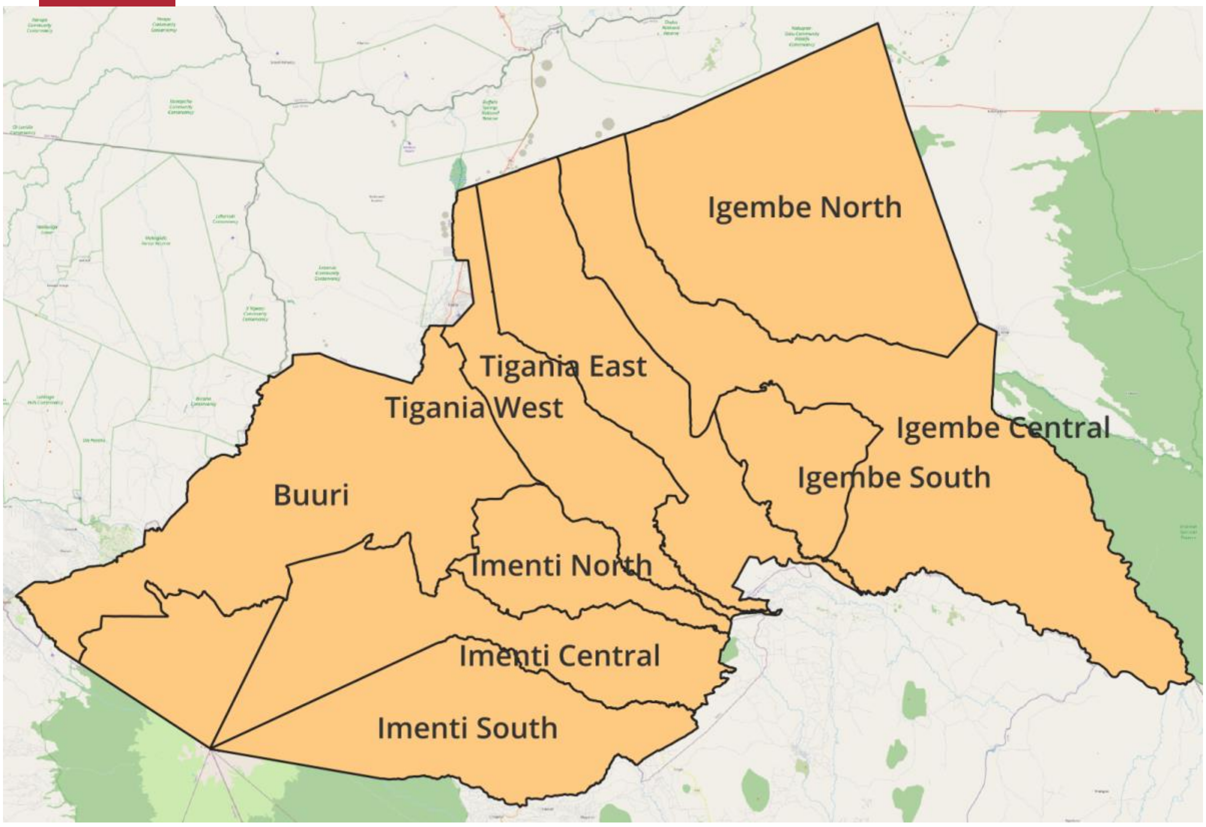

Meru County, Kenya Sub Counties

Working paper

Tools and approaches to support needs-based demand assessment and investment in County Energy Planning in Kenya

Ben Garside (IIED), Daniel Mwendwa (Oxford University), Adrian Onsare (KPLC/IESR) and Sarah Wykes (Loughborough University).

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Executive Summary

This working paper summarises the initial research to develop an assessment of county energy demand and build decision-maker understanding of the associated investment costs to meet that demand using the case study of the County Energy Plan (CEP) in Meru County Kenya (forthcoming, 2023). The Meru CEP was developed using the inclusive, cross-sectoral Energy Delivery Models (EDM) planning approach.

First, this paper explores the context and enabling environment in Kenya for county energy planning, namely the new draft regulations for the Integrated National Energy Planning (INEP) Framework. INEP is in part a response to Sustainable Development Goal (SDG) 7, and the need for energy services to be planned as enablers of wider SDGs. However, INEP provides minimal guidance to counties on tools and planning approaches to assess county energy demand as an enabler of wider development, and to develop energy services and projects using a cross-sectoral approach.

Second, the paper briefly analyses the global evidence on challenges in planning approaches to deliver SDG 7 as an enabler of sustainable development. These include the overwhelming focus on energy technology and infrastructure in plannng, which are often customised to local contexts and the needs of different groups. Another insight is the need to integrate non-energy supporting services for an energy service to function effectively, as well as to achieve overall development impact. For the poorest and marginalised groups, affordability is a key challenge. Targeted subsidies or "Energy Safety Nets" may be needed not just for electricity and clean cooking connection but also for sustainability of consumption. Finally, as outlined in the paper on *Data Needs for County Energy Planning* and in the latest INEP Framework, the disaggregated, granular energy and cross-sectoral data needed to build an accurate picture of energy demand and its drivers is often lacking.

The minimal attention paid to planning energy services as enablers of wider development goals of particular groups in particular contexts is also borne out by a brief, comparative survey of different approaches to energy planning. Alongside more traditional approaches, such as levelized/least cost electrification planning, scenario and integrated resource planning, more participatory and needs-based approaches exist.

The EDM process can be categorised as a "holistic", more bottom-up planning approach, where energy demand is conceptualised as a function of the energy services needed to deliver development impacts for target end users in a particular socio-cultural and economic context. EDM attempts to learn from research and practitioner experience on the need to integrate non-energy supporting services and proactively *build* demand for energy services for their successful functioning. The EDM process does not aim to cover *all* economic sectors in the county and *all* potential demand for energy services. It is explicitly designed for planners and end users (county government and citizens) to identify and *prioritise* development needs, in function of the reality of limited resources.

The Paper outlines the six holistic solutions developed under the Meru CEP:

1. Improved income from horticulture Farming
2. Improved income from poultry farming
3. Access to clean & affordable water
4. Access to basic health services

5. Access to better quality household lighting and to street lighting
6. Access affordable, cleaner, safer and reliable cooking fuels and technologies

The solutions developed to meet these needs include detailed costings and investment models for demonstration and scale up Phases of implementation, with allocation of multi-year county government budget (through the CIDP 2023-28 and ADP 2023-24), and co-financing support.

Using different visualisation and mapping tools, this papers shows the further reseach that has been carried out to enable decision makers such as Meru County Government (and national energy planners) to build their understanding of the solution investment costs, and to support discussion on prioritisation, the potential for co-financing and bundling investments, and electrification options. The current outputs involve the poultry, lighting and water solutions under the following activities:

Activity One – visualising individual solution and aggregate investment costs

a. County-wide visualisation or GIS mapping of each sectoral solution showing the locations where it will be deployed, and its associated investment costs (energy and non-energy) during the different implementation Phases.

b. Visualisation or GIS mapping showing the deployment of solutions, the locations and associated investment costs *per sub-county*.

Activity Two – identifying least cost electrification options

a. GIS mapping for several of the solutions (health and water) where the costs of on-grid or off-grid energy service components have been calculated, and the locations of deployment (i.e., level two health facility or borehole location respectively) are known, to identify which type of solution is most appropriate for which location.

In a future stage of research, activities one and two will be undertaken for all the solutions. In addition, component investment costs and locations will be analysed as follows:

Activity Three – visualising investment costs and co-benefits of bundling solution components

b. Additional mapping to visualise and aggregate the costs of different categories of activities (solution components) at county and sub-county level (e.g., training; access to finance etc). This can help identify co-benefits or economies of scale, such as maintenance and repair of solar home systems across several solutions or bundling micro-finance products.

Finally, modelling and analysis will be carried to assess "county energy demand", as follows:

Activity Four – estimating aggregate county energy demand from CEP solutions plus

a. The team will use modelling tools (e.g., OnSSET) to aggregate the energy components of all the CEP solutions to estimate the "energy demand" or potential load in particular locations (ward or sub-county). The team will then estimate the least cost electrification options for each location and identify the agency or level of government to deliver them.

b. Map potential locations for market centres, informed by the deployment of the EDM solutions and other data inputs, and their associated energy demand profile, as well as other sectors not identified as priorities during the EDM CEP process (e.g., education).

c. Depending on time and resource, explore options for the development of a web-based interactive tools (or a GUI) to communicate the modelling for implementation planning and investment decision making.

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List of Acronyms

ADP	ANNUAL DEVELOPMENT PLAN
CEP	COUNTY ENERGY PLAN
CIDP	COUNTY INTEGRATED DEVELOPMENT PLAN
EAE	ENERGY ACCESS EXPLORER
EDM	ENERGY DELIVERY MODELS
ESMAP	ENERGY SECTOR MANAGEMENT PROGRAMME
GIZ	DEUTSCHE GESELLSCHAFT FÜR INTERNATIONALE ZUSAMMENARBEIT (GERMAN DEVELOPMENT AGENCY)
GPS	GLOBAL POSITIONING SYSTEM
GUI	GRAPHICAL USER INTERFACE
IEA	INTERNATIONAL ENERGY AGENCY
IED	INNOVATION, ENERGIE, DÉVELOPPEMENT
INEP	INTEGRATED NATIONAL ENERGY PLAN
IRP	INTEGRATED RESOURCE PLANNING
IRENA	INTERNATIONAL RENEWABLE ENERGY AGENCY
LCOE	LEVELISED OR LEAST COST ELECTRIFICATION
KES	KENYAN SHILLINGS
KNBS	KENYA NATIONAL BUREAU OF STATISTICS
KPLC	KENYA POWER AND LIGHTING COMPANY

MAED	MODEL FOR ANALYSIS OF ENERGY DEMAND
MFI	MICROFINANCE INSTITUTE
MCIDC	MERU COUNTY INVESTMENT DEVELOPMENT CORPORATION
MoEP	MINISTRY OF ENERGY AND PETROLEUM
NESP	NATIONAL ENERGY SERVICE PROVIDER
OnSSET	OPEN-SOURCE SPATIAL ELECTRIFICATION TOOL
REREC	RURAL ELECTRIFICATION AND RENEWABLE ENERGY CORPORATION
SDG	SUSTAINABLE DEVELOPMENT GOAL
SETA	SUSTAINABLE ENERGY TECHNICAL ASSISTANCE PROGRAMME
SNV	STICHTING NEDERLANDSE VRIJWILLIGERS (DUTCH DEVELOPMENT ORGANISATION)
WRI	WORLD RESOURCES INSTITUTE
WWF	WORLD WILDLIFE FOUNDATION

1. Introduction

This working paper is a companion piece to the two previous working papers on *Data Needs for County Energy Planning in Kenya* and *Vertical Collaboration for County Energy Planning in Kenya* (October 2022). All three working papers, including future research to assess county energy demand, plus past and future outreach with actors involved in energy planning in Kenya, will inform the project level output on *County Energy Guidelines* under the UK PACT Project 3.1 (Knowledge Products).

This paper is informed principally by (a) research and practitioner challenges to SDG 7 implementation, especially initiatives to provide energy access to last mile end users; (b) an initial survey of different approaches to energy planning and how energy demand is conceptualised and quantified within these different approaches and; (b) the real-world experience of the Loughborough and International Institute for Environment and Development (IIED) team, County Governments and local partners in developing a County Energy Plan (CEP) for Kitui County (July 2021) and subsequently Meru County. The Meru CEP has been developed under the Sustainable Energy Technical Assistance (SETA) Programme through the Ministry of Energy funded by the European Union (see below). The methodology used to develop both CEPs is the needs-based Energy Delivery Models (EDM) planning approach (see Section Five below).

The team involved in developing this paper includes the international leads of the EDM team, based at Loughborough and IIED, who have been working on county energy planning in Kenya since 2018, one of the National Mentoring Experts (NMEs) supporting counties with energy planning under the SETA Programme based at the Institute of Energy Research and Studies (IESR) of the National power company, KPLC, and a UK PACT researcher based at Oxford University. The latter two team members are experienced in using various energy planning tools such as GIS mapping and OnSSET modelling,

The overall aims of the research activity summarised in this paper are, first, to explore how tools including GIS mapping and OnSSET modelling could be used to support visualisation and analysis of the Meru CEP solutions in terms of investment costs and electrification options to support investment decision making, including implementation prioritisation and planning, by county government and national planners, as well as delivery partners and potential co-financiers. As the Meru CEP has developed holistic solutions designed to meet the priority development needs identified by Meru County Government and citizens that integrate both energy and non-energy components, the investment models includes detailed costings for both energy and non-energy interventions to be carried out in two stages of implementatio, demonstration and scale up.

The second aim of the work, which is ongoing and will be captured in future outputs, is to explore the use of different modelling tools and approaches try to build picture of county energy demand, based on the aggregage energy demand or load and geographical locations of this load required to implement the CEP solutions and meet the priority development needs in Meru County that the solutions are designed to meet. This demand picture will not cover *all* economic sectors in the county and *all* potential demand for energy services. The EDM process is explicitly designed for planners and end users (county government and citizens) to identify and *prioritise* development needs, in function of the reality of limited resources available from county and national budgets and other sources of financing. However, additional analysis will aim to identify potential demand from new market centres, in function of clusters of CEP solutions and other data sets, as well as from other sectors not identified as priorities in the CEP process, such as education, to build a more comprehensive demand picture for Meru County.

2. Context and enabling environment for energy planning in Kenya

Energy planning in Kenya is now a mandate of both the national energy service providers (NESPs), such as the Kenya Power and Lighting Company (KPLC), led by the Ministry of Energy and Petroluem (MoEP), and the 47 county governments under the Fourth Schedule of the Constitution of Kenya (2010), and the Fifth Schedule of the Energy Act (2019). Under the Energy Act, the national government is required to develop an Integrated National Energy Plan (INEP) and county governments, MoE and NESPs are mandated to develop county energy plans as inputs to the design of the INEP.

However, both Kenya's Energy Policy (2018) and subsequent research have identified several challenges to achieving integrated planning, including significant gaps in the data sets needed for both county and national energy planning, as well as data governance issues, and weaknesses in coordination between national and county level actors. The two working papers produced previously under the UK PACT Project, *Data Needs for County Energy Planning in Kenya* and *Vertical Collaboration for County Energy Planning in Kenya* (October 2022) have analysed these challenges in some depth and the Ministry of Energy has in response made important changes to the draft regulations or Framework for Integrated National Energy Planning (INEP) being developed to guide NESPs and county governments on their planning functions and mandates.

2.1 INEP Framework for Energy Planning

The INEP Framework has been under development since 2021 and is still under discussion by the MoE, associated state agencies and other stakeholders, including the Council of Governors as the umbrella body representing Kenya's county governments. The latest version of the Framework reviewed by the LU team dates from February 2023. This iteration contains significant improvements to the INEP structure and functions, including two new sections on *Coordination* and *Data Management* which contain many of the recommendations from the two Working Papers produced under the UK PACT Project.

The INEP Framework recognises the energy planning now takes place in the context of Sustainable Development Goal (SDG)7 on access to affordable, reliable, sustainable and modern energy for all, and that "to provide reliable and affordable energy for all, there has to be a paradigm shift from the traditional energy planning to adequately respond to the evolving global energy market, [and] the changing roles and responsibilities across the energy value chain." (INEP Foreword).

INEP further recognises that "the energy sector is a major enabler of wider economic & social development" (1.8.2). Thus, the INEP appears to acknowledge the increasingly accepted view, that energy planning and service delivery should not be a standalone, siloed process but address "wider societal goals" as expressed in international, national, sub-national (& regional) development goals and plans. At the county level, the INEP Framework specifically references the County Integrated Development Plans (CIDPs) that counties produce every five years as their development programming blueprint, and which inform the production of Annual Development Plans (ADPs) and budgetary allocation (1.8.1).

Furthermore, the Framework recognises that this will "[c]hallenge long-standing assumptions [and] rules-of-thumb in traditional energy planning [….] The traditional energy value chain was linear with energy carriers produced centrally and distributed to a passive end user." (1.2). This assumed passivity of the end user in energy planning is no longer acceptable". The Framework further states that: "Increasingly, environmental regulations, low-cost energy resources, *customer preferences and* *investments*, and risk management will drive investment decisions" (1.2, emphasis added). Thus, the INEP appears to recognize in principle the need for active participation of customers or end users in the planning of services and that these services should be designed to meet their needs, along with other societal considerations such as environmental sustainability.

The INEP stipulates a process for developing county energy plans (CEPs) and mandates the content of CEPs. Based on the understanding that previous energy planning prior to INEP has been top-down and the sole purview of the MoEP and its associated agencies at the national level, there is a need to ensure that planning approaches and tools are fit for purpose, if truly integrated, inclusive and also cross-sectoral - given the enabling role of energy in sustainable development – energy planning is to be achieved.

2.2 Current support for county energy planning

Different stakeholders are currently supporting county governments to develop their county energy plans using different planning approaches/methods and tools. These stakeholders include the MoE through the Sustainable Energy Technical Assistance (SETA) project, the World Resources Institute (WRI), and Strathmore University. Development organizations such as GIZ, WWF, and SNV are also funding county energy planning processes. One of the most recent programmes targeting a large number of actors involved in energy planning is the SETA Project.

The SETA project (2020-23) aims to assist the national energy institutions and the county governments through a comprehensive capacity development program in developing resilient and implementable sustainable energy plans under the INEP Framework.[1] SETA is a partnership with the MoEP and is funded by the European Union. SETA is led by Innovation, Energie, Développement (IED) and Practical Action. The Centre for Sustainable Transitions (STEER) at Loughborough University and the International Institute for Environment and Development are project partners. The intended impacts of the SETA project are the following:

- Improved capacity of the energy sector actors and other stakeholders at the national and county level for integrated planning, developing and implementing RE, EA, and EE projects.
- More effective engagement in energy planning of the private sector and CSOs, and vulnerable and poor groups, mainstreaming of gender, climate change, environment, and other critical issues.

SETA has adopted the Energy Delivery Model (EDM) methodology (see Section 5) as a means of both designing the first generation of CEPs in 12 counties (under what is termed the Advanced Training Programme or ATP) and more widely strengthening the understanding of inclusive and cross-sectoral planning approaches among other counties (46 counties participated in a Basic Training Project) and national actors (including MoE and other national service providers, the Council of Governors, private sector and civil society organisations). This includes ongoing discussion with officials in the MoE and other agencies involved in developing the INEP Framework.

Under SETA, Meru County was chosen as the "demonstration" county where a full EDM planning process will be carried out, and where the planning activities under the six-step process will be "mirrored" by a further 11 counties, supported by classroom training sessions. The next section explores different energy planning approaches, to give the context and rationale for why the EDM planning approach was developed as a response to perceived need for alternative approaches to

[1] See https://www.seta-kenya.org.

traditional energy planning and delivery approaches in order for energy services to deliver more optimal development outcomes, and to meet the SDG 7 target of universal access to affordable, reliable and sustainable modern energy by 2030.

3. Approaches to energy planning

3.1 Progress on energy access as an enabler of sustainable development

In 2012, the former UN Secretary-General Ban Ki-moon stated " "Sustainable energy is the golden thread that connects economic growth, social equity, and a climate and environment that enables the world to thrive". Bhattacharyya (2012) alluded to the emerging global consensus that sustainable development cannot be achieved without access to affordable, modern, sustainable, and reliable energy. Alstone et al., (2015) demonstrated the linkage between access to electricity and improvement in human development in terms of productivity, gender equality, education, health, and safety. Furthermore, initital analysis by United Nations Development Program (UNDP) (2017) reinforced the enabling role of energy by demonstrating the linkages between Sustainable Development Goal (SDG) number 7 and the other 16 SDGs.

Despite its importance for human development, there has been mixed progress to date on reaching SDG 7 universal access target. Whereas the overall number of people accessing electricity globally was approximately 91 percent in 2020 as compared to 81 percent in 2010, the significant majority of those without access are found in Sub-Saharan Africa according to the latest *Tracking SDG 7: The Energy Progress Report* (International Energy Agency (IEA) et al, 2022). 733 million people globally remain without electricity access, of which 568 million are in Sub-Saharan Africa. Similarly, 2.4 billion people, or 31 percent of the world's population, lack access to clean cooking fuels and technologies (ibid).[2] Out of the 20 countries with the lowest access to clean cooking fuels and technologies, 19 are found in Africa (ibid). Sub-Saharan Africa has the majority of access-deficit countries.[3]

Many countries in Sub-Saharan Africa, including Kenya, face a range of challenges when it comes to energy service delivery, including poor (unreliable) grid infrastructure, limited access to modern energy sources, and high levels of poverty. Traditional energy planning has focussed on extending the national grid, including into rural areas where consumption (demand) often remains low due to a variety of factors.

Research by Yadoo (2012) analysed the technical, economic, social, environmental and institutional rural mini-grid programmes Peru, Nepal and Kenya with an aim to improving their overall development impacts of such mini-grid deployment. Some of the critical findings included the following insight into the key activities and planning approaches which could improve developmental impact for end users could be improved:

- Generation of a sense of local responsibility for electricity system and upkeep among end users and wider stakeholders.
- Separation of project management from ownership to ensure it is professional and efficient, with appropriate checks and balances.
- Tailoring the energy system to local needs, desires and cultural specificities, especially as regards choice of management model (e.g., in Nepal a cooperative management model was

[2] The World Health Organization (WHO, 2022) identified electricity, solar, biogas, natural gas, and liquefied petroleum gas as clean fuels. Additionally, it considers clean cooking technologies as those that are fuelled by clean fuels.
[3] Defined as countries with access rates under 90% or with over five million people lacking access to electricity.

preferable, whereas in other contexts a private business or social enterprise model might work better).

- Future-proof systems by including demand growth margins in the original project design
- Carry out rigorous risk analysis, including financial, social and environmental risks and develop appropriate mitigation strategies
- Try to influence the enabling environment (e.g. raise awareness of technologies, improve access to finance, engage in policy dialogue)
- Engage private sector in partnerships, promote hybrid public-private models

Other research carried out by SEforALL, CAFOD and ODI in six countries, including a case study in Kenya, has shown that energy access (electricity and cooking) initiatives designed in particular to reach "the last mile" of energy consumers, usually poor and marginalised groups, similarly found that these initiatives often fail to reach their objectives, or deliver sub-optimal results (SEforALL et al, 2020).

The research recommended that distinct approaches are needed to support energy connections (e.g., wires and transformers, LPG stoves) and ongoing consumption (e.g., monthly electricity bills and regular fuel consumption). There is a need for targeted subsidies or "Energy Safety Nets" for the poorest and marginalised groups to ensure sustainability of consumption. These must be designed to target specific groups and contexts, and take into account the need to disaggregate the energy needs of different groups, including the different needs of women and men (SEforALL et al, 2020). In addition, there is a need for enhanced data collection to understand energy consumption and needs of last mile, poor and marginalised end users, and to target subsidies appropriately (ibid).

3.2 Challenges to planning energy services as enablers of sustainable development

Ongoing challenges for energy planning in many access-deficit sub-Saharan African counties include siloed planning within governments and other supporting agencies focussing only on technology and infrastructure delivery rather than designing energy services as enablers for wider development goals and sectors, despite the SDG vision. Products and services for access usually focus on the technology and infrastructure first and foremost, which are often not customised to local needs and contexts. There is lack of understanding of local contexts for reaching last mile consumers, where small businesses face constraints around finance, access to reliable equipment, knowledge and other challenges that prevent uptake.

While grid rollout through parastatals is slow and expensive, there are opportunities to electrify rural areas and deliver on SDG 7 more quickly with rapidly-evolving off-grid renewable technologies. Planning for off-grid deployment, at least for domestic use, has often been left to the private sector, possibly due to the assumption that the grid will arrive someday. Whilst this has created a dynamic off-grid products and services market in some countries such as Kenya, it also can also result in the lowest income and remotely located groups being left behind (KNBS, 2019).[4,5] There is also limited data on levels of access achieved in off-grid locations.

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[4] For example, Kenya's 2019 national census shows significant numbers of households in rural areas using kerosene as their primary lighting source.

[5] See SEforALL et al, 202(b) for analysis of the success of last-mile electrification initiatives in Kenya.

4. Approaches to energy planning and demand assessment

An initial survey of the literature has identified a number of different approaches that are used for energy planning, each with its own strengths and weaknesses. It should be noted that this survey was not intended to be comprehensive but rather to develop a conceptual framework for the research and start to explore different conceptions of demand in different planning approaches.

Some of the approaches surveyed analyse various aspects of cost as well as other factors, and can be used for evidence-based planning which goes beyond "grid only" plannning to deployment of a variety of technology solutions appropriate for local contexts. These include:

- **Levelised Cost of Electrification (LCoE).** Also known as least-cost energy planning, LCoE is an economic approach to energy planning that aims to identify the most cost-effective mix of energy resources to meet a given level of demand. It involves the use of modelling tools, such as those deployed under the UK PACT CCG Project, to compare the costs of different energy resources and technologies, taking into account factors such as capital costs, operating costs, and fuel prices.[6] LCoE is widely used in developing countries where cost is a primary concern.
- **Scenario Planning.** This is a method of energy planning that involves the development of different scenarios based on different assumptions about the future, such as population growth, economic development, and technological progress. It is used to identify the potential risks and opportunities associated with different scenarios, and to develop strategies to address them. Scenario planning is widely used in both developed and developing countries (IRENA, 2020).
- **Energy Efficiency Planning** is a methodology that focuses on reducing energy consumption through the implementation of energy efficiency measures, such as building retrofits, appliance standards, and industrial process improvements. It aims to reduce the need for new energy supply by improving the efficiency of existing energy systems (see IEA, 2022). Energy efficiency planning is widely used in both developed and developing countries.
- **Integrated Resource Planning (IRP).** IRP is a comprehensive approach to energy planning that takes into account all available resources and considers a range of factors, including cost, reliability, environmental impact, and social factors (Jairaj et al., 2014). It involves the development of a long-term energy plan that balances supply and demand, and includes a mix of different energy sources, such as renewable energy, fossil fuels, and nuclear energy. IRP is widely used in developed countries and is gaining popularity in developing countries (D'Sa, 2005).
- **Participatory Energy Planning** is an approach that involves the active participation of stakeholders, including local communities, in the energy planning process. Best practice IRPs will include public participation (US Department of Energy, 2013 & Jairaj et al, 2014). It aims to ensure that the energy needs and priorities of local communities are taken into account, and that energy planning decisions are transparent and inclusive. Participatory energy planning is widely used in developing countries, where community engagement is often critical to the success of energy projects, as discussed in McGookin et al. (2021), Xavier et al (2017) and Batidzirai et al (2021).

These approaches are not mutually exclusive and are often combined. For example, LCoE takes an assumed electricity demand as an input parameter. The demand itself may be modelled through

[6] A useful definition and technical explanation of LCOE is provided by the Corporate Finance Institute (CFI, 2023).

scenarios which are based on a set of assumptions or parameters – for example the ESMAP Multi-Tier Framework (MTF) (ESMAP, 2022) which expresses different levels of quality and quantity of power.

4.1 Levelised or least cost electrification planning and scenario planning

LCoE is a useful way of modelling technology choice but is not without perceived limitations. According to Renewable Energy World (2014), these include:

- The use of assumptions instead of data – an approach common to various modelling tools, including scenario planning.
- Using data that supports the modeller's own objectives (for instance, assuming overly-low costs for infrastructure or operations and maintenance and too high generation values).
- Adjusting model inputs to arrive at a particular output.

There can also be an assumption that cost and price are synonymous whereas in reality the levelized cost and overall lowest cost does not always reflect the actual price paid by the customer or the total cost when other costs are factored in, for example the need for grid backup where the grid service is unreliable (ibid).

IRENA (2020) recently analysed use of scenario planning as a tool to assist a global sustainable energy transition, identifying both strengths and weaknesses of this approach through review of different case study examples. IRENA made the following recommendations regarding future use of scenario planning:

- **Strengthening scenario development** through the following interventions:
  - Establishing a strong governance structure: a sustainable energy transition will require broad participation and stronger co-ordination across different government institutions.
  - Expanding the boundaries of the scenarios being developed. To adequately reflect the complexities of the transition, models and scenarios need to better address new technologies, business models and disruptive innovations.
- **Improving scenario use** through the following interventions:
  - Clarifying the purpose of scenario-building. Scenarios can be used for different purposes, depending on the context and the goals being pursued. These purposes and assumptions should be made clear to avoid misinterpretation.
  - Ensuring transparent and effective communication. Transparency ensures the quality of scenarios and builds trust. Scenario assumptions and results need to be clearly communicated to stakeholders and innovative communication methods are now emerging.
- **Identifying capacity-building approaches** through the following interventions:
  - Building the right type of scenario capacity in government. The capacity to use scenarios can be created using modelling tools within government institutions. If modelling is outsourced, governments must still ensure they have the capacity to understand the results.

IRP is distinct from traditional least cost energy generation expansion planning in several ways. According to International Rivers (2013), the differences can be summarised as follows:

	Conventional "Least-cost" generation expansion planning	IRP
Bottom-up load forecasting	No	Yes
Generation costs	Yes	Yes
Demand-side management options and costs	No	Yes
Transmission and distribution costs	No (typically added after optimization)	Yes
Risks of fuel price volatility, drought, carbon taxes, etc.	Little or no consideration	Yes
Social and environmental "externality" costs	No	Yes
Public involvement throughout process	No	Yes
Scenario and sensitivity analysis to ensure "least-cost" under different cost or demand assumptions	Little or no consideration	Yes

Figure 1: Comparison of best practice IRP with conventional least cost planning (ibid)

Least-cost planning has traditionally excluded transmission costs or added them after the fact once minimum generation costs are calculated. According to International Rivers, there is limited assessment of risk in traditional least cost planning and an : "[conventional least-cost planning] makes a fixed assumption about all costs (including, crucially, fuel costs) and then optimizes based on this assumption. This yields a plan that is only optimized for a future that turns out to be similar to the assumptions that were adopted." (ibid). Environmental and social factors are not considered, nor are other in-sector risk factors such as fuel price volatility.

However, it should be noted that conventional least-cost planning has evolved in complexity and is now commonly understood as LCoE. Some of the modern modelling tools used for LCoE such as the Open-Source Spatial Electrification Tool (OnSSET).[7] The strengths and limitations of various approaches and tools used for LCoE will be analysed in further detail in the next iteration of this paper.

4.2 Integrated Resource Planning (IRP)

According to Nichols & von Hippel (2000) and International Rivers (2013), best practice IRP involves a wide range of stakeholders to promote change and progress to more user-centric energy systems. The process used fo IRP can be summarised into the following steps or stages:

- **Establish scope and objectives.** This includes engaging stakeholders to develop is termed in some IRPs as an "energy vision", that is, outcome-focussed theory of change statements with inputs from different stakeholders. This vision is often aspirational, looking to future expansion. It can be used as as standalone statement or part of a more detailed energy plan and can help identify challenges and their interconnectedness.
- **Survey energy use patterns and develop demand forecasts**. Demand forecasts can also be referred to as 'energy profiles' or 'demand profiles'. There are multiple approaches to developing these.
- **Investigate electricity supply options**. This can include identifying scenarios to meet supply and/or modelling demand (e.g., generation fuel mix scenarios). The latter are more focussed on end user needs but may be modelled on assumed demand rather than real-world data.
- **Investigate demand-side management measures**. This includes energy efficiency measures and consumer behaviour pattern management.

7 http://www.onsset.org/about.html

- **Prepare and evaluate supply plans.**
- **Prepare and evaluate demand-side management plans.**
- **Integrate supply- and demand-side plans into candidate integrated resource plans.**
- **Select the preferred resource plan.** In more participatory approaches to IRP, the resource plan would be selected by by referring options back to stakeholder groups for further discussion and agreement.
- **During implementation of the plan, monitor, evaluate, and iterate.**

WRI has identified ten components of a well-constructed IRP (Figure 2), noting that national energy strategies such as South Africa's Integrated Resource Plan, India's Five-Year National Electricity Plan and Thailand's Power Development Plan include many of these components but none contains all ten.

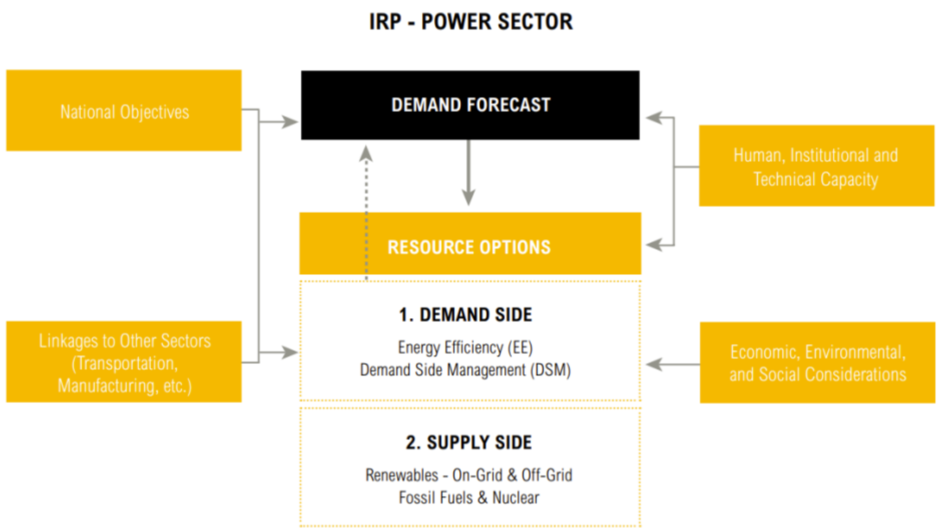


Figure 2: Schematic Diagram of an Integrated Resources Plan (IRP). Source: Jairaj et al (2014)

Finally, Integrated National Energy Planning in general has evolved to include four planning steps or stages, as summarised in Figure 3 below *(*Munasinghe & Meier, 1993*).* It is the fourth stage, looking at the electricity sub-sector, that focusses in more detail on modelling demand and, at the micro-level, carrying out stakeholder engagement to identify demand.

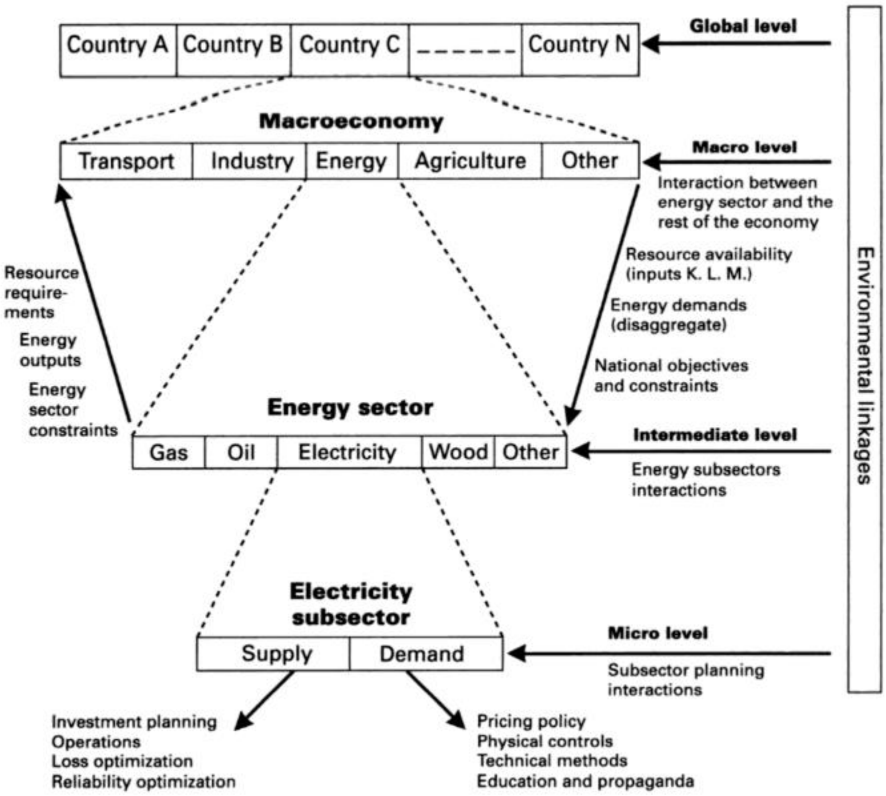


Figure 3: Hierarchical conceptual framework for integrated national energy planning (INEP) and environmental analysis. Source: Munasinghe & Meier (1993)

In fact, Kenya's draft Integrated National Energy Planning Framework (INEP) can be seen as endorsing a similar planning process to IRP for the different plans to be developed at national and county level and for the subsequent development of the integrated national energy plan to which they are inputs. However, where IRP tends to focus on the electricity sector only, integrated national energy planning usually includes cooking energy planning. In Kenya's case, there is a strong focus on the power sector in the INEP but it also includes cooking access and bio-energy resource and use.

As noted above, estimating energy demand in conventional energy planning may be assumed or based on various scenarios. IRP makes more efforts to assess demand as well as develop demand-side management (energy efficiency) strategies, and as part of the planning process, to engage stakeholders who represent end-users. The level of stakeholder engagement can vary widely with respect to breadth and depth of participation for both assessing demand and (co-)designing the energy system that is selected for implementation.

4.3 Participatory and needs-based energy planning approaches

There are several approaches to needs-based energy planning, which differ in their methods of quantifying demand and determining the best energy solutions, in terms of services and products to meet end-user needs. The most common approaches can be categorised as follows:

- **Bottom-up Approach**. Also referred to as a "detailed approach", this quantifies energy demand by looking at the individual components and segments of the energy system. This approach starts from a detailed study of the energy demand from each segment of the economy, such as the residential or the commercial sector (US Department of Energy, 2013 & Mougouei &, Mortazavi, 2017).

- **Top-Down Approach**. This approach, also called "high level" quantifies aggregated energy demand by looking at the overall patterns of energy consumption across sectors, regions, and time periods. The aim is to quantify the energy consumption of an economy as a whole, using statistical analysis or econometric models (ibid).
- **Hybrid Approach**. A combination of top-down and bottom-up approaches. It starts by gathering detailed data on the energy demand of individual segments of the economy, then uses statistical or econometric models to simulate the energy demand at the macro level.
- **Energy Intensity Approach**. This approach quantifies energy demand based on the energy needed per unit of output or activity. It calculates energy demand by looking at the energy required per unit of activity, such as for each unit of production.[8]

In addition, we can identify a "holistic approach", where energy demand is conceptualised as a function of the energy services needed to meet the development needs of target end users in a particular socio-cultural and economic context, and to deliver development impacts. Such an approach attempts to learn from the insights of research and practitioner experience of energy access programming to develop holistic solutions integrating the non-energy supporting services that are usually needed to *build* the demand for energy services and products, and, ultimately, deliver the wider development impacts.

Such approaches can carry out detailed secondary and primary socio-economic research, including on the ground needs assessment working with end users and stakeholders, value chain analysis and developing business models to deliver holistic solutions to meet the development needs of specific target groups. Although a hybrid approach may be used, the bottom-up approach is more emphasised (through the participatory needs assessment) combined with strong local stakeholder engagement to build buy-in and actively stimulate demand. The EDM methodology is an example of this type of approach.

A range of tools can be used to assess demand and develop demand management strategies under the above approaches. For example, bottom-up tools include energy audits, which involve conducting a detailed evaluation of energy usage patterns and equipment use in order to identify demand as well as opportunities for energy savings and efficiency improvements. Energy intensity methods include engineering calculations - mathematical calculations to determine the energy requirements for a given system or process.

Top-down methods include use of electricity sales data and demand records from automated system monitoring. Expert analysis involves consulting with experts in the field to gain insight into energy usage patterns and potential areas for improving service delivery and energy efficiency. Simulation modelling involves creating computer simulations of energy usage patterns in order to gain insight into demand and potential improvements. Economic and demographic historical data are also used to project future demand scenaris that are difficult to capture using end-user data. An assessment of the differences between top-down and bottom-up approaches is given in Figure 4 below.

[8] For a definition and discussion on energy intensity of economies in the context of SDG7, see the SDG7 tracker at https://sdg-tracker.org/energy.

Top-down models	Bottom-up models
Use an "economic approach"	Use an "engineering approach"
Give pessimistic estimates on "best" performance	Give optimistic estimates on "best" performance
Cannot explicitly represent technologies	Allow for detailed description of technologies
Reflect available technologies adopted by the market	Reflect technical potential
The "most efficient" technologies are given by the production frontier (which is set by market behavior)	Efficient technologies can lie beyond the economic production frontier suggested by market behavior
Use aggregated data for predicting purposes	Use disaggregated data for exploring purposes
Are based on observed market behavior	Are independent of observed market behavior
Disregard the technically most efficient technologies available, thus underestimating the potential for efficiency improvements	Disregard market thresholds (hidden costs and other constraints), thus overestimating the potential for efficiency improvements
Determine energy demand through aggregate economic indices (GNP, price elasticities), but vary in addressing energy supply	Represent supply technologies in detail using disaggregated data, but vary in addressing energy consumption
Endogenize behavioral relationships	Assess costs of technological options directly
Assume there are no discontinuities in historical trends	Assume interactions between energy sector and other sectors is negligible

Figure 4: Characteristics of top-down and bottom-up approache. Source: van Beeck (1999).

The value of bottom-up approaches to assessing demand is well documented. Schramm & Munasinghe (1983) and subsequently Munasinghe (2013), drawing on decades of experience in INEP planning in developing country contexts, give the following summary of the strengths of this type of approach:

> Demand forecasts could be made either on the basis of statistical evaluations and projections of past consumption trends, or on the basis of specific micro-studies. The former approach is appropriate in industrialized nations in which data coverage is excellent and energy-consuming activities are ubiquitous, complex, as well as mature, so that changes from observed trends are slow. In most developing nations, although trend-line extrapolation is common, a micro-survey-research type approach will usually be more useful because it will yield more reliable results. This is so because statistical data are often lacking, or of poor quality Munasinghe (2013).

This insight into the significant gaps in availability, accessibility and quality of data sets required to carry out integrated energy planning in Kenya, including to assess end user demand, particularly at the sub-national level, is also supported by the experience of county energy planning in Kenya, as documented in the UK PACT CCG Working Paper on *Data Needs for County Energy Planning*. In addition to the last of secondary and primary data, Munasinghe & Schramm (1983) and Munasinghe (2013) identify further limitations to more top-down demand assessment approaches:

> [S]ectoral demand changes resulting from specific policies, such as rural electrification programs or the establishment of new industrial plants, for example, can be very substantial relative to existing demand. Such program- or project-specific effects on future demand usually cannot be forecast on the basis of observed past or present consumption data. However, such case-by-case investigations must necessarily be limited to surveys of the larger energy consumers or energy-related development programs. Both for reason of costs and time, forecasts for sectors such as urban or rural households, commercial activities, or transportation, for example, must normally be based on statistical data analysis, although specific factors such as changes in relative prices, disposable income, rate of urbanization, or sectoral production, must be specifically considered as determinants of future sectoral energy demand (ibid).

Bottom-up demand assessment can also be a useful entry point for partipatory approaches to planning and design of energy systems and interventions. The utility of this is not limited to developing country contexts. IRP, which developed originally in the USA, has a strong emphasis on participation in its best practice form (again, the realities of implementation vary widely). For example, one US Government publication targeting state-level planning, the *Guide to Community Energy Strategic Planning* (US DoE, 2013) follows similar IRP steps to those outlined above in section

4.3, and includes a strong emphasis on community participation as well as bottom-up data gathering to assess energy demand and promote consumer and stakeholder buy-in to proposed interventions.

Holistic approaches to energy needs assessment go further than just identifying the energy demand – for example, within a specific sub-sector. Such approaches involve much more intensive analysis of the non-energy interventions and supporting services that are required to deliver viable solutions to meet end-user needs, including energy services. Approaches to doing this vary significantly. Some are focussed on deploying specific products/services or technologies. Examples include the D-Lab (MIT) *Energy Needs Assessment Toolkit* (2017), which has a set of tools to guide organizations through the process of gathering and analysing information about the current energy access levels, aspirational energy needs, existing supply chain, and stakeholders in the communities of interest (focussing on identifying market opportunities).

Others start from needs identification and problem-solving to then tailor solutions to the meet the needs identified, such as the Energy Delivery Models approach (see next section). Similarly, the SELCO Foundation *Ecosystem approach* identifies household, health, education, and livelihood needs through a user centric and demand driven design approach. However, it places a particular emphasis on locally appropriate technology innovation. Other supporting pillars are affordable finance, skills and capacity, linkages to appropriate supporting partners, and the enabling policy environment.

There is also variety in scope, for instance some focus on specific sectors, or livelihood opportunities. Practical Action's Participatory Market Systems Development (PMSD) focusses mainly on identifying and meeting livelihood needs and the market systems around these. A revision of their former market analysis, the PMSD puts an increased emphasis on participation with end-users to create working market models, identifying who is being marginalised from existing or proposed market systems.

MercyCorps has developed a handbook for humanitarian agencies on *Inclusive Energy Access in Emergencies* (2020), which is intended to build the capacity of humanitarian stakeholders on assessing energy needs of displaced people and calculate demand. This includes mixed methods such as qualitative participatory ranking of needs in focus groups, and quantitative such as surveys and automated metering of usage in households. There is an overall focus on the energy service delivery rather than non-energy supporting services.

In these various approaches, there are differences in the level of participation and co-design with end users and other local stakeholders that is promoted at different stages of the planning process. The common emphasis with holistic approaches is that they have been developed with the insight that approaching energy planning solely from the perspective of energy services/ infrastructure in function of energy needs of end users and associated demand in isolation from the *overall development impact* that these services can enable, and without paying attention to the range of enabling factors or challenges/gaps that can support or hinder delivery of that impact is likely to lead to sub-optimal or failed energy services, in terms of their financial, social and environmental sustainability. This is particularly the case in remote areas where, as noted above, demand often remains low even where grid-level electrification is available.

5. The Energy Delivery Models (EDM) planning approach

The EDM approaches energy as an enabler of wider development needs and through a six-step process (see Figure 1), systematically identifies the varied needs and contexts of end users (in this case, county citizens) and the gaps or barriers preventing these priority needs being met. These gaps can involve energy or other, non-energy factors (e.g., cost of inputs or access to markets for farmers). EDM then works with end users and other stakeholders to develop context-appropriate and costed solutions for inclusion in the CEP, and to inform Least Cost Electrification (LCE) and energy efficiency (EE) investments.

Figure 5: Energy Delivery Model (EDM) 6-step government and sector-level process for county energy planning. Source: Garside & Perera (2021)

The EDM approach was developed and tested for use at the community level in Indonesia and used subsequently to design new services and review existing projects in different countries in developing Asia and sub-Saharan by NGOs, businesses, and social enterprises. More recently, it has been adapted for use at the macro-level of county energy planning in Kenya, notably to develop the Kitui County Energy Plan (CEP), which was validated in November 2021 and now a CEP for Meru County as a demonstration plan for eleven other counties under the SETA Project.

The EDM approach recognises that coordination and collaboration between different stakeholders, including at national and county level, and across sectors is vital throughout its six steps to develop needs-and evidence-based solutions that meet the priority development needs of county citizens and are financially, environmentally, and socially sustainable.

Through its inclusive methodology, EDM engages local - and relevant national - stakeholders across sectors along the planning cycle to build understanding and buy-in of both the priority needs and the solutions developed to address them. This increases the likelihood that CEPs will be taken forward to implementation through the next generation County Integrated Development Plan (CIDP) and Annual Development Plans (ADPs).

In Steps One (*Identify Starting Point*) and Two (*Be Inclusive*) of the planning process, the EDM process enagages stakeholders by:

- **Establishing buy-in and form a partnership with the County government**. This formalises the planning mandate across county government, identifies key contact points between county and national level planners and other relevant ministries, and sensitises relevant stakeholders to the planning process and activities. It also identifies initial priority focus sectors for the process. A cross-sectoral Technical Committee is established for regular review and input to the CEP process, including validation of solutions developed. While the CEP process is managed by the Department of Energy, there is a Focal Point for the whole process, which in Meru is the Director of Planning but could also be an independent actor. The Focal Point's role is to coordinate and progress actions among all actors involved in the CEP development.

- **Mapping relevant stakeholders.** The aim is to be inclusive, mapping stakeholders that will help with further data gathering, as well as participate in later stages of planning, such as the baselining and needs assessment (Step Three) and solutions design, testing and optimisation, and preparing for implementation (Steps Four to Six).

In these latter steps, ongoing engagement with national entities – government, private sector, NGOs and development partners - for data collection and sharing and to build understanding of relevant policies and sectoral programmes/projects that could support solutions development and/or implementation of CEP solutions and priority investments, including through technical assistance and co-financing, is critical.

Many of the challenges described in the Working Paper on *Coordination for County Energy Planning*, in relation to vertical coordination and collaboration, were experienced during the development of the CEPs for Kitui County and Meru County, including significant challenges with data availability and sharing.

EDM involved detailed baselining and in-depth needs assessment activities in Step Three (*Build Understanding*), using a range of research and analysis tools including secondary data gathering (literature review), primary data gathering through household surveys, Key Informant Interviews (KIIs), Ward Adminstrator surveys and community and sectoral needs assessment workshops and Focus Group Discussions (FGDs).

Once the priority development needs have been identified, energy and non-energy gaps preventing the needs being met identified and initial value propositions developed to meet the needs - Steps Four (*Design and Test)* and Five (*Review and Optimise*) – it is necessary to do the following:

- Carry out further research, data collection and analysis and visualisation to develop the components of different solutions, both energy and non-energy.
- Identify the target groups and locations for both the demonstration and the scale-up Phases and visualise which solutions will be targeted in which locations across the counties to get a picture of the county coverage of the different solutions.
- Identify and calculate the least-cost options for delivering the energy components (grid electrification vs off-grid solutions) of specific solutions. It should be noted that this could be done from different perspectives, for instance least cost grid deployment does not always equate to least cost from the end user perspective (as discussed above).
- Calculate the overall investment costs for delivering specific solutions (energy including supporting services (repair maintenance) and non-energy supporting services).

It is important to note that this must include all the supporting services and interventions needed to deliver the development impact. The Delivery Model Canvas (see Figure 5) is a innovative tool adapted from Osterwalder's Business Canvas, to support the process of identifying all the different components needed for the solution. These are categorised into the delivery infrastructure (including the key activities, outputs, resources and partners/stakeholders), the end users (including how they will be involved and how they expect to participate) and accounting (financial but equally importantly social and environmental costs and benefits). It is critical that for every component of the solution, the costs and revenue streams are identified.

Figure 6: Delivery Model Canvas. Source: Garside & Wykes (2017).

A range of other tools/approaches are used to collect and analyse data for solutions development, including KIIs, mini surveys, value chain analysis, market mapping, GIS mapping, and LCoE modelling using OnSSET.

After detailed business and investment modelling, including full cost-benefit modelling, the aim is to develop fully financially, environmentally and socially sustainable solutions. These should subsequently be further tested and optimised. It is also important to dentify where there may be dependencies between solutions (for instance, in the solutions developed for Meru CEP below, the solution to increase income from horticulture cannot be delivered without a water management component, overlapping with the solution on access to affordable clean water). It is equally important to identify co-benefits from delivering one or more solutions (e.g., whether by placing a borehole for underserved populations in proximity to a health clinic, the needs for household access to clean water and to deliver clean water for health services can also be met) and to identify any financial, social or environmental risks related to the solution and develop mitigation strategies ahead of implementation.

6. Solutions developed under the Meru County CEP

The EDM planning process for the Meru CEP identified the following six areas of priority development need:

1. Improved income from horticulture Farming
2. Improved income from poultry farming
3. Access to clean and affordable water
4. Access to basic health services
5. Access to better quality household lighting and to street lighting
6. Access to affordable, cleaner, safer and reliable cooking fuels and technologies for households

The following section summarises the solutions that were developed to meet the priority needs. For each solution, a demonstration Phase for implementation followed by a scale-up Phase to end of year five of the CIDP cycle was envisaged. The poultry, lighting and water solutions have been used for the further Phase of research outlined in Section Seven below.

6.1 Improved income from horticulture farming

This solution focusses on targeting farmers along the horticulture value chain by switching to renewable-powered irrigation for improving farmer production yield and profit through improving water management, enabling access to irrigation, better access to quality farm inputs, training on good agricultural practice (GAP) and aggregation and access to markets. In the Demonstration Phase, it will target 150 farmers, and in the Scale Up Phase, it will reach 6,000 farmers.

	Group 1 Individual micro farmer	**Group 2** River group farmers irrigating larger plots	**Group 3** Distant farmers part of piped schemes
Crop mix:	**Season 1: tomatoes. Season 2: kale. Season 3: sweet potatoe. Crop rotation optimises farmer income.**		
Irrigation solution	System size: 0.25 acre **Pump and energy system**: Submersible pump, 50M electric cable, controller, 2 x 310W solar panel, 50M (40MM) HDPE Pipe and necessary fittings **Irrigation system**: Drip tape for 2 x 1/8 acre, plus 5000 litre tank and stand **After-sales services:** maintenance, repair, and 2-year warranty for the irrigation system	System size: 1 acre **Energy system**: Dayliff Sunflo-B-500-C3 pump, 4x250W solar panels, cabling and piping, solar array mounting structure and security. **Irrigation system**: 20,000 Lts tank, 1 acre drip infrastructure, tank stand, security fencing and concrete housing for pump. **After-sales services:** maintenance, repair, and 2-year warranty for the irrigation is to be discussed with the technology suppliers and the possibility of supplying the system as a package, rather than as components, eg. with Davis & Shirtliff	System size: both (0.25 and 1 acre) **Energy and irrigation system** as described in group 1 (0.25 acre) and 2 (1 acre)

Figure 7: Horticulture solution business model. Source: Draft Meru CEP (2023).

Solution Component	Description	Unit cost (KES)	No. of farmers/acres	Total cost (KES)	Amount and Source of finance (KES)			
					Farmers	Government/ Other public funding	SACCOs /MFIs	Suppliers
Water management	Establishing water committees			517,500		517,500		
	Installation of meters (KES per meter)	17,250	142	2,449,500		2,449,500		
	Training and enforcement (KES per farmer)	11,500	142	1,633,000		1,633,000		
Inputs	Sensitisation and introductions to agro-dealers			345,000		345,000		
	Farmer inputs (1st sweet potato season) KES per acre	83,300	89	7,392,875	3,696,438	3,696,438		
Irrigation	Cost of filter (those with pump only)	3,000	71	213,000	213,000			
	Deposit for irrigation system	61,231	142	8,694,808	8,694,808			
	Financing for irrigation equipment (supplier)	60,001	36	2,130,044				2,130,044
	Financing for irrigation equipment (MFI)	113,415	142	16,104,947			16,104,947	
	End-user subsidy for irrigation equipment (50%)	178,771	142	25,385,549		25,385,549		
	Farm ponds	100,000	45	4,500,000	2,250,000	2,250,000		
Training	Training the extension officers/other	920,000	1	920,000		920,000		
	Farmer Group Training by Extension officers/suppliers	12,000	142	1,704,000	1,704,000			
	Demo farms (1 acre system)	772,780	3	2,318,340	695,502	1,622,838		
	Demo farm (0.25 acre system)	174,761	5	873,807	262,142	611,665		
Implementation, monitoring and evaluation	Project management			4,000,000		4,000,000		
	M&E			2,300,000		2,300,000		
Total (KES)				**81,482,371**	**17,515,890**	**45,731,490**	**16,104,947**	**2,130,044**
Total (USD)	**USD exchange**	**115**		**708,542**	**152,312**	**397,665**	**140,043**	**18,522**

Figure 8(a): Horticulture investment model – Demonstration Phase. Source: Draft Meru CEP (2023 .

Component	Description	Unit cost	No. of farmers/acres	Total cost (KES)	Amount and Source of finance (KES)			
					Farmers	Government/ Other public funding	SACCOs / MFIs	Suppliers
Water management	Establishing water committees			1,035,000		1,035,000		
	Installation of meters	17,250	3,000	51,750,000		51,750,000		
	Training and enforcement			11,500,000		11,500,000		
	Farmers payment / Revenue from water metering	102,188	1,500	91,968,750	91,968,750	(91,968,750)		
Inputs	Sensitisation and introductions to reliable agro-dealers			690,000		690,000		
	Farmer inputs (1st sweet pot season)	83,300	1,500	124,950,000	124,950,000			
Irrigation	Cost of filter	3,000	3,000	9,000,000	9,000,000			
	Deposit for irrigation without subsidy	118,721	1,500	178,080,758	178,080,758			
	Deposit for irrigation with subsidy (20%)	91,445	1,500	137,167,002	137,167,002			
	End-user subsidy for irrigation equipment (20%)	70,197	1,500	105,295,994		105,295,994		
	Financing for irrigation equipment (supplier - 80%)	118,829	375	44,560,854				44,560,854
	Financing for irrigation equipment (MFI - 80%)	334,776	1,125	376,623,120			376,623,120	
	Financing for irrigation equipment (supplier - 100%)	120,003	375	45,000,938				45,000,938
	Financing for irrigation equipment (MFI - 100% of balance)	292,929	1,125	329,545,230			329,545,230	
	Farm ponds	100,000	900	90,000,000	45,000,000	45,000,000		
Training	Training the extension officers (govt and out-source)	13,800,000	1	13,800,000		13,800,000		
	Farmers training	12,000	3,000	36,000,000	36,000,000			
Access to finance	Improving access to finance	3,500,000	1	3,500,000		3,500,000		
Implementation, monitoring and evaluation	Project management			10,000,000		10,000,000		
	M&E			6,000,000		6,000,000		
Total investment (KES)				**1,666,467,645**	**622,166,510**	**156,602,244**	**706,168,350**	**89,561,792**
Total investment (USD)		115		**14,491,023**	**5,410,144**	**1,361,759**	**6,140,594**	**778,798**

Figure 8(b): Horticulture investment model – Scale Up Phase. Source: Draft Meru CEP(2023).

6.2 Improved income from poultry farming

These solutions will provide poultry farmers with reliable, affordable electricity and infrastructure for incubation and brooding plus reduced cost inputs, access to finance and markets. It will target four existing model villages established under a previous development project for collective incubation and aggregation as well as individual incubation by new farmers in proximity to the villages. In the Demonstration Phase, it will target 125 farmers, rising to around 900 farmers in the Scale Up Phase. It will focus on improving governance and reactivating farmer group membership, access to improved equipment and infrastructure and improved and lower cost inputs to optimise production, farmer training, increase in extension officers and aggregation and access to markets.

Component	**Rationale**	**What and How**	
		Existing Model Village (MV)	**Individual farmer**
Membership activities	Ensure effective group functioning /planning and growth – support for governance	Re-invigorating existing MVs – sensitisation/demo farmers >200 active members	• Identifying target areas and farmer groups
Equipment	Optimise use of incubation equipment to near 100% utilisation to maximise hatch rate and reduce losses for collective incubation and brooding including - full-time MV staff employed	• Training on use of incubator • Repair/replace any broken equipment • Install new 1056 incubator (85% hatch rate) with subsidy and finance • Automated candling • After Base year, the MV invests in more incubators	• 96 solar egg incubator (90% hatch rate) • Chick brooder- - paraffin lamp • Solar lighting system - 3 power LEDs with 300 lumens total flux (100 lumens per lamp). 5 year lifetime, 6000 mAh Lithium Ferro-Phosphate (LFP) battery • All with subsidy and finance
	Provision of reliable and affordable energy to minimise spoiling	• Install diesel back-up generators and M/R • All with subsidy and finance	• SHS incl. M/R/savings for battery replacements • All with subsidy and finance
	Reduce feed costs	• Feed mill and mixer. All with subsidy and finance	n/a
	Aggregation and feed hall to provide additional space	• New aggregation hall	n/a
Inputs	Consistent supply of quality fertilised eggs	• Contracting with suppliers with capacity to meet cyclical demand. Subsidies for first 5 months until mature birds ready.	
		• Feasibility study to start a breeding farm	
	Reduce cost & secure supply meds	• Negotiate with vets for bulk purchase by MVs and farmer • Subsidies for first 5 months until mature birds ready	
	Reduce feed costs	• Negotiate with agro-dealers for bulk purchase feeds • Subsidies for first 5 months until mature birds ready	
		• Develop a feed mill and mixer at MV	• Feed from MV mill
		• Assess feasibility of own feed production	

<table>
<tr><td>Training</td><td>Improving poultry management practice, productivity & marketing
“Learn and do” & champion farmers</td><td colspan="2">• Increased EO support & specialist training of Eos, transport costs
• Flock health & disease surveillance and control
• Improved poultry breeds & management (layers, chicks, housing).
• (Re)train on equipment operation/basic maintenance
• Feed & nutrition requirements, knowledge of inputs/appliances to improve production, suppliers
• Business skills, production planning, risk & financial management, record keeping & negotiation
• Market knowledge and marketing skills</td></tr>
<tr><td rowspan="2">Access to finance</td><td></td><td colspan="2">• Access to financial services incl. SACCOs/table banking
• Subsidies for feed & fertilised egg purchase for first 5 months prior to mature birds ready for sale (50% start up fund for MV; 70% for farmers)</td></tr>
<tr><td></td><td>• 50% subsidy govt on back-up generators provided to MVs, incubator and feed mill and mixer and 50% subsidy provided on new buildings</td><td>• 50% govt and MFI financing for new 96 egg solar incubator plus paraffin brooding and solar LED lighting. To avoid market distortion, could be framed as intro discount for appliances.
• Farmer pays 10% deposit</td></tr>
<tr><td>Access to markets</td><td></td><td colspan="2">• Aggregation & support for access to new markets</td></tr>
</table>

Figure 9: Poultry solution business model. Source: Draft Meru CEP (2023)

Solution Component	Description	Cost per MV (KES)	No. of MV / farmers	Total cost (KES)	Amount and Source of finance (KES)		
					Model Village	Govt/public funding	MFIs
Model Villages							
Operation and Maintenance of MV for first 5 cycles (before mature chickens sold)	Utilities (grid and genset diesel)	307,063	1	307,063	307,063		
	Personnel	180,000	1	180,000	180,000		
	Maintenance of equipment	17,946	1	17,946	17,946		
	Administration and Governance	135,000	1	135,000	135,000		
	Marketing	62,500	1	62,500	62,500		
	Other	6,250	1	6,250	6,250		
Feasibility studies	Feasibility study/demo plot on own production of feed			1,982,259		1,982,259	
	Feasibility study - brooder farm			2,000,000		2,000,000	
Market access	Market mapping			557,510		557,510	
Total MV expenses (capex and opex for 5 cycles)				**9,618,723**	**1,571,724**	**7,786,784**	**260,214**

Solution Component	Description	Cost per model village (KES)	No. of MV / farmers	Total cost (KES)	Amount/source of finance (KES)		
					MV	Govt/ public funding	MFIs
Model Villages							
Governance/membership	Reinvigorating existing MV	185,837	1	185,837		185,837	
Inputs	Negotiation/service agreements with agro-dealers/ breeders			371,674		371,674	
	Fertilised eggs for 5 cycles	316,800	1	316,800		316,800	
	Commercial feed (for 3-week chicks)	360,701	1	360,701	180,350	180,350	
	Vaccinations	55,427	1	55,427	55,427		
	MV active farmer members - support for feed for 5 cycles	10,124	100	1,012,376	303,713	708,663	
Incubation infrastructure	Diesel genset backup	237,188	1	237,188	47,438	118,594	71,156
	Incubator (deposit, subsidy and finance)	118,319	1	118,319	23,664	59,159	35,496
Equipment	Deposit for mill and mixer	102,375	1	102,375	102,375		
	Financing for mill and mixer equipment (MFI/bank)	153,563	1	153,563			153,563
	Subsidy for mill and mixer equipment	255,938	1	255,938		255,938	
Other assets	Aggregation and feed hall/extra buildings	300,000	1	300,000	150,000	150,000	
Training	More extension officer support & specialist training plus transport costs	300,000	1	300,000		300,000	
	Member training and business supervision	600,000	1	600,000		600,000	

Figure 10 (a): Poultry solution investment model (aggregated incubation thorugh Model Villages) – Demonstration Phase. Source: Draft Meru CEP (2023)

Solution Component	Description	Cost per MV (KES)	No. of MV/ farmers	Total cost (KES)	Amount and Source of finance (KES)		
					MV/farmer	Govt/ public funding	MFIs
Individual farmers							
Identifying grouops	Identifying target areas & groups/SACCOs			111,502		111,502	
Inputs (for 5 cycles)	Fertilised eggs for 5 cycles	14,400	25	360,000		360,000	
	Feed from MV (for 5 cycles worth to maturity for 65%)	214,704	25	5,367,600	2,683,800	2,683,800	
	Mapping vet-dealers/negotiating service package	Included above					
	Support to establish bulk buying and access to finance	345,000	1	345,000		345,000	
Equipment	Deposit for incubator/lighting and brooder	4,170	25	104,260	104,260		
	Subsidy/Financing for incubator equipment (MFI)	37,534	25	938,340		521,300	417,040
Training	Training the extension officers/other	incl. above	1				
	Farmer Group Training (Y1)	12,000	25	300,000	300,000		
Total individual farmers for 5 cycles				**7,526,702**	**3,088,060**	**4,021,602**	**417,040**
Total demo costs				**17,145,425**	**4,659,784**	**11,808,386**	**677,254**
Implementation, monitoring and evaluation	Project management			4,000,000		4,000,000	
	M&E			2,477,824		2,477,824	
Total (KES)				**23,623,249**	**4,659,784**	**18,286,210**	**677,254**
Total (USD)	**USD exchange**	**123.8912**		**190,677**	**37,612**	**147,599**	**5,467**

Figure 10 (b): Poultry solution investment model (individual farmers) – Demonstration Phase. Source: Draft Meru CEP (2023)

Solution Component	Description	Unit Cost (KES)	No. of MVs/ farmers	Total cost (KES)	Amount and Source of finance (KES)		
					MVs/ Farmers	Govt/ public	MFIs
Model Villages							
Governance/membership	Re-invigorating existing model villages	185,837	3	557,510		557,510	
Inputs	Negotiation/ arrangements with agro-dealers/breeders			743,347		743,347	
	Fertilised eggs for 5 cycles for MV	316,800	3	950,400		950,400	
	Feed (for 3-week chicks) for MV	360,701	3	1,082,102	541,051	541,051	
	Vaccinations (5 cycles) for new MV	55,427	3	166,280	166,280		
Infrastructure & other equipment	Deposit for incubator (1056 eggs)	23,664	3	70,991	70,991		
	Financing for incubator kit equipment (MFI/bank)	35,496	3	106,487			106,487
	Subsidy for incubator equipment (50%)	59,159	3	177,478		177,478	
	Deposit for mill & mixer	102,375	3	307,125	307,125		
	Financing for mill and mixer equipment (MFI/bank)	153,563	3	460,688			460,688
	Subsidy for mill and mixer equipment (50%)	255,938	3	767,813		767,813	
	Diesel genset back-up	237,188	3	711,563	142,313	355,781	213,469
Other assets	Aggregation and feed hall	300,000	3	900,000	450,000	450,000	

Solution Component	Description	Unit Cost (KES)	No. of MVs/ farmers	Total cost (KES)	Amount and Source of finance (KES)		
					MVs/ Farmers	Govt/ public	MFIs
Model Villages							
Training	More extension officer support & specialist training plus transport costs	300,000	3	900,000		900,000	
Training	Member training and business supervision / Production planning -training, inputs need collation, production cycles, poultry breeds, flock health etc for one year	600,000	3	1,800,000		1,800,000	
Operation and Maintenance of MV (for 5 cycles until sale of mature birds)	Utilities (grid and genset diesel)	307,063	3	921,188	921,188		
	Personnel	180,000	3	540,000	540,000		
	Maintenance of equipment	17,946	3	53,837	53,837		
	Administration and Governance	135,000	3	405,000	405,000		
	Marketing	62,500	3	187,500	187,500		
	Other	6,250	3	18,750	18,750		
Market access	More extension officer support & specialist training plus transport costs			557,510		557,510	
Total MV expenses for capex and opex for 5 cycles		**Sub-total**		**12,385,569**	**3,804,035**	**7,800,891**	**780,643**

Figure 11 (a): Poultry solution investment model (aggregated incubation thorugh Model Villages) – Scale Up Phase. Source: Draft Meru CEP (2023)

Solution Component	Description	Unit Cost (KES)	No. of MVs/ farmers	Total cost (KES)	Amount and Source of finance (KES)		
					MVs/ Farmers	Govt/ public	MFIs
Individual Farmers							
Identifying groups	Identifying target areas and poultry groups/SACCOs to work with		1	111,502		111,502	
Inputs	Fertilised eggs for 5 cycles	14,400	75	1,080,000		1,080,000	
	Feed from MV (for 5 cycles worth to maturity for 65%)	214,704	75	16,102,800	16,102,800		
	Mapping vet-dealers/ negotiating service package	incl. above					
	Support for bulk buying & access to finance	345,000	1	345,000		345,000	
Infrastructure & other equipment	Deposit for incubator/lighting& brooder (individual farmer)	4,170	75	312,780	312,780		
	Financing for incubator equipment (MFI)	37,534	75	2,815,020		-	2,815,020
Training	Training extension officers/providers	incl. above	1				
	Farmer Group Training (Y1)	12,000	75	900,000	900,000		
Total individual farmers		**Sub-total**		**21,667,102**	**17,315,580**	**1,536,502**	**2,815,020**

Figure 11 (b): Poultry solution investment model (individual farmers) – Scale Up Phase. Source: Draft Meru CEP (2023)

6.3 Access to clean & affordable water

This solution aims to improve access to water in the lower region of Meru by promoting efficient water pumping with sustainable maintenance and repair, improved community governance of waterpoints and raising awareness on water conservation and rainwater harvesting. In the Demonstration Phase, it will target a 30% expansion over current access, rising to 60% in the Scale

Up Phase, through replacement of diesel powered boreholes to electricity (including solarized boreholes), introducing water metering, piloting community scale water purification, enhancing household purification and capacity building on water management and water resource conservation.

Solution component	Short term activities (<3years)	Medium term (4-5 years)
Piloting community scale water purification in Igembe, Tigania and Buuri	• Piloting community water purification by reverse osmosis in each ward in lower Igembe south and Central, in Tigania East. • Training water management committees on simple trouble shooting of the purification equipment • Identifying and training local technicians on operation and maintenance of water purification equipment	• Continuous annual training on water quality and conservation at the sub-county level (Igembe, Tigania and • 2-Training local solar experts on systems repair and maintenance through annually PPP e.g. in collaboration with Technical institution, equipment suppliers
Enhancing adoption of household scale water purification equipment	• Plan and implement 6 Exhibition of residential water purification technologies in every ward in target sub-counties • Create linkage and financial models to have PAYGO on water purification equipment purchase	• Annual exhibition in all the wards for residential scale water purification equipment
Capacity building on water management and water resource conservation	• 6 – Training sessions for water management committees on water resource conservation • 1 - Water conservation awareness campaigns through roadshows • Producing and distributing fliers for efficient use of water	• 18 training session on water management and conservation • 3 – roadshows on water conservation

Solution component	Short term activities (<3years) (atleast 30% of hhds are within 1km radius to borehole)	Medium term (4-5years) (atleast 60% of hhds are within 1km radius to borehole)
Replacement of diesel powered boreholes to least cost energy option for pumping	• Changing three boreholes in Athwana, Ntunene and Antuamba from diesel operated to electricity	
Expansion of electricity powered borehole in underserved regions of Igembe, Tigania and Buuri	• **63** Number of boreholes in Igembe south, central and North • **33** Number of boreholes in lower regions of Buuri • **31** number of boreholes in Tigania Central • Establishing **127** community water management committees • Training **127** community water management committees	• **126** Number of boreholes in Igembe south, central and North • **32** Number of boreholes in Tigania East and West • **57** Number of boreholes in lower regions of Buuri • Establishing **214** community water management committees • Training **214** community water management committees
Installation of water meters	• **369** digital meters installed in existing boreholes without meters • Setting up data capture protocol for water demand • Training community water management committees on meter reading and data capture • Participatory setting of metering tariffs for purified and non purified water	• Installing **213** digital water meters for new public boreholes • Training community water management committee on meter reading and data capture
Rain water harvesting and domestic scale water ponds	• **50** number of households to be supported with rain water harvesting tanks (5000l/hhd) and • **25** number of household supported with domestic scale water ponds for animals (10,000l/hhd)	• **150** number of households to be supported with rain water harvesting tanks (5000l/hhd) and • **100** number of household supported with domestic scale water ponds for animals (10,000l/hhd)

Figure 12: Water solution business model. Source: Draft Meru CEP (2023)

Phase 1			Unit cost	No.	Total (KES)	Meru/public funding (KES)	End users (KES)	Finance (KES)
Changing diesel driven boreholes to solar PV	5m3/hr @ 200m		3,709,889	5	18549445	18549445		
	8m3/hr @ 200m	200m	4,430,576	10	44305763	44305763		
	12m3/hr @ 200m	200m	6,580,540	5	32902699	32902699		
	Sub-total			**20**	**95757908**	**95757908**	**0**	**0**
Borehole expansion	5m3/hr @ 200m	200m	3,709,889	33	122426338	122426338		
	8m3/hr @ 200m	200m	4,430,576	87	385460142	385460142		
	12m3/hr @ 200m	200m	6,580,540	18	118449717	118449717		
	Sub-total			**138**	**626336196**	**626336196**	**0**	**0**
Community scale water purification	16% of daily output (m^3/day)	9.6	4,779,000	4	19116000	19116000		
	16% of daily output (m^3/day)	14.4	4,814,000	16	77024000	77024000		
	Water qia;out tests		5,000	20	100000	100000		
	Sub-total			**20**	**96240000**	**96240000**	**0**	**0**
Water meters	Bulk water meters - public borehole		75000	231	17325000	17325000		
	Bulk water meters - new boreholes		75000	138	10350000	10350000		
	Domestic water meters		3000	0	0			
	Health facility		3000	27	81000	81000		
	Kiosk		3000	369	1107000	1107000		
	Sensitisation / awareness		200000	32	6400000	6400000		
	1 year - Water fees (clean water)		214920	50	-10746000		10746000	
	1 year - Water fees (potable water)		21024	1000	-21024000		21024000	
	Sub-total				**35263000**	**35263000**	**0**	**0**

Phase 1		Unit cost	No.	Total (KES)	Meru/public funding (KES)	End users (KES)	Finance (KES)
Solar water purification	Formation of actor network for distribution system (Cash/PAYGO)	500000	1	500000	500000		
	Establishment of collaboration agreements	500000	1	500000	500000		
	Market activation activity 1: Roadshows in Igembe, Tigania and Buuri	3000000	1	3000000	1500000		1500000
	Product exhibition in the three regions (annually)	3000000	1	3000000	1500000		1500000
	Purification systems (large, piped)	50000	50	2500000		250000	2250000
	Purification systems (tabletop)	5000	200	1000000		100000	900000
	Sub-total			**9500000**	**4000000**	**250000**	**5250000**
Water management committees	Establishment of water management committees	200000	25	5000000	5000000		
	Training of water committees	200000	25	5000000	5000000		
Training technical staff		20,000	300	6,000,000	6000000		
Sub-total training and water committees				**16000000**	**16000000**	**0**	**0**
Repairs							
	Rainwater collection tanks	4200	20	84000	84000		
	Rainwater collection roofs	15000	20	300000	300000		
	Dew harvesting			0			
	Farm ponds	100000	20	2000000		2000000	
Rainwater harvesting	**Sub-total**			**2384000**	**384000**	**2000000**	**0**
Project management				20000000	20000000		
M&E				6000000	6000000		
Total (KES)				**907,481,104**	**899,981,104**	**2,250,000**	**5,250,000**
Total (USD)				7,324,823	7,264,286	18,161	42,376

Figure 13(a): Water solution investment model – Demonstration Phase. Source: Draft Meru CEP (2023)

Phase 2			Unit cost	No.	Total	Meru/public funding	End users	Finance
Borehole expansion	5m3/hr @	200m	3,709,889	57	211463674	211463674		
	8m3/hr @	200m	4,430,576	100	443057634	443057634		
	12m3/hr @	200m	6,580,540	56	368510231	368510231		
	Sub-total			**213**	**1023031539**	**1023031539**	**0**	**0**
Community scale water purification	16% of daily output (m^3/day)	9.6	4,779,000		0	0		
	16% of daily output (m^3/day)	14.4	4,814,000		0	0		
	Water quality tests		5,000	582	2910000	2910000		
	Sub-total			**0**	**2910000**	**2910000**	**0**	**0**
Water meters	Bulk water meters - public borehole		75000		0			
	Bulk water meters - new boreholes		75000	213	15975000	15975000		
	Domestic water meters		3000	5000	15000000		1500000 0	
	Health facility		3000	0	0			
	Kiosk		3000	213	639000	639000		
	Sensitisation / awareness		200000	32	6400000	6400000		
	Water fees (clean water)			50	0	0	0	
	Water fees (potable water)			1000	0	0	0	
	Sub-total			**5426**	**38014000**	**23014000**	**1500000 0**	**0**
Solar water purification	Market activation activities: Roadshows in Igembe, Tigania and Buuri		50000	1	50000			50000
	Product exhibition in the three regions (annually)		50000	1	50000			50000
	Purification systems (large, piped)		50000	1000	50000000		5000000	45000000
	Purification systems (table top)		5000	5000	25000000		2500000	22500000
	Sub-total				**75100000**	**0**	**7500000**	**67600000**

Phase 2		Unit cost	No.	Total	Meru/public funding	End users	Finance
Water management committees	Establishment of water management committees	200000	35	7000000	7000000		
	Training of water committees	200000	35	7000000	7000000		
Training technical staff		20000	300	6000000	6000000		
	Sub-total training and water committees			***20000000***	***20000000***	*0*	*0*
Repairs							
	Rainwater collection tanks	4200	500	2100000	1050000	1050000	
	Rainwater collection roofs	15000	500	7500000	3750000	3750000	
	Dew harvesting			0			
	Farm ponds	100000	500	50000000		50000000	
Rainwater harvesting	**Sub-total**			**59600000**	**4800000**	**54800000**	**0**
Project management				20000000	20000000		
M&E				6000000	6000000		
Total (KES)				**1244655539**	**1099755539**	**77300000**	**6760000 0**
Total (USD)				**10,046,360**	**8,876,78 5**	**623,93 5**	**545,64 0**

Figure 13(b): Water solution investment model – Scale Up Phase. Source: Draft Meru CEP (2023)

6.4 Access to basic health services

This solution targets level two health facilities (dispensaries) without a reliable, affordable electricity and water supply and with other non-infrastructure challenges including staff retention/recruitment, and lack of medical supplies and equipment which are hampering delivery of "good enough" outpatient services. It will prioritize selected level two facilities, at least 25 in the Demonstration Phase, rising to 50 in the Scale Up Phase, through supply of reliable electrification and essential appliances, improving water access (including provision of new dual-use boreholes, a co-benefit from the water solution), improved procurement, including more energy efficient appliances, and stock taking, staff capacity building needs assessment and training.

	Group 1 Grid connected plus back up	**Group 2** New grid connection plus back up	**Group 3** Off grid
Electricity	**Energy System**: Add 6kVA Petrol Generator to existing	**Energy System**: Single Phase Grid+6kVA Generator	**Energy System**: 3kW Solar, with 2.4kWh Battery Bank(Backup)
Water	**System**: New dual use solar borehole or piped water; 26 facilities with new solar borehole, 6 piped water (Imenti) and remaining facilities have customised solutions. **Governance:** Water Committee with L2 representation		
Appliances & equipment	• Repaired or replaced basic appliances/equipment • Supplier mapping for EE appliances • Provision of maintenance/repair & staff training • Feasibility on bulk purchase of equipment		
Medical & supplies	▪ Identification of essential medicines list for all levels ▪ Quantification to ensure optimal stocks ▪ Procurement arrangements ▪ Construction of 50 stores in level II ▪ Purchase of shelves and pallets for all level II and III ▪ Policy on service charging ▪ Training - digital stock taking & charging ▪ Community sensitisation		
Staff retention & recruitment	▪ Feasibility studies to benchmark best staff recruitment and rationalization practices ▪ Annual training and refresher courses for levels II health service providers.		

Figure 14: Health solution business model. Source: Draft Meru CEP (2023)

Component		Unit cost (KES)	No.	Total cost (KES)	Amount/Source of finance (KES)		
					Govt	Supplier/ MFIs	Other
WATER	Establishing water committees	200000	25	5,000,000	5,000,000		
	Solar borehole/installation – 26 @200m depth and 12cubic meter/hour yield	6,580,540	26	171,094	17,109,4036		
	Installation of meters	3,000	26	78,000	78,000		
	Feasibility studies water solutions (32)	200000	32	6,400,000	6,400,000		
Sub total				11,649,094			
ELECTRICITY	Backup Generators	87,000.00	30	2,610,000.00	2,610,000.00		
	New Grid Connections	90,000.00	30	2,700,000.00	2,700,000.00		
	SHS	1,363,998.37	30	40,919,951.19	40,919,951.19		
	Grid+Generator OPEX costings (year 1)	354,122.85	30	10,623,685.35	10,623,685.35		
	SHS OPEX costings (year 1)	274,970.99	30	8,249,129.67	8,249,129.67		
APPLIANCES EQUIPMENT	New appliances	406,824.00	60	24,409,440.00	24,409,440.00		
	Repair of appliances(year 1)	20,341.20	60	1,220,472.00	1,220,472.00		
	Annual Maintenance	40,682.40	60	2,440,944.00	2,440,944.00		
Training	Training in appliance operation/maintenance	Lump sum					
	Training - digital stock taking & charging						
	Benchmarking of staff R & R best practice						
STAFF R & R	Training needs/benchmarking			50,000,000	50,000,000		
Sub total				143,173,622	143,173,622		
	Project management			4,000,000			4,000,000
	M&E			2,300,000			2,300,000
	Total (KES)			**149,473,622**	**149,473,622**		
	Total (USD)			**1,185358**			

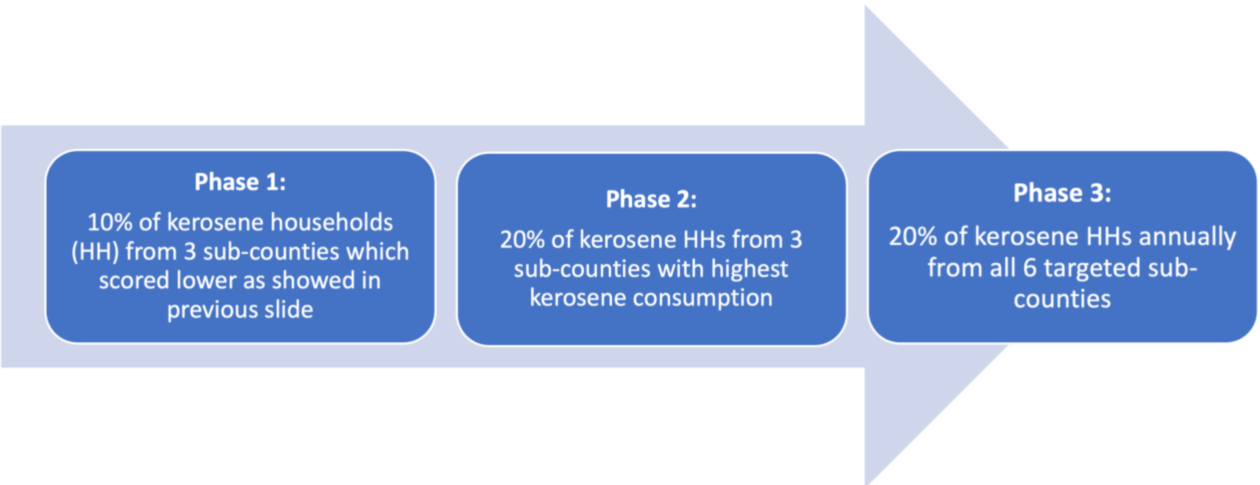
Figure 15: Health solution investment model – Scale Up Phase. Source: Draft Meru CEP (2023)

6.5 Access to household lighting (Tier One)

This solution builds on LCoE planning carried out for the Meru CEP, working with KPLC, to map current grid and plans for future grid expansion and to develop scenarios to deliver different levels of access to electricity aligned with the World Bank Multi-Tier framework for Measuring Energy Access (MTF). This analysis showed that significant impacts could be delivered by moving kerosene users to solar home systems. The aim is to target 3,600 users in the Demonstration Phase rising to 12,500 in the Scale up Phase. In addition, a county plan on street-light/floodlight deployment annually over 5 years (CIDP period) will be developed, with a strategy to train technicians. This component could be a cross-cutting supporting service for other solutions involving deployment of SHS (horticulture, poultry, health).

System	Sunking Home 200X	
Payment terms	**Current Scenario (market price)**	**Proposed model (similar to grid) per unit**
Cash Price	11,000 KES	Bulk pricing with direct importation (landed cost 10,000 KES)
Project admin costs (20% factor of unit price)		2,000 KES
PAYGO deposit	1,600 KES	1,000 KES (connection fees)
Daily payment	50 KES	10 KES
No. of days for ful repayment	384 days	1,100 days Full payback in 3 yrs. From yr 4, start to raise cash for replacement products
Total price	**PAYGO: 20,800KES**	**LEASE MODEL:12,000 KES**
% price difference cash vs PAYGO	89.09% (20,800 KES vs 12,000 KES)	

Figure 16: Household lighting solution business model. Source: Draft Meru CEP (2023)



Description	Phase 1	Phase 2	Phase 3
No. of targeted HHs	3,600	7,200	12,500
a) Bulk purchase T1 system (KES)	43,200,000	86,400,000	150,000,000
b) Project management (KES)	2,100,000	5,600,000	7,000,000
c) M&E cost (KES)	2,300,000	4,600,000	7,200,000
Supporting public finance (energy docket – b + c)*	**4,400,000**	**10,200,000**	**14,200,000**

Figure 17: Household lighting solution investment model. Source: Draft Meru CEP (2023)

6.6 Access to clean cooking solutions

This solution has not been developed into a fully costed investment model given the significant data gaps on consumption, and the drivers of end-user practices and preferences for fuels and technologies, at the granular sub county and ward level needed to develop sustainable solutions. However, different pathways to move different types of end-users onto cleaner cooking pathways have been identified with a suggested priority for moving firewood users onto improved cookstoves proposed. Further research and discussion is needed with the County Government to develop appropriate solutions and develop viable business models and fully costed investment models.

CIDP priorities	Solution component	What	Why (aim) and how
Provision of clean energy **Development of energy policies**	**Targeted support to HH using rudimentary cooking solution (firewood and charcoal traditional stoves (A)**	A. Transition to cleaner/efficient cooking solution (use of ICS) B. Transition to cleaner fuels + cooking technologies	• Achieve transition to cleaner/clean cooking solution:- • Identify the most viable and cost-effective transition pathway to cleaner and clean cooking solutions. • Public awareness and sensitization initiative of benefits of using cleaner/clean cooking solutions • Undertake feasibility studies to understand better the different transition pathways • Analysis of different models to determine the most viable path including looking at aspects like costs of different fuels and cookstoves, proximity to existing forests, socio-cultural and habitual factors, ability to pay by end user, ability to transition, fuel switching costs) • Train local artisans in quality production and installation of ICS+ repair &

			maintenance of cooking technologies – marketing skills
	Support to HH currently purchasing solid biomass fuels +use ICS (B)	A. Transition to higher tier stoves and fuels	Achieve transition to cleaner cooking solutions and universal access to clean, affordable, faster and safer cooking solutions: • Promote transition to use of charcoal and ICS for those using purchased firewood • Public awareness and sensitization initiative of benefits of using cleaner/clean cooking solutions • Undertake feasibility studies to understand better the different transition pathways • Analysis of different models will be done to determine the most viable path including looking at aspects like costs of different cooking solution, socio-cultural and habitual factors
		B. Transition to clean cooking solutions	Promote transition to modern and clean cooking solutions for those using charcoal +ICS. • Public awareness and sensitization initiative of benefits of using cleaner/clean cooking solutions • Undertake feasibility studies to understand better the different transition pathways Analysis of different models will be done to determine the most viable path including looking at aspects like costs of different cooking solution, socio-cultural and habitual factors
	Support HH using Kerosene and LPG (C)	A. Transition from using kerosene to clean cooking solution	Achieve universal access to clean, affordable, faster, and safer cooking solutions:- • Public awareness and sensitization initiative of benefits of using cleaner/clean cooking solutions

		B. Switch from one clean cooking solution to another	• Undertake feasibility studies to understand different transition pathways Analysis of different models will be done to determine the most viable path including looking at aspects like costs of different cooking solution, socio-cultural and habitual factors

Figure 18: Cooking solutions transition pathways. Source: Draft Meru CEP (2023)

Improved woodstoves names/brands	Yr1: 10% of HH	Yr2: 20% of HH	Yr3: 30% of HH	Yr4: 20% of HH	Yr5: 10% of HH	Yr6: 10% of HH
Maendeleo Jiko fixed	20,196	40,393	60,589	40,393	20,196	20,196
Maendeleo Jiko portable	4,327	8,655	12,983	8,655	4,327	4,327
Jiko Smart **Kuni Okoa** **Jiko Dura** Supersaver	4,327	8,655	12,983	8,655	4,327	4,327.

Improved woodstoves names/brands	Yr1: 10% of HH	Yr2: 20% of HH	Yr3: 30% of HH	Yr4: 20% of HH	Yr5: 10% of HH	Yr6: 10% of HH
Maendeleo Jiko fixed	70,687,811	141,375,623	212,063,434	141,375,623	70,687,811	70,687,811
Maendeleo Jiko portable	6,491,737	12,983,475	19,475,213	12,983,475	6,491,737	6,491,737
Jiko Smart **Kuni Okoa** **Jiko Dura** Supersaver	20,773,560	41,547,121	62,320,682	41,547,121	20,773,560	20,773,560

Figure 19: Cooking solutions potential investment model. Source: Draft Meru CEP (2023)

7. Analysis and visualisation of solutions to inform investment decision making

7.1 Rationale and use case for visualisation and modelling of Meru CEP solutions

The solutions developed for the Meru CEP included detailed costings and investment models for both Demonstration and Scale Up Phases of solution implementation. This includes allocation of multi-year county government budget allocation and financing support in principle from Meru Microfinance Institute (MFI) and Meru County Investment Development Corporation (MCIDC) for different solution implementation activities and outputs. These financing sources have been integrated into the Meru County Integrated Development Plan (CIDP) 2023-28, and financial planning for the first year of implementation (2023-24) will now begin through the Annual Development Plan (ADP) process.

The first aim of the research reported in this paper is to explore the use of different tools that can enable Meru County Government (and national energy planners in the context of Kenya's draft INEP) to understand the investment costs and options proposed under the CEP solutions. This means understanding the implementation costs of the solutions during the Demonstration and Scale Up Phases, as well as the aggregate costs for implementation of both Phases, and the breakdown of investment costs per sub county, according to the locations where the solutions are to be deployed. The latter analysis can only be carried out for those solutions that have already identified, at a minimum, the sub-county locations for deployment of the solution. Some solutions, such as health and livestock (poultry), have already identified the specific locations (including GPS coordinates) for deployment of solutions over the two implementation Phases.

The categories outputs envisaged under this first activity of supporting understanding of investment costs and options are as follows:

Activity One – visualising individual solution and aggregate investment costs

a. County-wide visualisation or GIS mapping of each sectoral solution showing the locations where it will be deployed and its associated investment costs (energy and non-energy). There will be three layers showing the individual Demonstration and Scale Up Phases, and an aggregation of both.

b. Visualisation or GIS mapping showing the deployment of solutions, the locations and associated investment costs *per sub-county*.

Activity Two – identifying least cost electrification options

c. GIS mapping for several of the solutions (health and water) where the costs of either an on-grid or off-grid energy solution component have been calculated (including operation and maintenance) and the locations of deployment (i.e., level two health facility or borehole location respectively) identified, to analyse which type of solution would be most appropriate for which location.

Activity Three – visualising investment costs and co-benefits of bundling solution components

d. Additional maps enabling the county government and other co-financier or investors to visualise and aggregate the costs of different categories of activities (solution components) at county and sub-county level (e.g., training; access to finance etc). This will enable (co-)funders or investors to understand the costs of delivering these components not just for one solution but bundled across solutions, at a county or sub-county wide scale, to identify co-benefits or economies of scale. For instance, maintenance and repair of SHS is a component of several solutions. This could be funded as a cross-cutting function involving training of local technicians by County Government or through a private-public partnership with a SHS or solar appliance business. Equally, if access to micro finance at more affordable rates is a component of several solutions, then a finance provider (e.g, Meru MFI) might be more interested in financing these products if they are bundled. Such visualisation could also support negotiations on bulk purchase agreements for county wide use of particular appliances or equipment etc.

Activity Four – estimating aggregate county energy demand

a. The team will use modelling tools (e.g., OnSSET; see below) to aggregate the energy components of all the CEP solutions in the Demonstration and Scale Up Phases in specific locations (wards or sub counties) to estimate the "energy demand" or potential load in that location. This will build an picture of aggregate demand by identifying the potential load from deploying X number of electrified boreholes, health clinics, model village incubation hubs, crop irrigation systems, household lighting solutions and so on. The team will then try to estimate the least cost electrification options for each location (ward or sub-county), and to identify which agency or level of government could deliver them (depending on whether these are on or off-grid solutions).

It is important to highlight that the CEP solutions developed and the related energy demand identified through the EDM process do not cover *all* economic sectors in the county and *all* potential demand for energy services - and the EDM process does not intend to. It is explicitly designed for planners and end users (in this case county government and citizens) to identify and *prioritise* development needs, in function of the reality of the limited resources available to deliver development plans and projects (in this case, CIDPs and the CEPs aligned with them). For this reason, in order to build a more comprehensive picture of county energy demand, the following additional research and modelling will be undertaken:

b. Modelling of potential locations in Meru County where market centres could be developed, informed by the deployment of the EDM solutions in different county locations and their associated energy demand profile and by other data inputs, as well as the potential demand from other key development sectors that were not idenitified as priorities in the EDM CEP process (e.g., education).

However, it should be noted, again, that research and insights from practitioner experience shows that neither the overall development impact that the solutions seek to deliver, nor the identified demand for energy services will *automatically* follow from providing energy infrastructure and services alone (for instance, Bonan, Pareglio, & Tavoni, 2017 & Sustainable Energy for All and Power for All, 2017).

There is a need to proactively *build demand* for energy services and products among end users by delivering a holistic solution that includes other non-energy supporting interventions (IIED, 2017). So in the case of delivering power for irrigation of cash crops by farmers, without supporting interventions such as further Good Agricultural Practice (GAP) training, access to finance for both the energy system and inputs, innovations in water management and usage, and consistent access to markets, the development impact of improving incomes and the demand for power for irrigation will not materialise.

7.2 Methodology

For the current report, data from three solutions was used: poultry and lighting for mapping under activity one and water for mapping under activity two. The investment costs for poultry were fully mapped (county-wide and per sub-county) because the locations for the implementation Phases are clearly identified. The lighting solution locations are less granular, as only sub-counties where the solutions will be undertaken are identified (specific locations will be selected by county government during implementation planning). The water data used for activity two also included the GPS coordinates for the implementation locations of the solutions.

The first step was to convert the EDM demand data collected to raster format that can be used with energy planning tools such as Open-Source Spatial Electrification Tool (OnSSET)[9], Model for Analysis of Energy Demand (MAED)[10] and Energy Access Explorer (EAE).[11]

The work to produce the GIS files for Activity Four is yet to be completed. The plan is to develop demand data using various tools, included exploration of OnSSET, MAED and EAE. OnSSET, for example, has a feature for considering productive uses of energy in developing least cost electrification pathways. We will produce raster files to represent the demand from solutions suggested in health, education, poultry, lighting and agriculture. The expected challenges include where there is a lack of specific location coordinates due to the stage of implementation planning. This might lead to very low-resolution datasets. However, we will work further with the county government to pinpoint where the solutions will be implemented.

In addition, we will aim to estimate additional demand from education (which was not identified as a priority need sector under the EDM process) and market centres. Energy demand from the education sector will be based on the number of unelectrified educational facilities in the county, while demand from potential market centres will depend on the plans by the county government to establish new market centres or to electrify already existing market centres. Publically available datasets and, if available, additional data from the Meru County Government, will be used to calculate energy demand from educational facilities and market centres.

Once the various raster files have been developed, OnSSET will be used for modelling the data and showing how integrating these new solutions affects the least cost electrification mix, that is, the investment costs of grid extension, minigrids and standalone energy supply systems.

A final stage could involve exploring the development of an interactive, web-based platform or Graphical User Interface (GUI) to visualise the various solutions developed and the various pathways for electrification. This could allow county and national planners and other stakeholders, including potential co-financiers, to visualise the deployment of the CEP solutions, to analyse different electrification and investment options, and to decide and prioritise investments and investment locations. It should be noted that investment decisions will also depend on other decision-making factors and criteria (e.g., alignment with CIDP programmes, geographical spread, inclusion of marginalised groups etc.).

8. Current Outputs

The outputs achieved are visualisation of investment costs and electrification costs and options for solutions for water, health, poultry and lighting as outlined above.

For reference, Figure 20 shows the nine Meru sub counties.

9 http://www.onsset.org/about.html
10 https://www.iaea.org/publications/7430/model-for-analysis-of-energy-demand-maed-2
11 https://www.energyaccessexplorer.org/about/

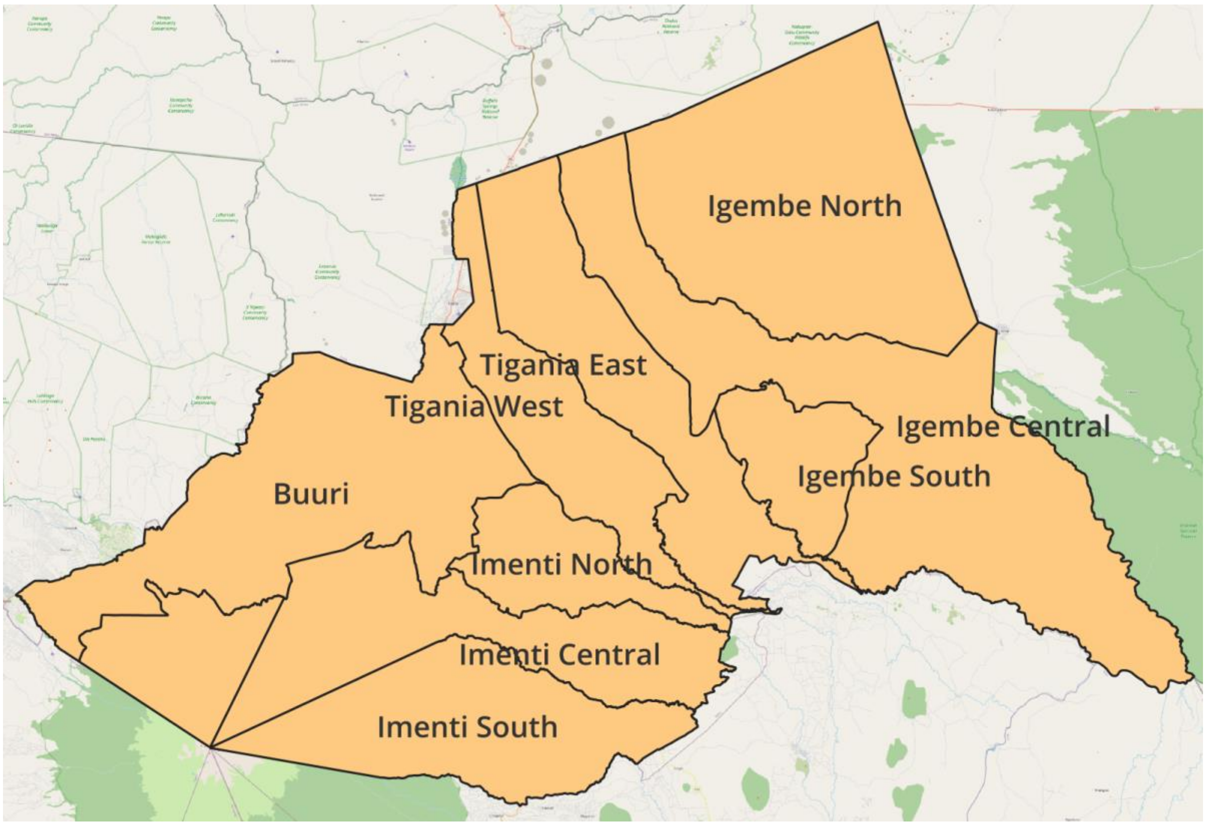


Figure 20: Sub counties in Meru County

Output one: visualisation of county and sub-county investment costs for poultry solutions

The poultry solution involved aggregation for incubation through four model villages that had already been established by a previous project. These villages would collectively serve a group of farmers, and each would also serve up to 25 individual poultry farmers who would carry out an individual incubation model in the surrounding. The four model villages are located in Kangeta, Ntalami, Ngonyi and Mbaria as shown in Figure 21.

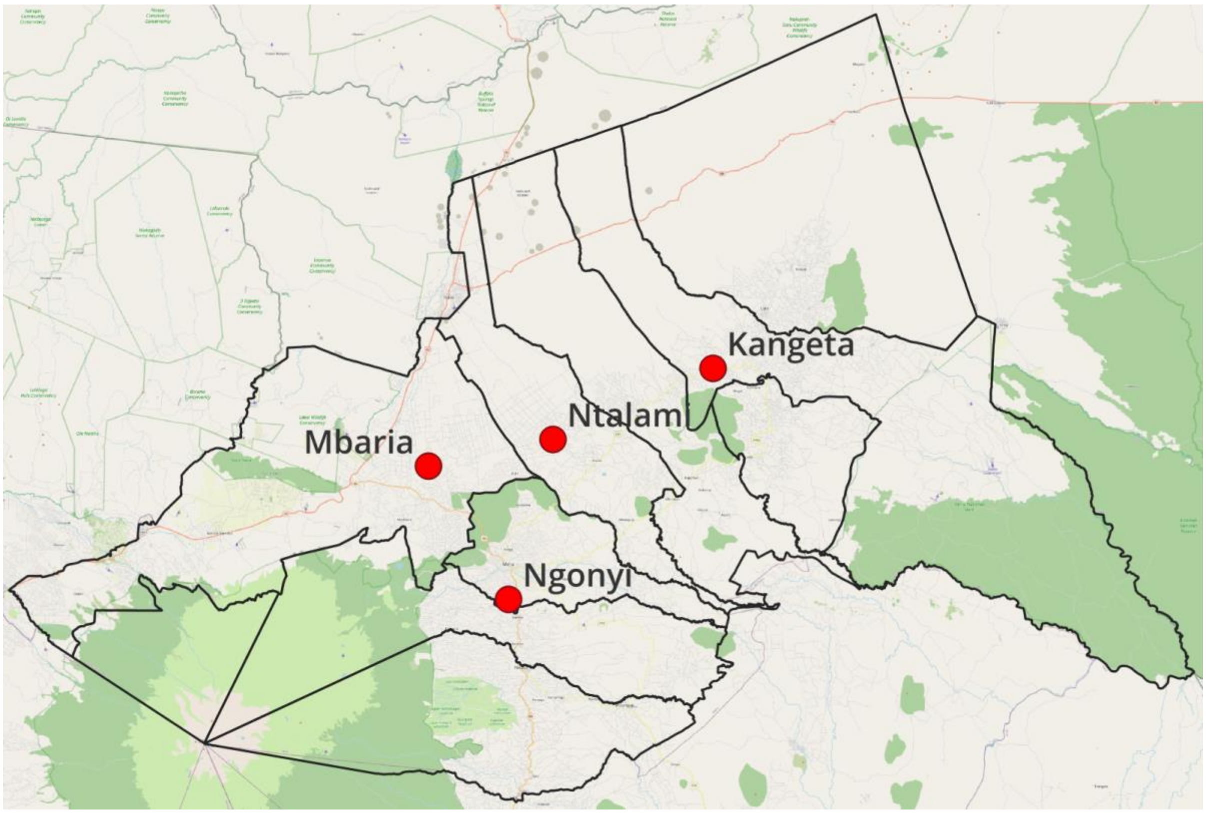


Figure 21: Location of poultry Model Villages

The solution implementation is to take place in two Phases, the Demonstration Phase, and the Scale Up Phase. The first will cost KES 23.6 million. The Kangeta model village located in Igembe central was selected for the Demonstration Phase. The associated sub county costs for this Phase are as shown in Figure 22.

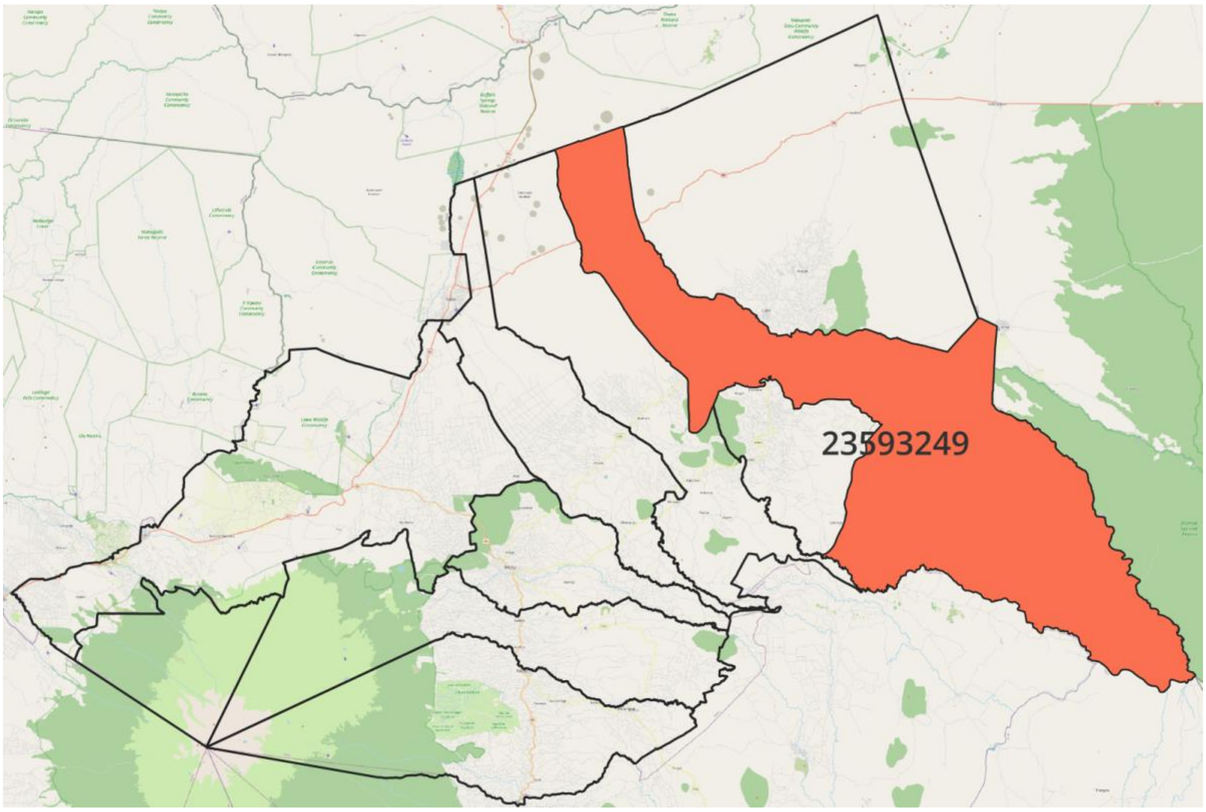


Figure 22: Poultry costs per subcounty in Demonstration Phase (KES)

The Scale Up Phase involves implementing the solution in the remaining villages to both serve a group of farmers and to support a further 25 individual incubation farmers in the surrounding area (75 total). The total cost of this base was KES 50 million which was divided among the three model villages to give KES 16.7 million for each of the model villages. The distribution of the scale up costs in the sub counties is as shown in Figure 23. The sub counties covered in this Phase are Tigania West, Buuri and Imenti North.

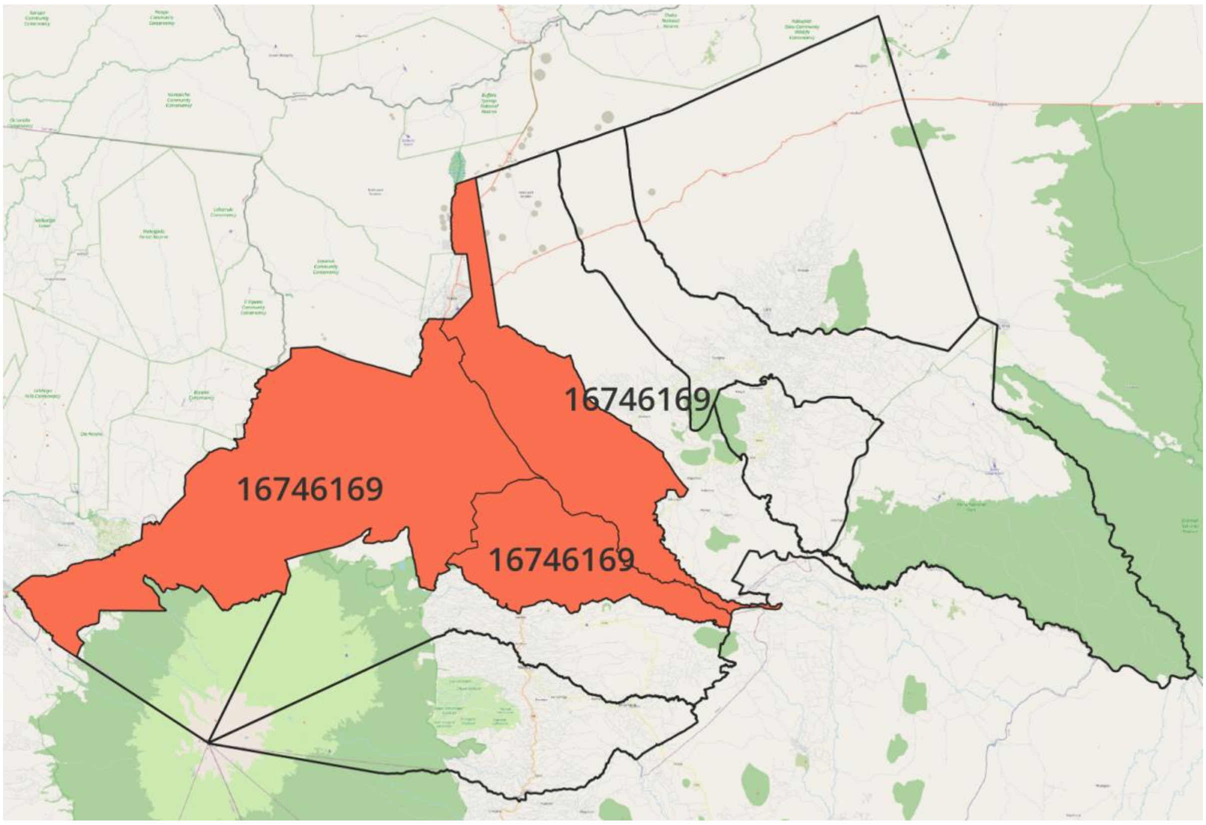


Figure 22: Poultry investment costs per subcounty in Scale Up Phase (KES)

Output two: Identifying electrification costs for household lighting solutions

The lighting solutions involves replacing kerosene lighting with offgrid solar lighting. The solution has three Phases: Phase 1 involves connecting 10% of targeted households in three sub counties, Phase 2 involves connecting 20% additional households in the sub counties considered in Phase 1, and Phase 3 involves connecting 20% of targeted households in five sub counties.

Phase 1 sub counties are Tigania West, Tigania East and Igembe North. The connection costs were calculated at the rate of KES 12,000 per household connection, therefore, the costs obtained correspond to the households connected. The costs for Phase 1 are as shown in Figure 24.

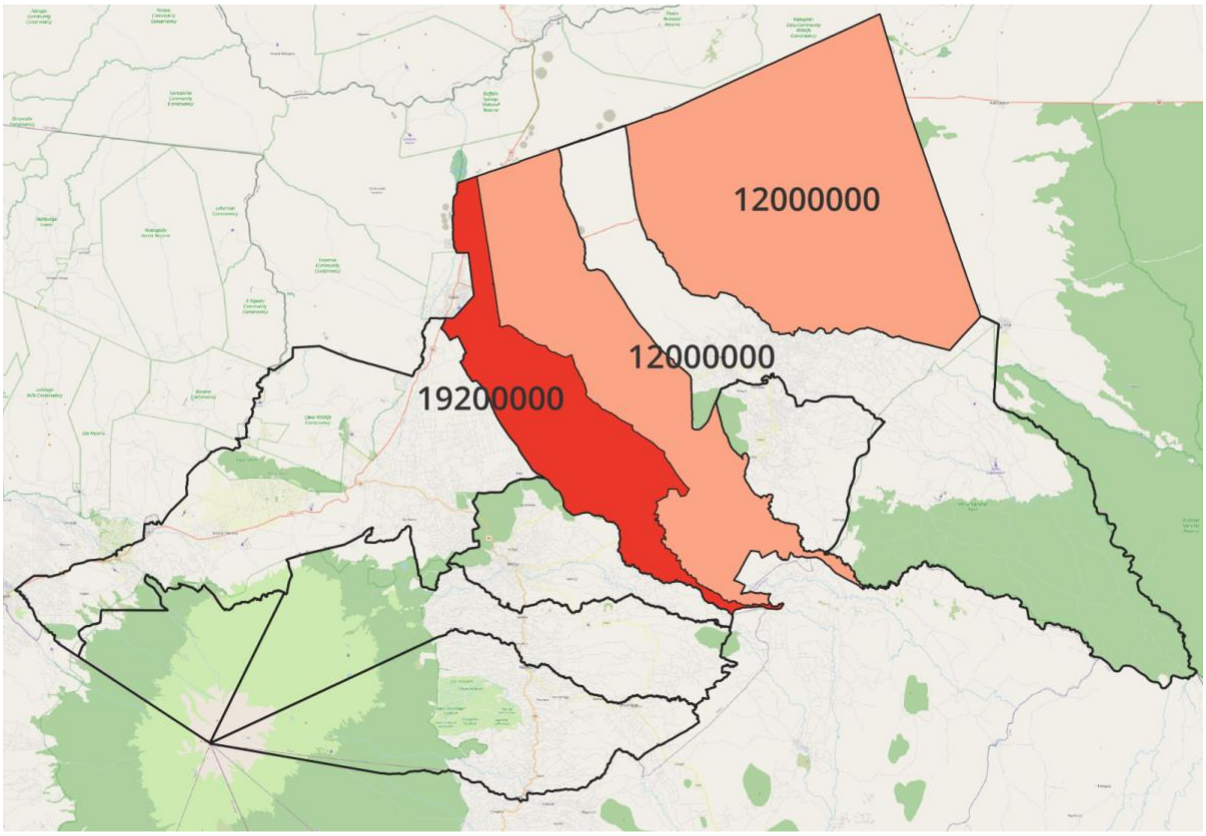


Figure 24: Lighting Costs per sub county in Phase 1 in KES

Phase 2 involved similar counties as Phase 1. However, in this case 20% of the households were connected. The costs are as shown in Figure 25.

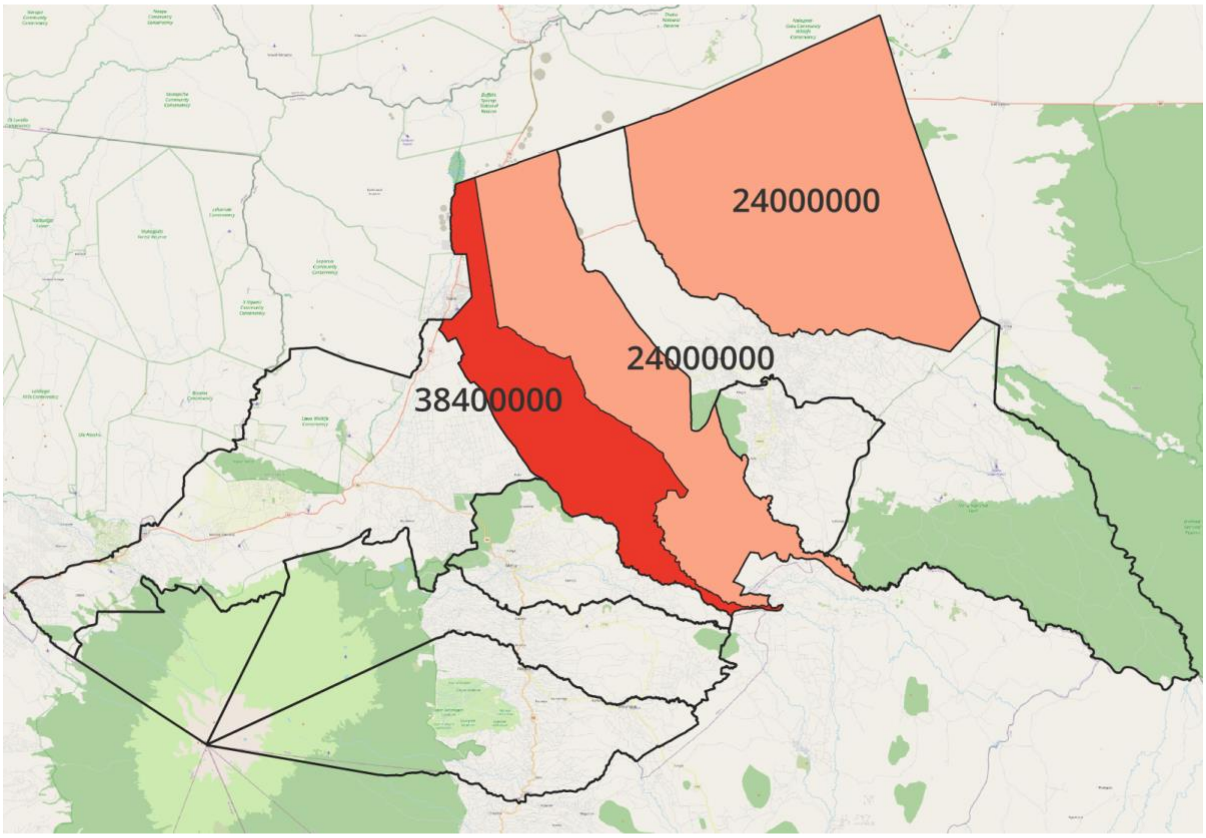


Figure 25: Lighting Costs per sub county in Phase 2 (KES)

The connections for Phase 3 increased from three to five sub counties as shown in Figure 26. The additional sub counties in this Phase are Buuri and Igembe Central.

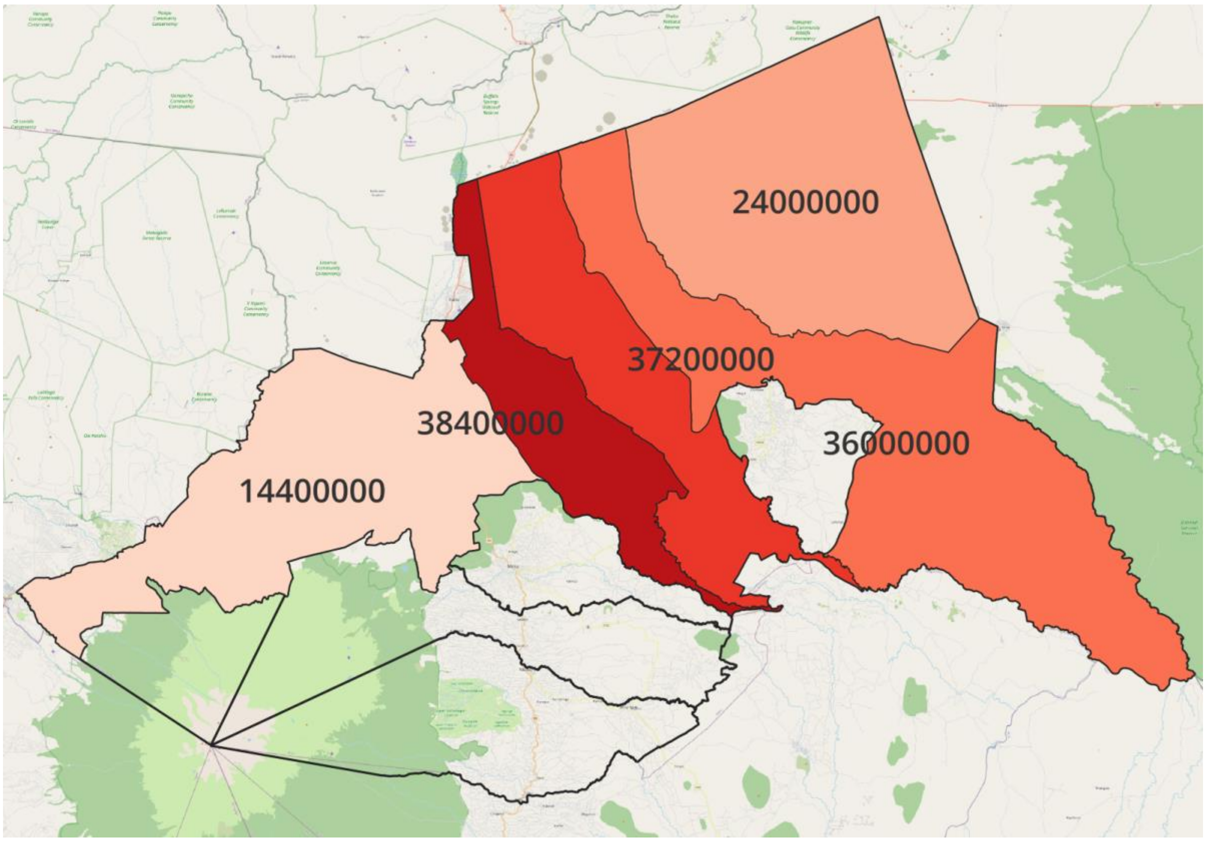


Figure 26: Lighting Costs per sub county in Phase 3 (KES)

Output three: Identifying electrification options and costs for water solution

The water solution has three components. First is solarisation of diesel-powered boreholes, second is provision of new boreholes and third is water purification of community water. There are twenty boreholes to be solarised, eight new boreholes and six purification centres to be installed. The costs for the boreholes were approximated based on the yield of the boreholes. In this case, the costs only include the capital costs of installing the boreholes. The mapping of the solution was undertaken using python programming and quantum geographic information system (QGIS) software.[12] The code and the files used for the mapping can be found on Github. The location of all the boreholes in the county is as shown in Figure 27.

12 https://qgis.org/en/site/about/index.html

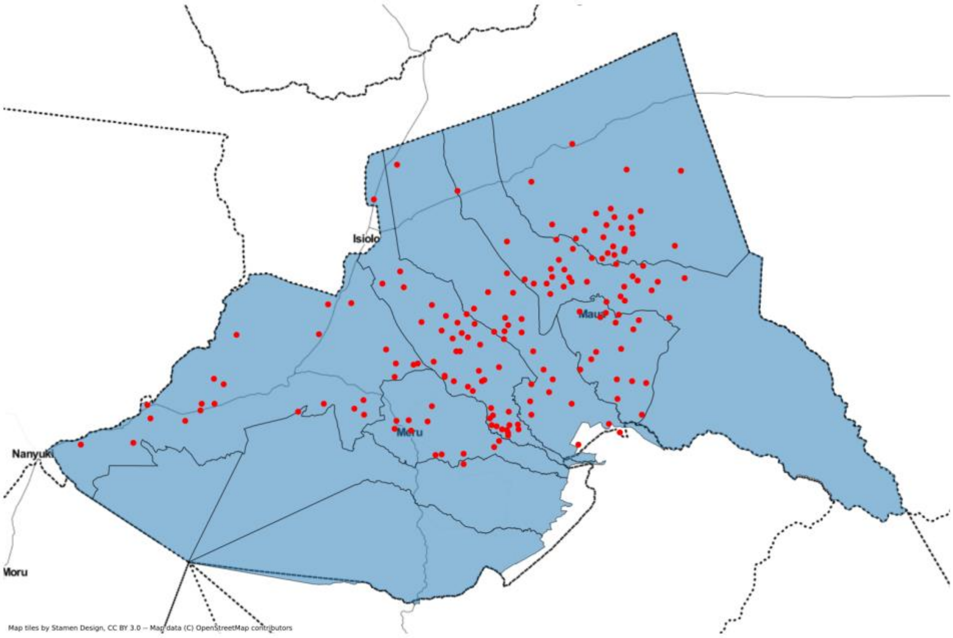


Figure 27: Distribution of boreholes in Meru County

For solarisation, the cost was determined based on the average borehole yield and depth in the county. The solarisation costs per sub county are as shown in Figure 28. The highest investment cost of KES 53.1 million will be required in Igembe Central sub county.

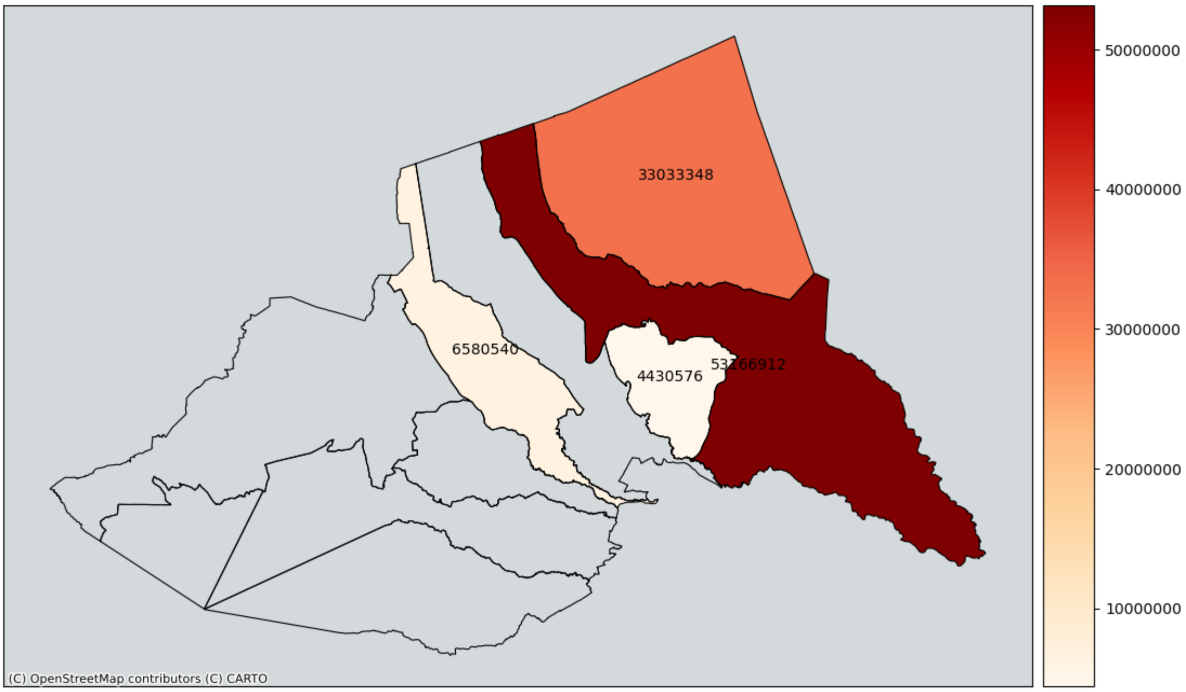


Figure 28: Investment costs for solarisation of boreholes (KES)

The borehole installation was to be done in two Phases. The costs for Phase 1 (demonstration) are as shown in Figure 29 while those for Phase 2 (scale up) are as shown in Figure 29. For Phase 1, the highest investment of 137.3 million will be required in Tigania East. For Phase 2, the highest investment of 368.5 million will be required in Igembe North sub county.

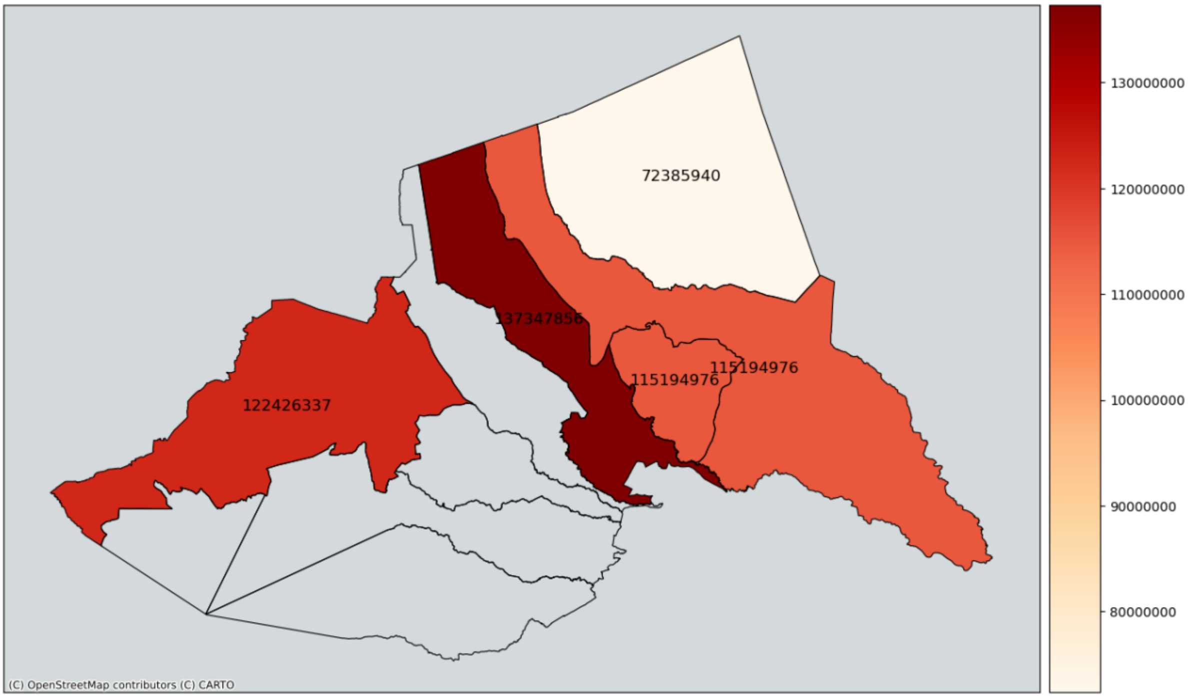


Figure 29: New borehole investment costs for Phase 1 (KES)

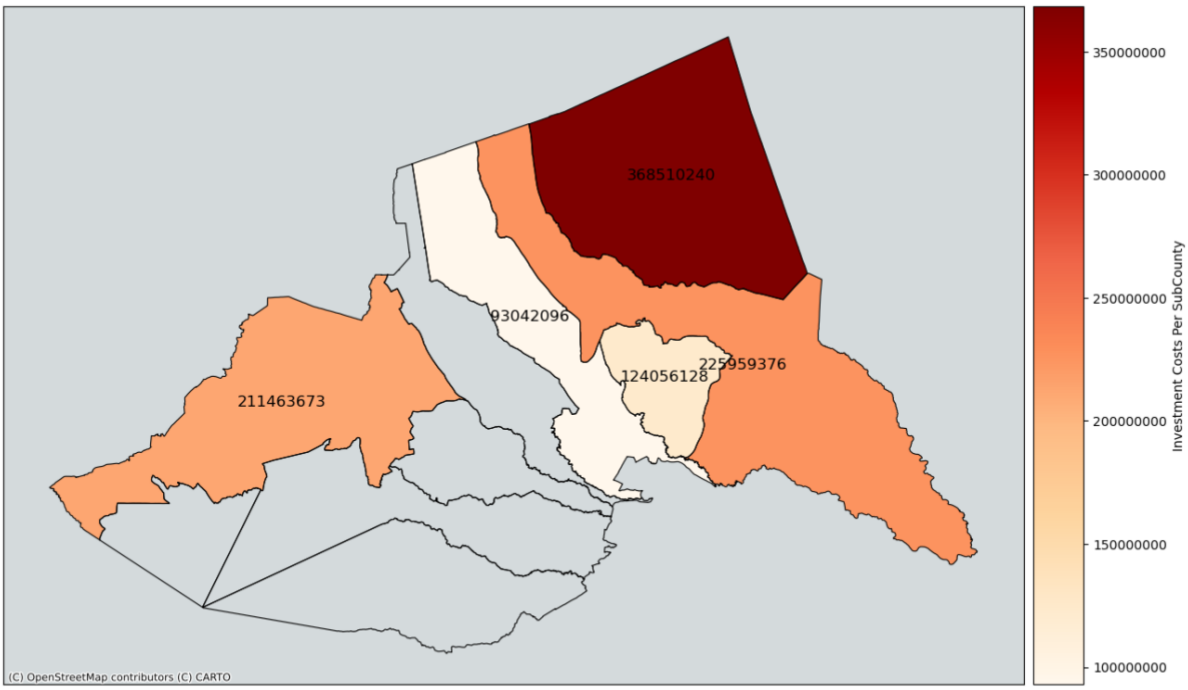


Figure 30: New borehole investment costs for Phase 2 (KES)

The costs for water purification per subcounty are as shown in Figure 31. The highest cost of KES 67.7 million will be required in Igembe South sub county.

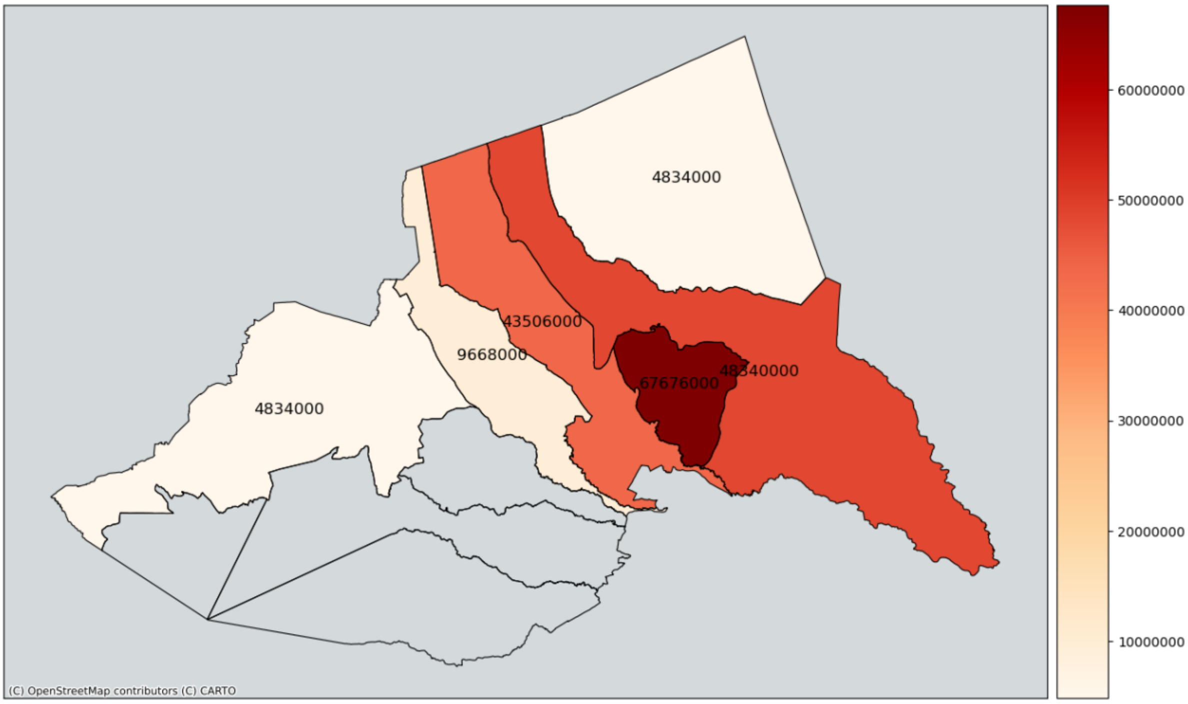


Figure 31: Water purification costs (KES)

9. Future research

The next steps undertaken will be to complete Activities One and Two above for all the sectoral solutions (where feasible). In the case of health, the specific locations of the priority level two facilities to be targeted under the solution 50 are already identified and the costs of the three energy solution options have been calculated (namely, on grid with existing connection and back-up system; on grid with new connection and back-up system; or off grid SHS with battery). Under Activity two, the most appropriate solution for each location will be identified (following the methodology outlined for the water solution electrification mapping above). For the horticulture solution, the identification of specific locations for implementation are yet to be decided as part of Demonstration Phase planning, although the targeted sub counties are identified. For the cooking solution, aggregate investment costs for the priority pathway identified of moving users from firewood to improved cook stoves (ICS) have been calculated but no locations for deployment have been identified.

Additional mapping under Activity Three will be undertaken to visualise and aggregate the costs of different categories of activities (solution components) at county and sub-county level (e.g., training; access to finance etc).

Finally, modelling will be done under Activity Four, starting with creating raster datasets to estimate county energy demand resulting from the proposed EDM sectoral solution (health, water, agriculture, poultry, lighting) as well as additional data for demand from the education sector and market centres. Using the demand datasets developed, OnSSET will be used to generate least cost electrification pathways for Meru County. The findings of the next stage of research on how EDM data can be converted or “translated” into GIS energy demand datasets for use with planning tools such as OnSSET, MAED, EAE and Open-Source Energy Modelling System (OSeMOSYS),[13] the opportunities

13 http://www.osemosys.org/

and challenges, using Meru County CEP solutions as a case study, will be written up in two outputs: first, an academic paper and, second, a briefing for policy makers.

If there is sufficient time and resource available, the team will explore options for the development of a web-based interactive tools (or a GUI) to support planning and investment decision making in relation to the sectoral solutions developed under the EDM planning process and potential services and investments needed to meet other potential demand from the education sector and market centres.

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