Energy system and access planning integration: dedicated clean cooking tools can enhance the granularity of data relied upon for demand estimates in energy system optimization models (e.g., OSeMOSYS). In addition, eCooking demand might impact the optimal generation

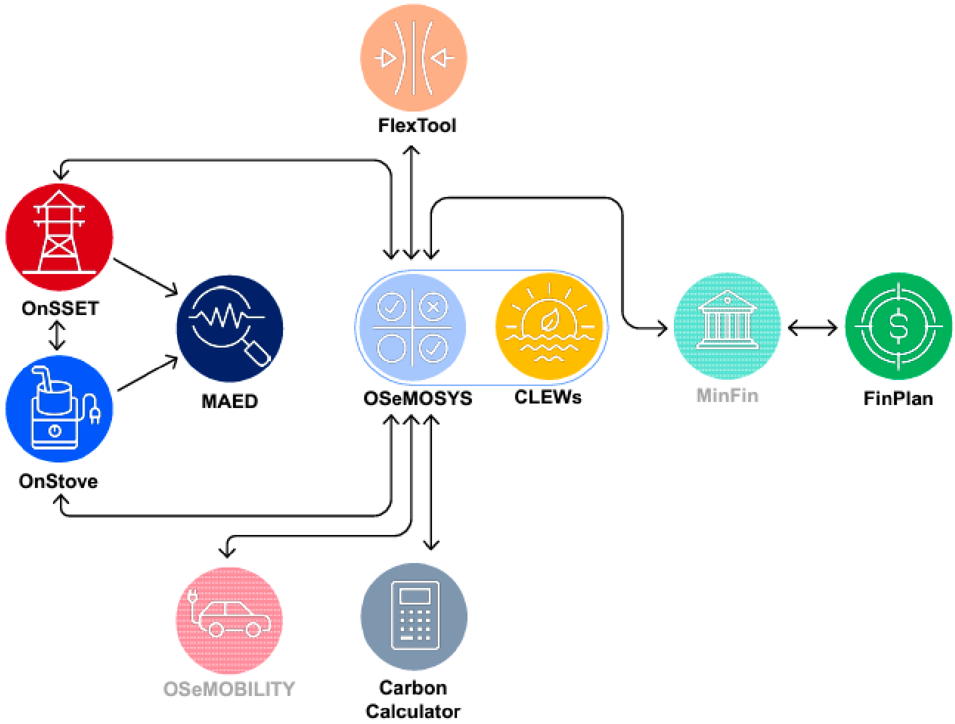
mix and/or investment required to serve the increased load, which may impact the cost-reflective grid tariff. This, in turn, may modify the equilibrium returned by the geospatial tools for electrification and cooking planning, yielding updated results for least-cost solutions (grid versus off-grid) and the optimized mix of cooking technologies. This process could be iterative until the overall result converges to an optimal equilibrium.

Recent years have seen an increase in the number of attempts combining relevant planning tools to increase the level of cross-sectoral and vertical integration of energy planning, particularly as more open-source tools have become available. However, most initiatives are focusing on parts of the above integrations: in addition to the ICCPT, relying on REM, a proprietary solution, the KTH Royal Institute of Technology, the CCA and the WRI are currently integrating OnStove with OnSSET for a study in Kenya (Khavari 2024); IRENA is working on linking SPLAT with OnSSET (e.g. IRENA 2024); and the IIASA and the WRI are exploring a similar integration between a variation of MESSAGE, OnSSET and the Multi-sectoral Latent Electricity Demand (M-LED), generating geospatial and disaggregated demand estimates (Falchetta et al. 2023).

An opportunity exists to combine open-source tools into a holistic energy modelling analytical workflow able to enhance political and financial decisions. The soft linking between OSeMOSYS, OnSSET and OnStove may offer one route to delivering energy planning in a more integrated manner, and can be further enhanced with linkages to other open-source tools generating financial, technical and climate insights (Tan et al. 2023; CCG 2023). This work, illustrated in figure 14, is currently supported by CCG[11].

[11] For a wider overview of CCG's modelling tools, please see APPENDIX 1: Overview of CCG modelling tools..

FIGURE 14: Developing an energy modelling analytical workflow based on open-source tools



Source: CCG (2023).

CHAPTER THREE

DATA NEEDS FOR MODELLING CLEAN COOKING

Data ultimately underpin any energy modelling exercise and the resulting energy plans, yet access to quality datasets covering all required dimensions is the most significant challenge in undertaking integrated energy planning exercises. Recent practices promoted by international organizations and academic professionals, including open access to energy datasets often linked with open-source modelling tools, might help speed up progress on developing more robust energy plans and policies.

Data requirements for any modelling exercise, encompassing indicators, granularity, coverage, accuracy and more, depend on factors such as the modelling methodology and tools employed, the specific energy system under examination, and the scope of the modelling endeavour. Regardless of the modelling approach, the bedrock of obtaining fit-for-purpose plans lies in the availability of reliable input data and assumptions; the quality and accessibility of data pose significant challenges to many modelling initiatives. This issue is particularly pronounced in regions with low levels of energy access. For example, to obtain a breakdown of relevant technologies for end-use services, e.g., cooking, heating, transport, etc., a combination of detailed data by consumption categories and robust assumptions for the future is required.

Several factors contribute to this data deficit, including the absence of established data collection mechanisms or systematic surveys, the precarious sustainability of these efforts impacting the continuity and reliability of historical data records, and the lack of effective cooperation and collaboration among various government ministries. Ethical and security concerns, unwanted reputational exposure, additional workload and institutional inertia for data collection and sharing also limit the availability of data, particularly open-access data (Pfenninger et al. 2017). In addition to these underlying structural challenges, securing data for clean cooking planning exercises is particularly arduous, as the sector relies on the informal collection of fuelwood, illegal charcoal value chains and traditional stove ownership, for which data are inherently more difficult to collect and less reliable than for more formalized sectors and fuel types, such as liquefied petroleum gas (LPG) or electricity. Also, obtaining data to accurately describe baseline cooking practices and use, or the historical evolution of consumer preferences over time, severely limits both the level of detail possible for modelling exercises and planners' abilities to calibrate their models using historical data. This difficulty stems from the lack of aggregated supply-side data for cookstoves and appliances, the high level of informality in many fuel distribution supply chains, and the lack of metering data that track specific household electricity end uses including electric cooking (eCooking). Data collection surveys can fill in the gaps, but they might not always be feasible (e.g., due to time constraints, cost or other limiting factors).

Moreover, the accessibility of existing datasets ultimately drives data availability, and determines their availability for modelling exercises. To promote transparency, auditability, and bolster data availability and retrievability, it has now become common practice to publish documentation outlining the methods and assumptions used for the model, and make the input datasets available, whenever possible. A number of organizations, such as Climate Compatible Growth (CCG) and Sustainable Energy for All (SEforALL), have issued guidance on data governance (Howells et al. 2021; SEforALL 2020). Modelling initiatives like the International Energy Agency's (IEA's) World Energy Outlook (WEO), Open Source Spatial Clean Cooking Tool (OnStove) and Open Source Energy Modelling System (OSeMOSYS) refer to publicly available datasets and/or create input files as baseline references. Additionally, an increasing number of online platforms and dedicated websites (see Table 2) are promoting open knowledge and transparency through the creation of visualization tools or comprehensive repositories of information, which enable the download of underlying data, and a conscious effort could be made to make the underlying data accessible.

TABLE 2: Examples of platforms and dedicated websites promoting open access to relevant data sources

PLATFORMS & DEDICATED WEBSITES	ORGANIZATION	DETAIL
ELECTRIFICATION AND CLEAN COOKING		
EnergyData.Info	World Bank	Open-data platform providing access to datasets and data analytics that are relevant to the energy sector, including electrification and clean cooking
RISE	World Bank	Set of indicators to help compare national policy and regulatory frameworks for sustainable energy, including electrification and clean cooking
Tracking SDG7	IEA, IRENA, World Bank, WHO, UN Statistics Division	Global dashboard to register progress on the targets of SDG7, including electrification and clean cooking
Energy Access Explorer[12]	WRI	Open-source, interactive platform that uses mapping to visualize the state of energy access in unserved and

[12] The Energy Access Explorer has recently merged with the Clean Cooking Explorer (CCA 2024).

PLATFORMS & DEDICATED WEBSITES	ORGANIZATION	DETAIL
		underserved areas, including electrification and clean cooking
SEforALL Universal Integrated Energy Planning (UIEP) Tool	SEforALL, GEAPP, The Rockefeller Foundation	Interactive data visualization platform displaying several layers of data, including results from extensive geospatial modelling and optimization, including electrification and clean cooking
World Bank Data Catalog, including Multi-Tier Framework surveys	World Bank	Datasets from the World Bank's microdata, finances and energy data platforms, as well as datasets from the open data catalogue.
CLEAN COOKING ONLY		
Clean Cooking Planning tool	World Bank, MECS	Visualization of potential transition pathways for universal access to clean cooking, including eCooking
ELECTRIFICATION ONLY		
Global Electrification Platform	World Bank, KTH, Development Seed, WRI, Derilinx, Google, University of Cambridge	Open-access, interactive, online platform that allows for an overview of electrification investment scenarios for a selection of countries; does not include eCooking

Source: Authors.

Data quality is determined by consistency, completeness, accuracy, granularity and recency. Obtaining consistent and up-to-date data is particularly challenging for geospatial exercises that require complete and harmonized data inputs, ideally generated in the same way and at the same time for all geographic units of interest under the study. The paucity, patchiness or fragmentation of data often force modellers to generate complete geospatial datasets out of several input files. In this case, assumptions to ensure data comparability across all geographic units or the extrapolation of missing data become crucial. The fragmentation of clean cooking data is a particularly acute challenge in the clean cooking sector, as data are typically owned by multiple stakeholders, covering different sub-sectors. Below are key data input categories involved in clean cooking planning. As highlighted above, this section aims to provide a high-level overview.

Energy demand: To project the demand, detailed baseline data and historical trends on population density, peoples' lifestyles, household sizes, and wealth/affordability are required and can typically only be obtained through costly (and time-consuming) demand-side surveys[13]. Estimating the mix of cooking technologies is made difficult by complex customer behaviours. On the one hand, changes in cooking habits tend to be slower than expected due to people's attachment to their current habits. On the other hand, the cooking sector has traditionally relied upon the use of biomass stoves, which have been used by households, sometimes simultaneously, for both cooking and heating purposes. This dual use complexifies the estimation of the specific energy demand for cooking. In addition, stacking behaviours and affordability barriers tend to be overlooked or poorly integrated due to data gaps or the limited ability of tools to capture these aspects (Khavari et al.

[13] Over the last decade, technologies to support data generation and collection have improved significantly, reducing the associated cost and time. However, data collection for cooking continues to remain overwhelmingly based on manual collection processes due to the infrequent use of Internet-of-Things-enabled sensors in cookstoves.

2023). In the case of eCooking, this is further exacerbated by the range of eCooking appliances, spanning electric pressure cookers (EPCs), rice cookers, induction or hotplate stoves, kettles and more. Finally, due to relatively little research to date, data limitations, and the lower maturity of the clean cooking market for large-scale appliances, clean cooking models tend to focus on households, excluding by design institutional and commercial customers from the planning exercise. This exclusion poses a significant limitation in energy planning. Firstly, institutions such as schools consume large amounts of biomass for cooking (e.g., UoL 2023) and therefore present an important segment in need of cleaner cooking transitions. Secondly, institutions and commercial establishments are also more likely to have some access to electricity, either through the grid network or large off-grid energy systems, making them a viable target for eCooking consideration (e.g., WFP 2023).including through a cleaner stack of biomass combined with electricity (WFP and MECS, 2022).

While energy demand is inherently difficult to estimate or project, tools such as the World Bank's Multi-Tier Framework (MTF) survey (World Bank 2020) have helped generate data capturing the multi-dimensional nature of energy access, including both electricity access and access to clean cooking, covering aspects such as cooking behaviours and cookstove use patterns. As eCooking in low and medium-income countries (LMICs) is still relatively nascent, gathering data on electricity demand for cooking has also been challenging. However, data collection initiatives such as the Modern Energy Cooking Services (MECS) programme's series of Cooking Diaries (MECS 2024) have been instrumental in generating useful data on how much electricity households consume depending on what eCooking appliances they use. The use of electricity smart meters has made it possible to collect high-resolution consumption data. The emergence of remotely monitored eCooking devices (e.g., EPCs or induction stoves), with in-built consumption tracking capabilities, has also enabled collection of real-time, high quality and resolution data on electricity consumption for cooking purposes.

Cookstove and fuel characteristics, including stove lifetime and cost (operational expenditure and capital expenditure), stove thermal efficiency, emission levels and safety of use (three metrics measured through lab testing based on ISO/TR 19867-3:2018), as well as fuel availability, convenience of purchase and cost/affordability are important elements to capture all attributes of the MTF in the model. This can help estimate positive externalities on health, like averted disability adjusted life years (ADALYs) and gender (through an estimation of time saved by women and girls), and reductions in greenhouse gas emissions (GHG) and deforestation, and these positive externalities can be monetized in a cost-benefit analysis. Only then do the modelled socioeconomic and environmental benefits of modern cooking options outweigh the fact that solid fuels and traditional cookstoves are cheaper. However, quantifying and monetizing these externalities is technically and methodologically challenging, which makes it difficult to integrate them in planning/modelling efforts (SEforALL 2020). Finally, as models are dynamic in essence, the rate of technological innovation and its impact on affordability may need to be factored in, for example:

- PAYGO-enabled stoves can help overcome some affordability constraints
- Standalone eCooking solutions may become more cost competitive as scale increases
- Stove Use Monitoring (SUM) devices and blockchains may facilitate access to carbon markets
- The increased scale of production drives cookstove prices and distribution costs down
- Increased thermal efficiency reduces overall fuel costs

- The establishment of new fuel supply value chains (e.g., small-scale bioethanol production from the local sugarcane industry) may make cleaner and cheaper fuels available.

Infrastructure data add crucial contextual information to models and, for geospatial approaches, can help inform local variations in fuel and stove prices. For example, including road conditions and available electrical infrastructure can help estimate logistical costs and the general ease of doing business in particular regions. Additionally, detailed information on the quality of the power supply, including available capacity in low-voltage lines and transformers, and power availability during peak times of eCooking, enables us to determine which areas are best suited for eCooking technology. However, quality data at this level of granularity are often lacking and are typically only accessible through local and national government agencies responsible for their respective infrastructure segments, which can make them difficult to access. Further, these datasets are not always well maintained due to limited capacity or funding available to collect data systematically and regularly.

CHAPTER FOUR

OPERATIONALIZING INTEGRATED ENERGY PLANNING: POLICY, FINANCE & KNOWLEDGE FOR E-COOKING

Energy planning tools and models can help define implementation strategies and feed information into the design of specific support mechanisms, policy or projects that are relevant for the implementation and operationalization of energy plans. For integrated energy plans to materialize, multisectoral and multi-stakeholder concerted efforts, as well as deliberate action to direct resources effectively and efficiently to where they are most needed, are required. Similarly to cost-effective national and regional net-zero roadmaps, the development and implementation of integrated energy plans demands all parts of government break away from working in silos and integrate energy into policymaking across finance, labour, taxation, transport and industry (IEA 2021).

Typically, the responsibility for delivering on energy access goals falls on ministries of energy (or equivalent) or environment. However, inter-ministerial coordination is required to carry out the policy actions needed to successfully design and implement access to the whole range of energy access services. This is particularly pertinent in the case of clean cooking planning which, with its multiple cross-sectoral facets (including eCooking) is qualitatively a more complex endeavour than electrification planning. In addition, the complexity of the demand side for clean cooking services must be integrated into the considered interventions in particular when cooking demand is already satisfied through some form of fuel and stove combination (even in the case of a three-stone fire with firewood). Clean technologies must be competitive in price to be adopted, and competitive in cost to be sustainable.

In this section, we present strategies and mechanisms that can enable the operationalization and implementation of integrated energy plans, focusing particularly on those that can help drive progress on eCooking. We categorize these mechanisms under three pillars: policy, regulation, and strategy; financing; and knowledge generation and sharing.

4.1 Policy, Regulation and Strategy

Favourable policies and regulations can play a critical role in triggering change or speeding up progress in any sector. In the case of eCooking, several policy and regulatory instruments can help leverage existing opportunities to speed up progress where uptake has been limited or absent and address the main barriers that are hindering transitions to eCooking.

As affordability, availability, accessibility and quality of electric cooking and eCooking appliances are among the key barriers to uptake, along with the quality of electricity services and adequate after-sales services, an array of policy options could be considered by national governments to address them and promote eCooking uptake among households, businesses and institutions (such as schools, hospitals) alike. Tables 3-6 below offer examples of policy and regulatory mechanisms and strategies that could be explored to address these barriers and become an integral part of the implementation planning process.

TABLE 3: Examples of mechanisms to address the affordability barrier of eCooking

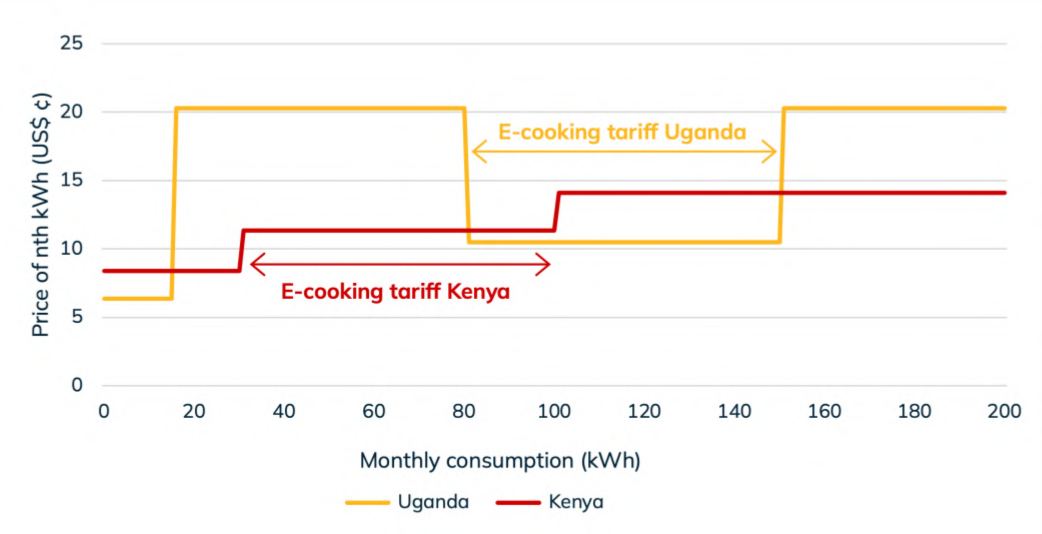
AFFORDABILITY OF ELECTRICITY:	AFFORDABILITY OF ECOOKING APPLIANCES:
• E-Cooking tariff for grid electricity set between the social and the standard residential tariff (for examples see Box 6 below) • E-cooking tariffs on mini-grids – to offer a direct incentive for connected consumers to adopt eCooking • Time-of-use tariffs – to encourage consumers to cook outside of peak times (could be applicable to both grid and off-grid electricity services); could be particularly applicable to businesses and institutions that might have more flexibility on when the cooking is done (e.g., cooking in schools that could be done during the day or overnight)	• Tax incentives (e.g., duty waivers, VAT exemptions, tax breaks, input tax credits for relevant components) to importers, distributers, and local manufacturers of quality eCooking appliances, particularly for small and medium-size enterprises (SMEs) • Direct subsidies for eCooking appliances: targeted to low-income segments and geographically (based on the local capacity of the network to accommodate a growing load; this would help avoid undermining utilities' commitments to improved network performance)

Given that both energy utilities and mini-grid developers tend to look for ways to boost energy demand, the adoption of eCooking among the customer base can be a win-win scenario as consumers gain access to more affordable clean cooking, while electricity providers earn higher revenue from increased consumption. This will require the involvement of energy regulators and adequate evidence to inform any tariff revisions and adjustments so that the affordability gap can be bridged without compromising the financial sustainability of the electricity providers. Box 6 highlights the Kenyan and Ugandan experiences of implementing eCooking tariffs.

BOX 6: E-cooking tariffs in Kenya and Uganda

Two East African countries have been making significant progress on driving eCooking transitions. An important milestone has been the eCooking tariffs introduced in Kenya and Uganda in the last couple of years. The cooking tariff in Uganda is one of the government's strategies to displace charcoal and other biomass-based cooking by making electric cooking cheaper than charcoal. It was introduced in 2021 under a declining block tariff structure, which allows for differentiated tariff levels based on the amount of energy consumed by households. Figure 15 shows the latest tariff schedule approved by Uganda's Electricity Regulatory Authority (ERA) tariff schedule (January 2024), for domestic consumers.

FIGURE 15: Tariff structure in Kenya and Uganda for residential customers



Source: Authors

However, while this tariff structure aims to encourage the take up of eCooking, all households whose consumption falls within this bracket benefit from the tariff, irrespective of whether they are using electricity for cooking or other purposes.

In Kenya, the Energy and Petroleum Regulatory Authority (EPRA) introduced a new customer categorization of tariffs in 2022 to promote transitions to eCooking as one of the strategies to mitigate climate change. The latest domestic consumer tariff structure[14] includes two ordinary domestic categories and a lifeline tariff, as illustrated in Figure 15.

The eCooking tariff in Kenya applies to a much lower consumption tranche than its Ugandan counterpart, such that the scheme will benefit more vulnerable households. EPRA cited research conducted by the Modern Energy Cooking Services (MECS) programme as the evidence base used to determine the new tariff structure. It showed that on average, 41 kWh/month is needed to cook with electricity in households where electricity has already been adopted. EPRA has also encouraged the Kenya Power and Lighting Company (KPLC) to pilot time-of-use tariffs for domestic customers who have smart eCooking appliances with capabilities to monitor power consumption while cooking. This is believed to be helpful in speeding up the adoption of eCooking ahead of the next tariff control period.[15]

[14] Data was taken from eCooking tariff announcement by EPRA.

[15] Data was taken from eCooking tariff announcement by EPRA.

Whether these assumptions will be confirmed by evaluation studies remains to be seen as the eCooking tariff is a recent development, and the time-of-use pilots have yet to be undertaken.

Accessibility of clean cooking solutions can be a significant barrier to uptake. Accessibility is dictated by the availability of specific solutions on local markets, as well as the ability of consumers to access them, regardless of where they are located. As in the case of many other, non-energy, products and services, the rural-urban divide is among the main challenges that will have to be considered at the planning stage, to ensure that all segments of the population in all geographic areas can be served.

TABLE 4: Examples of mechanisms to address the accessibility barrier of eCooking

ACCESSIBILITY:
• Creation of a favourable environment for private sector development to grow the market of eCooking appliances; could include tax incentives (e.g., duty waivers, VAT exemptions, tax breaks, input tax credits for relevant components) (similar to Table 3 above) • Infrastructure development to enable reach of rural and remote areas with a wide range of products, incl. eCooking appliances

In addition to electricity and appliance subsidies, policies to address the quality of available eCooking appliances and the asymmetrical information related to that quality will also have to be implemented.

TABLE 5: Examples of mechanisms to address the quality issues related to eCooking

QUALITY OF ELECTRICITY SUPPLY:	QUALITY OF ECOOKING APPLIANCES:
• Continued improvements of the quality of delivered electricity services, e.g., electricity loss reduction; voltage fluctuation reductions; boosting or rehabilitation of generation capacity • Adequate customer services (either by the electric utility or an off-grid electricity provider) to ensure and maintain high-quality delivery of electricity services	• Apply quality assurance mechanisms, including testing and certification, such as minimum energy performance standards (MEPS) that specify the minimum level of energy performance that appliances and equipment must meet or exceed before they can be supplied in the market), e.g.: - ISO 19867-1:2018 (ISO 2023a) and ISO/TR 19867-3:2018(ISO 2023b) (and other related ISO protocols): recognized internationally and provide a robust set of guidelines to ensure high-quality standards for clean cooking solutions - IEC 60335-1:2020: for safety of household electrical appliances with voltage not exceeding 250 V for single-phase appliances and 480 V for other appliances, including direct current (DC) supplied appliances and battery-operated appliances (IEC 2023) • Build adequate laboratory testing capability: this could be done locally or by partnering with neighbouring countries with existing and available laboratory capacity; development of protocols on testing and certification of eCooking appliances will also be required.

Integrated energy planning should consider the entire value chain, from uptake to end of life. Ensuring presence of timely and proper after-sales and end-of-life services will be another critical public policy area.

TABLE 6: Examples of mechanisms to address the after-sales and end-of-life issues related to eCooking

AFTER SALES AND END OF LIFE:
• Policies requiring after-sales and end-of-life services to be offered by the providers of eCooking appliances. This can be supported by the government, e.g.: - Facilitation of access to electronic waste (e-waste) management facilities (for recycling, upcycling, disposal) - Capacity building to equip the workforce with the necessary skills to maintain and repair eCooking appliances • Government incentives to promote collaborative research between private sector companies and academic institutions, e.g., on more efficient and effective ways of providing after-sales support and end-of-life management of eCooking appliances.

Related to the above challenge, **BOX 2** presents the case of Rwanda and its efforts to address its e-waste challenge. This case demonstrates how issues of end-of-life services for electric appliances, including eCooking appliances, can be managed through a public-private partnership.

BOX 2: E-waste management in Rwanda, building robust policy and raising public awareness

As with other e-waste, eCooking appliances need to be disposed of in a way that avoids possible harmful impacts on the environment and, in some instances, also human health (WHO 2021). Questions around the disposal of eCooking appliances will become more pertinent as the market for such appliances expands, enabling economies of scale in reverse logistics and e-waste management.

The market of eCooking appliances in Rwanda is nascent and only a very small fraction of the country's population uses household appliances such as electric pressure cookers (EPCs), rice cookers or induction stoves. Kettles and microwaves are among the more popular kitchen appliances. However, Rwanda generates some 7,000 tonnes of e-waste annually (ITU 2022), and less than 20 percent is being collected.

The Government of Rwanda (GoR) has taken a number of steps to put in place frameworks to manage e-waste. To raise public awareness, GoR recently launched the #GreenRwanda campaign to encourage e-waste returns by consumers to official collection points in Kigali and one other city – both managed by Enviroserve, the largest collector, recycler and refurbisher of e-waste in the country. It has the capacity to collect and process over 10,000 tonnes of e-waste yearly. The campaign aims to educate the public, create buy-in across the public and private sectors, and raise awareness of the dangers of improper e-waste disposal on health and the environment (ITU 2022).

The e-waste policy and regulatory environment is relatively advanced. Rwanda is one of just 13 nations in Africa with national legislation governing e-waste control. It is in the process of implementing Extended Producer Responsibility (EPR) guidelines to make the manufacturers of electronic devices liable for their take-back, recycling and final disposal (CLASP 2023). The Rwanda Utilities Regulatory Authority (RURA) also issued Regulation n°0002 of 26/04/2018 that governs e-waste management for safe disposal and recycling of end-of-life electrical and electronic equipment, requiring any person carrying out activities related to e-waste collection, transportation, retailing, importation, dismantling, recycling or refurbishment to hold a RURA licence (RURA 2018).

Many policy levers can be used to help translate integrated energy plans into reality. In the context of integrating clean cooking, and eCooking in particular, into energy plans, it may be beneficial for national policymakers to consider investing in the development of dedicated clean cooking strategies with a specific inclusion of eCooking strategies, or separate eCooking strategies where national clean cooking plans exist but exclude eCooking, as in Kenya, Malawi and Uganda. Such strategies can help governments and their partners to comprehensively tackle eCooking transitions and identify and follow the most effective policy pathway so that a robust eCooking ecosystem can emerge and grow.

Developing and implementing such strategies will require a well-coordinated stakeholder approach, particularly given the multi- and inter-sectoral nature of providing clean cooking access. It will call for those government policy arms directly working on energy access, primarily in the areas of infrastructure, environment, economic planning and finance, health and science, technology and innovation, to actively participate. Regular and coordinated policy revisions to respond to any challenges or emerging opportunities, e.g., as innovations enter the market or new solutions become available, will also be important.

4.2 Financing Innovative Delivery Models

Innovative financing and delivery models are critical for making eCooking appliances and the ongoing cost of the electricity service affordable (CLASP 2020). This will hinge upon private sector willingness, in particular solar companies, mini-grid developers and utilities, to adopt eCooking as part of the services offered to customers.

4.2.1 On-Bill Financing

In addition to tariff adjustments (as discussed in Section 4.1), public and private energy utilities could consider making eCooking an integral part of their services by offering appliances and the necessary appliance financing for end users. This could be in the form of on-bill financing whereby customers get access to a loan for the appliance, extended directly through the utility, which is then paid over time by adding a surcharge to the electricity bill or by increasing the tariff paid by the customer for a specified period of time over which the value of the appliance is paid off (this could include interest for the utility or, if possible, be offered interest-free particularly for the poorer segments of the consumer base). On-bill financing of eCooking appliances has been included in the mandate of a number of universal electrification funds in Africa, such as the Programme for Universal Electrification (PEPT[16]) fund in Cote d'Ivoire (Decree n°2018-809) or the TINGA Fund under development in Togo (Decree n°2021-129), but has rarely been implemented at scale due to the primary focus of these funds on connections, funding requirements exceeding available financing, and the weak financial position of most utilities that prevents them from extending consumer credit. Latin America has significantly more experience with the provision of consumer finance through on billing. A notable example is the Ecuadorian Efficient Cooking Programme,[17] launched in 2014 by the Ministry of Electricity, which promoted the replacement of gas stoves with

[16] Programme d'électrification pour tous.

[17] Programa de Cocción Eficiente.

induction cookers through a credit line to the utility for the extension of a credit to households covering both the investment and installation cost of the appliance (Figal Garone et al. 2019).

To design such schemes, attention needs to be paid to potential implications of the banking regulation that may be triggered by the choice of certain financial instruments. Also, whilst an increased electricity load can in theory strengthen the utility's financial position, a number of conditions need to be met for this to materialize, in particular cost-reflective tariffs and adequate investments to ensure uninterrupted access to electricity. The latter links back to the importance of robust energy system and access planning. In addition, eCooking loads should be factored into the mini-grid or the national grid planning from the get-go to accommodate those loads as and when the service becomes available, rather than as an add-on that might require system adaptations (e.g., generation and energy storage capacity expansion, or larger transformers).

Utilities are also well positioned to act as finance intermediaries. They own large amounts of data on consumers, many of whom have little to no measurable financial activity. Frequency of payments, as well as time and quantity of energy consumption, can be used to help expand access to credit for customers. Therefore, utilities could explore the opportunity to allow third parties, e.g., banks or local micro-finance institutions, access to their consumer data to assess credit profiles and facilitate access to loans that would otherwise not be available to consumers. Using these data, however, will require obtaining consumers' informed consent and full transparency, and possibly be offered to them as an optional service (an opt-in) rather than a default (with an opt-out option).

4.2.2 Results-Based Financing

Results-based financing (RBF) is another form of finance that can help boost availability and affordability of eCooking appliances and help providers to sell products in instalments. RBF has become an important funding tool for the sector over the last decade and has proven especially well suited for sufficiently mature markets for the targeted technologies, for example in terms of private sector presence, consumer awareness and fuel supply (MECS & Energy4Impact 2021). While RBF schemes have been particularly common in the improved cookstoves space, there are only few examples of eCooking RBFs. Notable examples include the Global LEAP Awards' Results-based financing (Global LEAP+RBF), supported by EnDev, implemented with the objective to accelerate the global appliance market of EPCs by providing incentives to appliance suppliers and distributors to scale up the distribution of quality-verified products (CLASP 2021). In Rwanda, a Clean Cooking RBF subsidy scheme, co-financed by the World Bank's Clean Cooking Fund through the Rwanda Energy Access and Quality Improvement Project (EAQIP), covers various clean cooking solutions, including eCooking and reduces system prices at varying amounts allocated for different socioeconomic segments of the Rwandan population (REG 2022).

Recently, the Modern Cooking Facility for Africa (MCFA) managed by the Nordic Environment Finance Corporation (Nefco) and focused on modern cooking technologies, has correlated in-built incentives with the overall performance of a given technology against the Multi-Tier Framework (MTF) and fuel supply. For eCooking, this means that companies applying to the MCFA can propose to add renewable energy (RE) generation capacity or storage to strengthen the distributed energy systems on which eCooking is proposed to be installed. Whilst eCooking is strongly represented in MCFA's portfolio, no application combining the provision of eCooking and the addition of RE generation capacity was received during MCFA's first call for proposals. A similar trend was observed in the Beyond the Grid Fund for Africa (BGFA), also managed by Nefco, where only a handful of applications included eCooking as part of their off-grid electrification projects. Although, some opportunity exists to strengthen the linkages between the two programmes and promote the uptake of eCooking, the experience in BGFA and MCFA points more generally towards the need for building and strengthening relationships between off-grid operators and eCooking manufacturers and distributors, as well as unpacking other potential barriers.

Despite the transformational potential of RBF grants for the sector, upfront grants will continue to play an important role, as they can be used for structural investments, such as developing a carbon project, funding market research or research and development (R&D) (Energy4Impact 2022).

4.2.3 Lending Instruments

Governments can support financial institutions in providing concessional loans to eCooking appliance distributors with the aim of increasing their ability to offer consumer credit. Relevant financial instruments to consider include concessional lines of credit and loan guarantees, in particular for local currency financing. These instruments are important in the context of low- and middle-income countries (LMICS) where access to capital for small and medium-sized enterprises (SMEs) is limited and when available, prohibitively expensive. Such facilities could be applicable to a whole array of eCooking appliances and could significantly speed up the uptake of eCooking.

Opportunities for blended finance, which brings together private capital and development finance for projects that contribute to sustainable development while providing financial returns to investors, could also be explored for eCooking and wider electrification efforts, particularly through RE systems. Sub-Saharan Africa (SSA), South and Southeast Asia (SEA) have been reported as regions where such financing can have the highest potential for impact due to the high relevance for climate change mitigation and energy access and conducive environments for private sector investment (Tonkonogy et al. 2018). Lessons can also be learnt from the off-grid electrification sector where pay-as-you-go (PAYGO) delivery models for solar home systems (SHS) have been widely deployed to help address the affordability barrier (e.g., ESMAP 2020; WRI 2016).

4.2.4 Equity Instruments

Innovative financing mechanisms that can support the growth of the eCooking market through private sector development will also play an important role. These can include patient equity funding, equity crowdfunding campaigns and equity de-risking instruments (Energy4Impact 2022).

4.2.5 Carbon Finance

An increasingly prominent form of financing for clean cooking ventures has been carbon finance. Carbon credits, which are generated through project activities and subsequently sold, have mainly come from two sources: the Clean Development Mechanism (CDM) (UNFCCC N/D) and the Voluntary Carbon Market (VCM) that has operated in parallel as an alternative source of carbon credits for clean cooking projects. Under the VCM, private companies can voluntarily offset their emissions (Stritzke & Bricknell 2022). The Africa Carbon Markets Initiative (ACMI) launched at COP27, which seeks to unlock the potential of VCMs for financing Africa's energy, climate and development goals, reaffirms the critical role carbon finance will play in the energy sector.

Among the biggest challenges for accessing carbon finance has been the measurement, reporting and verification (MRV) of carbon credits. MRV is a process through which the amount of greenhouse gas (GHG) emissions reduced by a specific mitigation activity over a period of time are measured and the findings are then reported to an accredited third party. The third party verifies the report to certify the results that then make the basis for the issuance of carbon credits (World Bank 2022). E-Cooking is a form of modern cooking that offers an opportunity for much easier and more efficient MRV than other clean cooking solutions, thanks to the ability to apply smart meter technologies to appliances. A significant step in facilitating access to carbon finance for smart eCooking providers has been the Gold Standard methodology to quantify GHG impacts from metered cooking appliances through the direct measurement of energy or fuel (MECS 2022).

BOX 3 presents an example of eCooking providers who are already benefitting from carbon finance thanks to the embedded smart metering that enables accurate and fast MRV.

BOX 3: Digital Monitoring, Reporting and Verification (dMRV) for eCooking solutions

Digital Monitoring, Reporting and Verification (dMRV) is one of the latest innovations in the clean cooking sector. It enables remote monitoring of cooking appliances and real-time reporting and verification of their usage. E-Cooking appliances are among the best suited clean cooking solutions to leverage this innovation given that the time of use and amount of power consumed can be tracked through smart meters and these data can then be sent into a central database using sim cards or other Internet of Things (IoT) applications. There are companies focusing on eCooking in SSA and SEA that have embedded dMRV into their solutions, opening up a range of opportunities for more affordable cooking services.

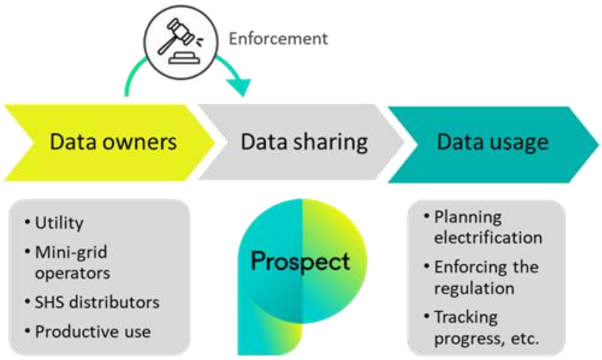
ATEC, a company providing tier 5 cooking solutions in Bangladesh and Cambodia, has patented an eCooking induction stove that tracks and verifies usage. Usage data are then aggregated through a GSM sim-card IoT integration and converted into certified 100 percent dMRV carbon credits through a range of standards, starting with Gold Standard. All credits can be tracked in real time by the credit buyers via ATEC's dMRV Data Platform. Each stove automatically validates carbon credits for up to 15 years, which allows ATEC to reduce the upfront cost of the stoves to the consumers, thanks to the generated carbon credits (ATEC 2023). The IoT and digital functionality of the stoves also integrates with mobile money providers, meaning households can also receive carbon credit payments directly. ATEC and MECS have been piloting this 'Cook-to-Earn' initiative (up to a 5 kWh/household limit per day) with Fair Climate Fund as the credit buyer. Monthly payments are made into the user's mobile money account based on the usage data captured (Batchelor 2022).

In Uganda, PowerUP provides EPCs with integrated digital usage monitoring. The company uses technological innovations to develop high-tier, high-quality cooking solutions for customers in low-income contexts in Uganda and beyond. PowerUP offers an EPC with a dMRV functionality that opens up opportunities for PAYGO integration and detailed usage monitoring for retailers, and dMRV for carbon credit generation based on actual usage – in a similar manner to ATEC. PowerUP already benefits from the generated carbon credits that also allow them to sell their products at more affordable rates than other EPCs on the market.

To leverage the existing and emerging opportunities for carbon and clean cooking co-benefits finance (e.g., time savings of health impacts of PM 2.5 and CO emission reductions in ADALYs), governments can support digitization efforts to make digital MRV solutions more available and accessible to the clean cooking sector. Digital platforms like Prospect, an open-source solution, or Odyssey, a proprietary tool, offer the possibility to automatically and systematically collect comprehensive usage and product data from a wide range of energy systems (on-grid, off-grid and appliances such as cookstoves).

The MRV data collected could have a variety of uses, including facilitating planning through the provision of accurate market data (e.g., average portfolio at risk, consumer behaviour data, etc.); improving coordination to ensure additionality of funding and minimizing potential market distortions; and monitoring deployment against contractual targets to facilitate payment of pre-agreed incentives (e.g., RBF). Figure 16 below gives an example of the possibilities offered by a nationwide and comprehensive adoption of Prospect. In addition, digital MRV can help companies to access carbon finance with earning higher quality credits due to improved reliability and soundness of the MRV process. However, a capacity building line of support extended to the private sector is useful to ease the navigation of the often complex (and costly) process of getting carbon accreditation (Zhang & van der Vleuten 2023).

FIGURE 16: Digital MRV, from data ownership to data usage: the example of Prospect



Source: Access to Energy Institute (A2EI) (2023).

Unlocking these emerging opportunities could enable transformative impact for millions of households. This will take a concerted global effort to create an enabling environment that can facilitate the integration of eCooking into national planning, including electrification planning and RE investments (ESMAP & MECS 2020).

4.3 Knowledge Generation and Sharing

While quality data availability and accessibility are paramount to building robust Integrated Energy Plans (IEPs) (see Section 2.3), knowledge generation and sharing that goes beyond the technical modelling of energy access is just as critical for informing integrated energy planning and its assumptions, particularly for an area as complex as clean as modern cooking adoption. It is also indispensable for the implementation of such integrated plans. In return, integrated energy planning approaches can help identify local gaps in knowledge and technology that can in turn assist with a more targeted and effective allocation of available funds towards research and innovation areas critical to continue developing breakthrough solutions addressing the main barriers to uptake. For example, issues of appliance energy efficiency, affordability, suitability for deployment in different contexts (including weak and off-grid), or power storage for more affordable and accessible battery-supported eCooking.

E-Cooking has historically received limited attention from researchers, however, there has been an uptick in studies and pilots focusing on eCooking in the last decade, focusing on both on- and off-grid settings. Pivotal publications on eCooking – its viability and cost-effectiveness – have impacted the shift in the clean cooking sector towards not only considering eCooking as a clean cooking option, but actively including it in energy planning given the great strides made on electrification efforts across LMICs.

Table 7 lists different types of published outputs focusing on eCooking over the last decade, with examples of publications that have been impactful in the energy sector, and that have specifically contributed to the bridging of the electrification/clean cooking divide.

TABLE 7: Types of publications and examples of published outputs that have informed eCooking transitions in recent years

E-COOKING ASSESSMENTS:	
MECS & WB (2020a) – state of access to modern cooking, incl. eCooking MECS & WB (2020b) – cost competitiveness of eCooking	MECS & GIZ (2022) – 8-country eCooking market assessment series
COOKING DIARIES:	
Njobvu et al. (2022) - Zambia	Energy4Impact (2022) - Rwanda
Naluwagga et al. (2022) - Uganda	Sokh et al. (2021) - Cambodia
TaTEDO (2022) - Tanzania	Leary et al. (2019) - Kenya
ACADEMIC PUBLICATIONS:	
Leary et al. (2021a) – battery-supported eCooking	Batchelor et al. (2018) – solar eCooking in Africa
Sánchez-Jacob et al. (2021) - impact of integrating electric cooking into electrification planning	Yangka & Diesendorf (2016) – benefits of eCooking in Bhutan
Batchelor et al. (2019) – synergies between electrification and eCooking	
E-COOKING SCENARIOS:	
EED & MECS (2023) - cooking only with electricity in Kenya: - economics of cooking solely with electricity - socio-cultural and behavioural challenges associated with transitions to eCooking	

The published evidence has already informed policymakers and their decisions concerning the bridging of electrification and clean cooking, tariff revisions (e.g., EPRA 2023), and financial support to the eCooking sector to boost uptake (e.g., BRD 2023).

Another positive trend helping inform the sector has been the uptick in eCooking pilots powered by solar PV mini-grids and standalone systems in LMICs. Several mini-grid providers have piloted eCooking with their consumers to better understand how to tailor their offerings and business models and boost affordability, while at the same time benefitting from higher revenues. Examples include:

- Renewvia in Kalobeyei (Kenya)
- ARC Power in Rwanda
- Powergen in Tanzania
- EarthSpark International in Haiti

While the above have focused on adding eCooking appliances to the electricity service offering, solar eCooking has recently been gaining momentum. Companies like Pesitho, SUNSPOT and Solar Urja, have been developing standalone solar electric cooking solutions, leveraging progress made on the efficiency and affordability of solar PV over the last 10-15 years (IRENA 2017).

Appliance innovations include solutions such as the DC-powered EPC (van Buskirk et al. 2021), which has been piloted in Malawi and could be a game changer for rural areas where off-grid solar DC systems have become a common mode of electrification. Such studies and solutions demonstrate whether and how fully RE-based eCooking can be made possible (Batchelor 2015).

As most studies on eCooking have been carried out in the Eastern African region to date, additional focus, and research capacity, will have to be built in for other countries and regions embarking on eCooking transitions. Research, development and innovation could be prioritized by national governments to a greater extent, and more funding could be channelled to generating and sharing knowledge and evidence necessary to inform relevant energy sector stakeholders. As cooking falls predominantly within women's responsibility, it is also vital to both include women in knowledge generation and sharing as participants and as leaders so that they can not only contribute to research, but actually drive research agendas.

There are also opportunities to learn from, and leverage, tools and best practices that have been developed for other sectors, e.g. the consumer protection principles for the off-grid solar sector (GOGLA 2023) or the quality assurance framework developed by the Collaborative Labeling and Appliance Standards Program (CLASP) for emerging technologies for weak-grid settings (e.g. Global LEAP awards for solar pumping, EPCs and cooling), which can be formalized over time, turned into a certification or serve as a basis for an energy performance label.

Valuable lessons to increase the uptake of eCooking can be learnt from initiatives such as the Pika Na Power eCooking campaign in Kenya (Leary et al. 2021b), or GO Electric! championed by the Bureau of Energy Efficiency in India (BEE 2023), and other campaigns in the e-mobility sector that face similar consumer behaviour and perception challenges to eCooking (e.g., Sivakumar 2022). Such campaigns are already addressing consumers' concerns and developing strategies to raise awareness of eCooking and its benefits by reaching not only the end users, but also local and national policymakers, donors and investors, and the private sector – all of whom require more information and evidence to understand its value.

Knowledge sharing goes beyond making insights from eCooking studies or pilots (or other activities generating evidence) publicly available, it also requires a proactive approach to exchanging information across sectors and stakeholders, and at a higher level, across countries as well. For example, countries that already have the capacity to include eCooking into their plans and technical knowledge of eCooking solutions could offer to assist with such capacity building in other countries. A notable example is Nepal where a transition to eCooking is underway and where the Women's Network for Energy and Environment trained women who owned or worked in electrical appliance stores to provide maintenance and repair services for electric cookstoves. This was undertaken due to the lack of availability of after-sales services that was proving challenging for encouraging higher eCooking adoption. Similar approaches could be applied in other countries. They could help tackle both the need for capacity building and women's participation in the energy value chain, while at the same time supporting women's economic empowerment (Energia 2022).

CHAPTER FIVE

CONCLUSION

The benefits of eCooking are numerous, spanning positive health impacts, reductions in greenhouse gas (GHG) emissions and deforestation, and time and cost savings, particularly for women. Integrating cooking and electricity considerations in planning exercises and increasing the linkages between energy system and access planning is critical to: facilitate faster and more efficient transition pathways towards universal access to energy; unlock the potential of eCooking; and build more integrated and resilient energy systems that meet local demand reliably and affordably. Although most of the current planning initiatives tend to focus on parts of such integrated approaches, as discussed in this Knowledge Brief, there has been an increase in the number of attempts combining relevant planning tools to increase the level of cross-sectoral and vertical integration of energy planning, particularly as more open-source tools have become available. Fully integrating energy systems and energy access planning, while considering the electrification-cooking feedback loops in the latter, could allow planners to conceptualize the interplay between infrastructure availability, eCooking viability and demand, and system sizing and technology options from the start.

Comprehensive, integrated energy planning tools that tackle electrification and clean cooking holistically from system to access planning are still mostly aspirational. The recent development of the Integrated Clean Cooking Planning Tool (ICCPT) in Rwanda possibly constitutes the most significant methodological advance to date. It achieves a full methodological integration of clean cooking and electrification for energy access planning and captures the impact of the demand for eCooking on the electricity system through feedback loops. At the time of writing, the National Integrated Clean Cooking Plan (NICCP) was still under review by the Government of Rwanda (GoR). The NICCP and the ICCPT (together with related documentation) will be made public following the review process. Another promising approach is to combine open-source tools into a holistic energy modelling analytical workflow, such as the soft linking of the Open Source Energy Modelling System (OSeMOSYS), the Open Source Spatial Electrification Tool (OnSSET) and the Open Source Spatial Clean Cooking Tool (OnStove), which could be further explored to create an open-source alternative. Enhancing these approaches with linkages to other open-source tools could generate additional financial, technical and climate insights, critical for the implementation of energy access plans and informing political and financial decisions.

Access to high-quality, standardized data is critical to carry out energy planning modelling exercises. Common limitations of existing approaches arise due to insufficient, incomplete or inexistent data, particularly on current access to clean cooking in non-residential settings, such as schools and other institutions. Data scarcity is compounded by complex end-user cooking behaviours, including fuel and stove stacking, which characterize traditional cooking patterns. Technological developments, such as the democratization of GIS software, remote stove or appliance sensing and smart meters, mobile data collection and cloud-based applications, have opened up more efficient ways of generating, collecting, processing and storing data, and could be leveraged to close the data gap. However, standards and practices around data protection and data sharing need to be strengthened to avoid any legal or ethical breaches.

Access to quality data and the choice of energy planning tools underpin the relevance and validity of energy planning exercises that play a crucial role in shaping implementation strategies and informing the design of support mechanisms, policies and strategies necessary for energy plans to be realized. Achieving integrated energy plans requires collaborative efforts across sectors and stakeholders, along with effective resource allocation to address the most pressing socioeconomic needs at local and national levels. Cooperation among government entities is essential, transcending traditional silos to integrate energy considerations into broader policy domains such as finance, labour, taxation, transport and industry. Even though ministries of energy or environment typically bear primary responsibility for energy access goals, successful implementation of integrated energy plans necessitates inter-ministerial coordination to enact policy actions covering various energy access services. This coordination is especially vital for clean cooking planning, which involves complex cross-sectoral considerations, including the integration of eCooking solutions. Moreover, addressing the complexity of demand for clean cooking services requires interventions that account for existing cooking practices and the need for competitive pricing and sustainability. Hence, research will require continued support to empower the whole range of different stakeholders with adequate knowledge and evidence. In particular, issues around demand estimation for eCooking are critical for the development and implementation of both integrated energy plans and relevant policies and financing mechanisms for end users and providers of such solutions.

This Knowledge Brief has outlined selected strategies and mechanisms to facilitate the operationalization and implementation of integrated energy plans, which can advance eCooking solutions. However, a pressing need for improved knowledge sharing remains to inform future efforts in improving integrated energy planning tools and operationalizing the resulting plans. In order to accelerate clean cooking access in low- and middle-income countries (LMICs) and leverage increased electrification for eCooking, capacity building among stakeholders from the energy sector, as well as other related sectors, will be essential. Building coalitions such as the Global Electric Cooking Coalition (GeCCo), and its humanitarian inclusion sub-initiative, the Solar-Electric Cooking Partnership (SOLCO), to deliver universal energy access may help raise awareness of the need for more holistic energy planning to maximize the socioeconomic and environmental impacts of access to clean, modern and sustainable energy.

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APPENDIX 1: Overview of CCG modelling tools.

MAED	**What will future energy demand be?**
	MAED is a tool developed by the IAEA and is used to evaluate future energy demand of the industrial, transport, household, and services sectors based on a set of consistent socio-economic assumptions such as population and gross domestic product growth.
OnSSET and **OnStove**	**What is the least-cost pathway for reaching universal energy access?**
	OnSSET and OnStove are two geospatially explicit modelling tools developed by KTH that estimate the most practical and beneficial expansion path for attaining universal access to energy. OnSSET covers the electricity sector and estimates the optimal combination of certain grid and off-grid technology solutions for electrification planning. OnSTOVE covers the clean cooking sector and compares the relative potential of different cookstoves on the basis of their costs and benefits.
OSeMOSYS	**What is the least-cost energy expansion plan to meet projected demand?**
	OSeMOSYS, developed by KTH, is an integrated assessment and energy planning tool that performs long-term energy system planning and investment optimization. It determines the most cost-effective energy system configuration over a long-term modelling period. For power, OSeMOSYS optimizes the capacities of electricity generation and storage plants and, if desired, may also plan optimal end-use electrification and how this feeds into total electricity demand. A variation of this model, OSeMOSYS Global, is specially designed to evaluate the economics of cross-border power interconnectors and regional power pool integration.
FlexTool	**Does the least-cost energy expansion plan satisfy system operating constraints?**
	FlexTool, created by IRENA, analyzes short-term operational aspects of the power system, performing single-year flexibility analyses, to identify potential underlying flexibility bottlenecks. It also evaluates flexibility options, such as the deployment of (additional) electricity storage, electric vehicles, power-to-heat, power-to-hydrogen, and the implementation of demand response.
CLEWS	**Is the least-cost energy expansion plan compatible with land and water availability?**
	The CLEWs approach, which was developed by KTH, offers an integrated, nexus-based framework encompassing energy, water, land, and climate systems. By adopting a nexus approach, CLEWs transcends sectoral silos recognizing these systems are deeply interconnected and interdependent, considering linkages such as water for energy, energy for water, land for energy, energy for land, land for water, land for climate.
MinFin	**Is the least-cost energy expansion plan financially viable for the country?**
	MinFin is an emerging tool designed by CCG to examine national-level climate financing strategies to facilitate discussions with Ministries of Finance by translating energy investment plans into financing strategies. Users can determine the viability of implementing a financing strategy in a country, based on recent history and forward-looking projections.
FinPlan	**How should individual energy projects be financially structured?**
	FinPlan, created by IAEA, is a tool to assess the financial viability of projects, considering different technical and financial factors such as plant size, electricity generation, investment costs, discount rates, and so on. FinPlan uses these to calculate projected cash flows, financial ratios, shareholders' returns, and other financial indicators.
OSeMOBILITY	**What are the implications of alternative decarbonisation pathways for transport?**
	Work is currently underway within CCG to develop a plug-in model to OSeMOSYS that will allow for a deeper analysis of transport sector decarbonisation pathways in LMICs, while feeding into the overall energy system representation.
Carbon Calculator	**How does the energy expansion plan affect the evolution of the carbon footprint?**
	Work is currently underway within CCG to develop an interactive web-based tool based on the MacKay Carbon Calculator. The purpose of the tool is to enable users to explore different scenarios for national energy consumption and production. By choosing 'levels of ambition' for decarbonising different sub-sectors of the energy sector, users can visualise the potential impacts of different energy choices on the national carbon footprint, and chart potential carbon trajectories.

Source: CCG (2023).

ABOUT SUSTAINABLE ENERGY FOR ALL

Sustainable Energy for All (SEforALL) is an independent international organization that works in partnership with the United Nations and leaders in government, the private sector, financial institutions, civil society and philanthropies to drive faster action on Sustainable Development Goal 7 (SDG7) – access to affordable, reliable, sustainable and modern energy for all by 2030 – in line with the Paris Agreement on climate change.

ABOUT MODERN ENERGY COOKING SERVICES

Modern Energy Cooking Services (MECS) is an eight-year research programme funded by UK Aid (FCDO). We are a geographically diverse, multicultural and transdisciplinary team working in close partnership with NGOs, governments, private sector, academia and research institutes, policy representatives and communities in 16 countries of interest to accelerate a transition from biomass to clean, electric cooking.

ABOUT THE GLOBAL ELECTRIC COOKING COALITION

The Global electric Cooking Coalition (GeCCo) is comprised of eCooking advocates who work alongside other existing global and national initiatives promoting higher-tier cooking transitions by providing leadership, integration, knowledge, and funding that is exclusively focused on the rapid global scaling of electric cooking. The coalition represents a working group of international partners and provides a platform for engagement to unify work, avoid duplication and optimise output quality.