ENERGY DELIVERY MODELS

Using the EDM toolkit to analyse impact:

a small-scale horticulture project in Kenya

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The Energy Delivery Models (EDM) project is a collaboration between CAFOD and IIED that began in 2013. It aims to build our organisations' and partners' understanding of the enabling factors and barriers to delivering energy services to people living in poverty, learning from practitioner experience and research what factors can make or break a sustainable service. The EDM toolkit was developed after further research and piloting in 2017. It is a six-step process with two innovative tools focusing on inclusive planning and systematic problem solving. It aims to ensure the service is appropriate to the local context, meets end users' wider needs and is financially, socially and environmentally sustainable, to deliver maximum impact. The EDM toolkit can be used to design new energy services as well as to reflect on and improve existing services.

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Kenya Kitui region map: Paul Wooton

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ACRONYMS and ABBREVIATIONS

ACP-EU	African, Caribbean and Pacific European Union
CAFOD	Catholic Agency for Overseas Development
CB-GEP	Community Based Green Energy Project
EDM	energy delivery model
EU	European Union
FGD	focus group discussion
IIED	International Institute for Environment and Development
KES	Kenyan shilling
KNBS	Kenyan National Bureau of Statistics
MFI	micro-finance institution
NGO	non-governmental organisation
PPP	purchasing power parity
USD	American dollar
SACCO	savings and credit co-operative organisation

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Abstract

Access to modern energy services is vital for poverty alleviation and human development. In Kenya the agricultural sector has significant potential but is hampered by lack of electricity and water availability. From 2011 to 2014, CAFOD and local partners implemented a Community Based Green Energy Project aimed at addressing some of these challenges by providing energy services for rural and peri-urban communities.

One component involved providing greenhouses, solar-powered pumping systems and supporting services to 56 women farmer groups. This study reviews the project's impact on a sample of farmers groups in Kitui county. It uses the CAFOD and IIED 'energy delivery model' toolkit to analyse the project's impacts, using the learning to identify how challenges can be overcome, and future project design improved.

Executive summary

Access to modern energy services is vital for poverty alleviation and wider economic and human development, as recognised by the United Nations' Sustainable Development Goal (SDG) 7. Access via distributed energy solutions powered by renewable sources is often the most viable and cost effective for communities living in energy poverty. It provides a 'win-win' opportunity for both local development and for environmental protection, helping to address climate change.

In Kenya only 36 per cent of the population has access to electricity; in rural areas this drops to 12.6 per cent. The agricultural sector, particularly rural smallholder farming, has the potential to play a central role in development and alleviating poverty, but is held back by a lack of access to modern energy services for productive uses and reliable water sources. This is especially true of Kenya's arid and semi-arid rural areas, home to the poorest people. Few farmers can afford to irrigate their crops, and low rainfall means that rainfed agriculture is increasingly unsustainable. There is a strong case for adopting irrigation and crop cultivation methods that combine judicious water use with increased yields and for providing distributed renewable energy solutions to power more sustainable and productive agriculture.

Between 2011 and 2014, CAFOD and partners tried to address this water-energy-agriculture challenge in Kenya as one aspect of a Community Based Green Energy Project (CB-GEP). The project worked with 56 women's farming groups to increase their incomes and reduce environmental degradation by providing the groups with greenhouses equipped with solar-powered water pumps and drip irrigation facilities for horticulture production, along with a range of supporting services.

This report analyses this greenhouse component of the project using the energy delivery model (EDM) toolkit, the foundations of which were developed by IIED and CAFOD in 2013. The EDM is a participatory framework for designing energy services for poor men and women, building on the insights of previous practice and research. It aims to ensure end users are fully involved in the design of the energy service, so the service is customised to meet the end users' needs and local context and financially, socially and environmentally sustainable, delivering maximum impact.

The approach involves a six-step process, supported by two innovative tools (the Delivery Model Map and Canvas) to articulate the value proposition and develop it taking into account socio-cultural aspects and the enabling environment. The EDM toolkit can be used not just as a design tool by project/service developers and end users but, as in this case, to review existing projects. The EDM can be used to articulate the original 'value proposition' of the project/service, ask to what extent its intended impacts have been achieved, and recommend improvements, as well as generate learning that can inform more effective design of future energy services.

The Community Based Green Energy Project in Kitui County

The research focuses on a sample of farmer groups in Kitui County, a semi-arid region located 170 kilometres east of the Kenyan capital Nairobi. The poverty rates are high – 63.5 per cent against a national average of 45 per cent. The high population growth rate, high levels of unemployment, large number of rural households and high levels of food insecurity appear to be the main causes of poverty in the region. Water is scarce, and dependence on rainfed agriculture and population pressures on less fertile semi-arid land are key challenges.

Encouraged by non-governmental organisations, more farmers are adopting greenhouse technology to address these challenges. Horticulture in greenhouses uses water more efficiently and results in yields that are between five to ten times greater than in the open field. Drip irrigation is commonly used in greenhouses to reduce water losses due to evaporation and ensure efficient, timely irrigation. Water access and availability is a problem, however, with some NGOs providing diesel-powered pumps. The greenhouse component of the CB-GE project provided solar-powered pumps – a valuable example of distributed clean energy solutions impacting livelihoods, beyond household energy needs.

Using the 'energy delivery model' to analyse the greenhouse project

In the first stage of the research, a research design workshop used the EDM toolkit to understand the objectives and design of the original CB-GEP greenhouses project, including articulating its intended impacts or value proposition. The second stage involved field visits to a sample set of 11 farmer groups in Kitui County who had been involved in the greenhouse project, to gather information and evaluate whether the intended results and impacts of the project were achieved. Field questionnaires were developed based on the EDM canvas tool, with questions covering the project's value proposition, its end users (the farming groups), delivery infrastructure (the greenhouse, solar pumps and irrigation technology) and accounting (the costs and revenues associated with the service).

Findings

As well as evaluating these aspects of the greenhouse project, the field research evaluated the project's results against its original value proposition. The main intended impacts of the greenhouse project had been: "increasing rural incomes and improving food security for women and youth groups, while reducing environmental degradation and emissions from current energy systems in use and ensuring partner and community capacity to maintain the solutions."

1. **Increased rural incomes for 56 women and youth groups through energy systems investments in greenhouse cultivation:** ***Impact achieved***
   Horticulture in greenhouses has resulted in higher incomes: farming group members are earning between USD50 and USD200 per year from profits. Initially, solar water pumps reduced labour, time and cost on irrigation. However, the breakdown of solar water pumps within a year of installation affected profits as groups had to buy fuel for diesel generators. Nonetheless, the group horticulture production still benefits individuals, giving them higher incomes and access to valued 'table banking' facilities (the local term for the group savings and lending strategy), a benefit that was not fully anticipated at the project's design stage.
2. **Improved food security for the target groups by improving their incomes:** ***Impact not achieved/difficult to identify impact***
   While improved food security in the region was an intended outcome of the project, there is little evidence from the research to suggest that this target was achieved. The current small scale of the project means that the volume of produce from the greenhouse is too small to address this ambitious target. However, the greenhouses enable groups to produce vegetables during the dry season (May to September) and adds to the nutritional value of food sources consumed by group members and their wider community.
3. **Reduced environmental degradation and enhanced environmental protection:** ***Impact partially achieved***
   Water and energy supply and use were the two critical environmental factors for the project. For water supply and use, the drip irrigation systems enabled efficient water usage in a water-scarce area, and introduced the technology for the first time to most of the farming groups. For energy supply and use, the solar-powered pumps provided distributed clean energy to address a livelihood challenge. However, almost all the pumps broke down within 12 months of installation due to the ingress of muddy water, and many groups reverted to or began using diesel power. These technical problems could have been prevented at the design phase.
4. **Improved partner and community capacity to manage and maintain energy services in target areas:** ***Impact not achieved***
   Project design included activities to enable longer-term partner/community capacity to maintain the solar pumping systems after project closure, but the challenges were underestimated. Inadequate group training on using the pump systems and inadequate services for maintenance and repair meant that most groups were unable to prevent the pumps from breaking down. Moreover, service providers in charge of maintenance had neither the local networks nor the capacity to address multiple solar pump failures.

The findings from the field research led to a revision of the original value proposition, adding to the list of activities that would have been needed to support the intended impacts. For instance, under 'providing technology solutions' was added 'designing customised technology solutions for each location' and 'determining the willingness of end users to pay for technology systems and working out a financial model to allow for instalment-based payments' (see below).

Conclusions and recommendations

Project-specific recommendations:

1. **Rehabilitate or replace the solar water pumping systems for all greenhouses.**
2. **Develop a plan for ongoing maintenance, service and repairs by local technology and service providers.**
3. **Develop additional training and create a schedule for refresher training.**

Learning for future project/service design:

1. **Pilot technologies and delivery models at a smaller scale before widespread deployment.**
2. **Improve site selection and assessment so that project design can be customised.**
3. **Develop best practice hubs for farmer groups.**
4. **Integrate enterprise development training into livelihoods projects.**
5. **Build end users' knowledge of savings and credit facilities and funding sources.**
6. **Advocate for change in donor procurement policies.**
7. **Ensure the legality and enforceability of land leases.**
8. **Ensure adequate human resources are allocated for implementation and post-implementation activities during the design phase.**

Finally, the EDM toolkit proved very useful in terms of analysing the original CB-GEP greenhouses project, its objectives, intended impacts and design process. Identifying the gaps in the original project design, including those relating to socio-cultural factors, can help project developers to identify the modifications needed to address current operational challenges or anticipate future ones. It can also identify the successful components of project design that can be built on or replicated. In summary, the added value of the EDM toolkit is that it enables individuals or groups designing a new project or reviewing existing projects – including its end users – to problem solve in a rigorous and systematic way.

1. Introduction

Access to modern energy services is vital for poverty alleviation and wider economic and human development, as recognised by the United Nations' Sustainable Development Goal (SDG) 7 on ensuring access to affordable, reliable, sustainable, and modern energy services for all by 2030. Access via distributed energy solutions powered by renewable sources is often the most viable and cost effective for communities living in energy poverty. It provides a 'win-win' opportunity for both local development and for environmental protection, helping to address climate change.

With only 36 per cent of its population enjoying access to electricity, Kenya needs to scale up energy access to address its developmental challenges (IEA and World Bank, 2017; World Bank, 2014). In addition to Kenya's energy poverty challenge, the country's arid and semi-arid regions lack sufficient rainfall for agriculture – most farming in Kenya is rainfed (Ministry of Agriculture, 2010b). Some studies have indicated significant potential to improve livelihoods through better energy linkages for agricultural production, post-harvest storage and processing (Practical Action, 2016). The provision of energy services to support livelihoods (or 'productive uses' of energy) is an area of increasing interest for many development sector actors today both in Kenya and internationally (IEA and World Bank, 2017). It requires greater analysis and field implementation, given its significance in promoting sustainable rural economic development.

Between 2011 and 2014, as part of its Community Based Green Energy Project (CB-GEP), the Catholic Agency for Overseas Development (CAFOD) and its partners worked with 56 women's farming groups to increase their incomes and reduce environmental degradation through providing access to renewable energy. The project provided them with greenhouses equipped with solar-powered water pumps and drip irrigation facilities for horticulture production. Cultivation in greenhouses using drip irrigation systems allows for year-long production.

In 2011, the CAFOD CB-GE project appears to have been one of the few in the region to consider using the provision of renewable energy solutions, such as solar water pumping, to enhance productivity and incomes in agriculture. Considering the global challenges of the impact of climate change and unpredictable rainfall on smallholder agriculture, the need to increase agricultural yields to feed a growing population, and the lack of electricity access suffered by 1.06 billion people, this project is of relevance for researchers and practitioners not just in Kenya but also internationally.

With this in mind, CAFOD and its partner the International Institute for Environment and Development (IIED) decided to evaluate the greenhouse component of the CB-GE project and review whether it had met its intended impacts, and what were its successes and challenges. For this review, the research used the energy delivery model (EDM) approach developed by IIED and CAFOD. EDM is a bottom-up, participatory planning approach that helps stakeholders design energy services for poor and marginal groups so that they are financially, environmentally and socially sustainable and maximise development impact. It can also be used to review and improve an existing energy service (this is the second time the EDM approach has been used in this way). The EDM approach focuses on designing energy services that are rooted in end users' needs and appropriate to their local context. It is explained in greater detail in Section 3.

The research focused on 11 of the 28 farmer groups in Kitui county that benefited from the greenhouse project using semi-structured interviews and focus group discussions. Interviews were also conducted with implementation partners such as Caritas, Solar Works and government representatives including agriculture extension officers and local chiefs.

It should be noted that the research only provides a snapshot of some of the greenhouse projects, based on a limited sample set, and is not a comprehensive and scientific analysis of all the projects and groups. Nevertheless, the evidence and lessons from even this limited evaluation of the greenhouse project's successes and challenges are of significant value for designing future projects, as well as more broadly for understanding of the linkages between provision of energy and improvement of smallholder agriculture, particularly in regions that face similar challenges of energy poverty and water scarcity.

Section 2 provides information on the context for the project in Kenya, outlining the rationale for the CB-GEP and providing more detail on the greenhouses component, the focus of this research. **Section 3** gives an overview of the EDM toolkit, the methodology used for analysing the greenhouses project. **Section 4** outlines the research objectives and the methodology used in the two-stage research process. **Sections 5 and 6** outline the findings of the field research carried out to evaluate a sample of the projects using the EDM toolkit, and whether the original project impacts were achieved. **Section 7** articulates a revised value proposition to address the gaps in the delivery of the original project. The report concludes in **Section 8**, by reflecting briefly on the use of EDM as project design and review tool and offering recommendations on next steps for the greenhouse project and for integrating the learning from the review into future project design.

2. Context for the Community based Green Energy Project in Kenya

This section provides a brief overview of electricity access and smallholder agriculture in Kenya, with an emphasis on horticulture. It also discusses the relevance of the CB-GEP, particularly the greenhouse component – its intended impact and results, and the target end-user groups.

2.1 Energy and agricultural livelihoods in Kenya

The Community Based Green Energy Project (CB-GEP) was conceived in 2009 in response to the low rates of electricity in the country (more than 90 per cent of the population lacked access at the time) and the negative health and environmental impacts of energy use such as kerosene, diesel and firewood (REA, 2009; CAFOD, 2009).[1] The productivity of the 67 per cent of Kenyans living in rural areas was directly affected by the lack of access to modern energy services. Kenya's development framework, Vision 2030, launched in 2008, recognised the energy sector as one of three major pillars that must be improved to reach the goal of turning Kenya into a middle-income country (Government of Kenya).

According to the Global Tracking Framework 2017, which captures data up to 2014, only 36 per cent of the 48.5 million people living in Kenya have access to electricity (IEA and World Bank, 2017; World Bank, 2014). While 67 per cent of the population live in rural areas, only 12.6 per cent of these have access to electricity (World Bank, 2014).

According to 2015 data by the Energy Regulatory Commission (ERC), the population's current energy needs are primarily met from three sources: woodfuel (69 per cent of total energy), petroleum (22 per cent) and electricity (9 per cent) (ERC, 2015). The bulk of electricity generation is from hydro and geothermal sources (ERC, 2015). The demand for electric power has risen significantly since 2010 but supply is not keeping up with the increased demand (ERC, 2015).

The electricity sector in Kenya faces significant challenges including frequent power outages, low rates of connection, high costs of electricity, inability to meet demand and high power system losses (Boampong and Philips, 2016). Since rural settlements also have low load demand and are geographically dispersed, extending the grid to rural areas is even more challenging – and extremely slow (Boampong and Philips, 2016). The alternatives to electricity include kerosene and diesel/petrol for generators – both of which have negative health impacts and contribute to pollution.

Distributed energy solutions powered by renewable sources could help solve Kenya's current energy access gap and phase out the use of polluting fossil fuels by complementing grid extension to provide the 'last mile' of electricity access to unserved and underserved households. The off-grid and distributed electricity market in Kenya is estimated at around 6.7 million households (Ministry of Energy and Petroleum and SE4All, 2016) with access to micro and pico products, standalone systems and micro and mini-grids, mainly powered by solar, wind and hydro. Strengthening the enabling environment and wider ecosystem for delivering these distributed energy solutions could accelerate the provision of reliable, affordable and good quality electricity to rural communities and boost local economic development.

The issue of energy poverty is closely linked with that of income poverty. It is estimated that between a third and a half of the Kenyan population live below the poverty line (Ministry of Energy and Petroleum and SE4All, 2016). The poorest groups live in Kenya's arid and semi-arid areas (IMF, 2005).

The agriculture sector forms the backbone of the rural economy and plays a central role in addressing the issues of poverty and food security. While smallholder farmers account for 70 per cent of marketed agricultural production, their yields are below potential: according to the Institute of Development Studies, raising the productivity of these farmers could accelerate poverty reduction (IDS, 2006). In a country where 83 per cent of land is classified as arid or semi-arid,

1. In Kenya, 'access to electricity' is defined as a household within range of the grid, typically within 600 metres of a transformer.

depending on rainfall for agriculture is not sustainable. In 2014, the agriculture sector recorded mixed performance, mainly attributed to erratic rains, as rainfall in some regions was depressed. It is likely that these lower levels of rainfall caused a decrease in production for some crops as well as affecting pasture regeneration for livestock (ERC, 2015). Given these challenges, there is a strong case for adopting irrigation and crop cultivation methods that combine judicious water use with increased yield, to ensure more sustainable agricultural production.

2.2 Greenhouse horticulture in Kenya

Within the agriculture sector, Kenya's horticulture industry plays an important role in promoting food security, creating employment and alleviating poverty (ASCU, 2011). Employing over six million Kenyans directly and indirectly, the sector contributes to the household incomes of most of the country's farmers who carry out one form of horticultural production or another (Ministry of Agriculture, 2010a). However, the potential for horticultural production in Kenya's arid and semi-arid lands has not been fully realised due to a dependence on rainfed agriculture and the lack of sufficient rainfall to support sustainable farming in these regions (Ministry of Agriculture, 2010b).

Kitui county is located around 170 kilometres east of Nairobi. Kitui is the sixth largest county in Kenya by geographical area, and has a population of nearly 1.1 million. The population is growing around 2.1 per cent per annum and relies on relatively scarce arable, agricultural land, since the county is mostly arid or semi-arid with unreliable rainfall. According to the County Integrated Development Plan for Kitui for 2013 – 17, the poverty rates are as high as 63.5 per cent, against a national average of 45 per cent. The high population growth rate, high levels of unemployment, large number of rural households and food insecurity appear to be the main causes of poverty in the region.

In terms of energy access, most households rely on fuel wood or charcoal for cooking and kerosene/paraffin for lighting needs. Only 3.8 per cent of Kitui households are connected to the grid, although 20 per cent of households are defined as having access to electricity (County Government of Kitui, 2014). In addition, less than half of the market trading centres in the county are connected to electricity and electrification levels in the more rural parts of Kitui were negligibly low at less than 1 per cent (County Government of Kitui, 2014). In Kitui, as in many other regions of Kenya, the supply of electricity through the central grid – especially out to more rural or peri-urban zones – can be unpredictable, with power shortages and planned or unplanned customer blackouts occurring in peak demand periods.

The primary economic activities in Kitui include smallholder agriculture of mostly cereal crops, some livestock agriculture, metal and minerals mining and charcoal production (County Government of Kitui, 2014). Water is scarce, and dependence on rainfed agriculture and population pressures on less fertile semi-arid land are key challenges in Kitui (County Government of Kitui, 2014). The average farm size is about five acres. Farmers typically grow cereals, maize, millets, sorghum, greengrams, beans, cow peas and pigeon peas. The most common vegetable crops are cassava and sweet potatoes. Horticulture production has increased recently, particularly through the use of greenhouses to grow high-value fruits such as mangoes, papayas, water melons, tomatoes and avocados, with drought-resistant varieties giving better yields.

An increasing number of farmers are opting for protected cultivation using greenhouses (covered with plastic or glass) to produce vegetables during prolonged dry periods with optimum water usage (Simba, 2010; Casanova *et al*, 2009). This farming system also provides and maintains a controlled environment suitable for optimum crop production (Harmanto *et al*, 2005). Greenhouse cultivation uses water more efficiently and results in yields that are between five to ten times greater than in the open field (Sabeh, 2007; Vox *et al*, 2010). Drip irrigation is commonly used in greenhouses to reduce water losses due to evaporation and ensure efficient, timely irrigation. Greenhouses allow for more effective control of land, water, pesticide and fertiliser use when compared to open field cultivation.

Thus, they offer an opportunity to farmers in arid and semi-arid regions to grow vegetables throughout the year through optimum use of scarce water resources.

Governmental and non-governmental organisations (NGOs) have provided greenhouses and drip irrigation systems for horticulture production in Kitui to improve food security and income generation. As part of their livelihood improvement programmes in the area, the National Irrigation Board, the county government, and NGOs such as Agrosphere and Action Aid have provided greenhouses, drip irrigation kits, kits for plant maintenance inside greenhouses and tanks for water storage. A few projects have provided diesel generators to power water pumps.

Under the Expanded National Irrigation programme, the National Irrigation Board (NIB) introduced a project targeting farmer groups and learning institutions all over the country, to demonstrate greenhouse technology, among other technologies, to the community and encourage more people to adopt it on their own farms. Under the national greenhouse project the NIB distributed five greenhouses in Kitu; however, their main focus is on large irrigation schemes.

The Kitui county government has also introduced kitchen gardening programmes and supplied greenhouses. But a persistent challenge for such initiatives is water access and supply. Groups have dug shallow wells or resorted to 'scooping' water from the river bed to source the water required for drip irrigation in greenhouses; during the dry season, maintaining water supplies is particularly challenging. Pumps can help maintain the supply but are expensive to operate owing to the cost of fuel. This challenging water-energy-agriculture nexus, observed in these regions and throughout the project, is typical of arid and semi-arid developing regions around the world; lessons learnt from this initiative could therefore be significant for any projects aiming to replicate it.

2.3 The Community Based Green Energy Project

CAFOD began developing the Community Based Green Energy project in 2009 to provide access to modern, affordable and sustainable energy services for rural and peri-urban communities in Kenya, to enable income generation, improve food security, reduce environmental degradation and improve management of natural resources. The project was implemented from 2011 in three counties – Kajiado, Kitui and Isiolo – all classified as arid and semi-arid lands, with high rates of poverty, low access to modern energy systems and limited livelihood options. They are prone to extreme weather hazards (floods and droughts) and highly vulnerable to climate variations (EED Advisory Limited, 2015). The programme partners included the Catholic Dioceses of Kitui, Isiolo and NGO Dupoto-e-Maa to manage community mobilisation and field implementation, and Solar Works East Africa Limited, to undertake technology-related design and implementation.

The total funding for this programme was EUR2,320,000, with 75 per cent provided by the African, Caribbean and Pacific European Union Energy Facility, and 25 per cent by CAFOD. The overall goal was to "increase access to modern, affordable and sustainable energy services for 407,792 households, through 90 schools, 48 health centres and 69 community-based groups in rural and peri-urban areas in Kenya" (CAFOD, 2016).

This goal was to be achieved through four specific, closely related objectives:
1. To improve provision of energy services for schools and health centres in rural and peri-urban areas in target districts
2. To increase local incomes for rural and peri-urban youth and women's groups
3. To improve natural resources management by providing rural and peri-urban. communities alternatives to crude sources of energy such as wood fuel, kerosene and charcoal
4. To build the capacity of local partners and target communities to implement and manage modern energy systems.

The programme aimed to use distributed renewable energy to supplement existing energy sources, and contribute to sustainable socio-economic development in target areas. It capitalised on the existing network of CAFOD partners and community-level programmes. It was unique in its emphasis on providing energy access going beyond the level of household lighting to include energy services for information and communications technology, healthcare, education and agriculture. The target end-user groups included 56 rural schools, 32 health institutions and 64 women and youth groups, and the interventions included solar water-heating systems, energy-saving cookstoves and solar-powered appliances including lighting systems, refrigeration units and water-pumping systems.

Local partners and community groups were trained to operate and maintain the energy systems and to understand the benefits of sustainable environmental management. The aim was to ensure the long-term sustainability of the systems and to facilitate technology transfer and system replication across neighbouring regions. The project also focused on liaising closely with local government agencies and other civil society organisations to ensure buy-in to, and support for, the project's aims and implementation.

2.4 Focusing on the greenhouse project

This evaluation focuses on the 'productive uses' aspect of the CB-GEP: providing greenhouses to grow horticultural produce and improve the incomes of rural women and youth groups. The energy component of the project was the use of solar pumps to support drip irrigation in the greenhouses. While most distributed renewable energy solutions aimed at creating developmental impacts are usually restricted to **household** energy provision, such as providing solar home systems, the greenhouse project aimed to impact the end users' **livelihoods.** It also targeted women's groups, rather than individual marginalised farmers. These factors added to the complexity of the project's design and implementation.

The specific aims of the greenhouses project was to address the issues of rural youth unemployment and migration, income poverty and lack of access to sustainable energy; and to lower emissions of greenhouse gases. These issues were to be tackled broadly by building sustainable livelihoods, and specifically by increasing income generation for target groups, through the following activities:

- Growing crops in established greenhouses and practising water-efficient irrigation through solar water-pumping systems
- Supporting agricultural training for women's groups
- Facilitating training for groups on marketing and business management
- Training local youth on the installation of equipment and enabling the transfer and replication of energy-efficient technology (through the project's technical partner)
- Providing training on safety and equipment maintenance with the community, and building awareness of sustainable environmental management.

Through these activities, the project aimed to achieve the following outcomes:

- Increased rural incomes for 64 women and youth groups
- Reduced environmental degradation and enhanced environmental protection
- Improved partner and community capacity to manage and maintain energy projects through technology transfer in target areas.

The greenhouse and horticulture project provided a total of 56 solar water pumps for women's farming groups (the groups consist of women, men and youth – the definition of a woman's group can include men, if women are in the majority). 28 of the groups were located in Kitui county. 11 of these groups are the focus of this research.

The final project evaluation report that CAFOD submitted in October 2015 states that the provision of greenhouses and solar water pumping systems significantly improved the income of the local communities (EED Advisory Services Limited, 2015). Prior to implementation, 40 per cent of the women's groups farmed using petrol-powered generators, while the remaining 60 per cent used manual labour to irrigate their plots. The solar pump systems proved less expensive and reduced the labour involved in manual irrigation. However, technical problems caused most of the pumps to stop functioning within a year of installation (this issue is explored in Section 6.3).

The greenhouses and drip irrigation systems enabled farmers to grow high-value horticultural products such as tomatoes for sale in local markets and to generate income, establish private businesses, and participate in 'table banking' activities (the local term for the group savings and lending strategy).[2] In addition to additional income generated, CAFOD's evaluation concluded that providing greenhouses, water pumps and storage facilities in areas that are predominantly arid and pastoral enabled farmers to diversify their food intake and increase their food security.

The broad timeline for the greenhouse project is summarised in Table 1.

Table 1. Timeline of the greenhouse project

2011	2012	2013–2014	2015	2017
Proposal approved with original value proposition	Implementation of project – community mobilised and groups monitored Greenhouse installation begins	Solar pumps and greenhouses installed for all groups	Evaluation of CB-GEP on project completion Breakdown of a large number of pumps	Review of greenhouse project using EDM approach

2. Table banking is a group savings and lending mechanism where group members save on a regular basis and borrow short or long-term loans from these savings. The group's fund for lending to members could include low interest loans from banks and other sources.

3. The energy delivery model: a pro-poor approach to designing energy services

The research uses the 'energy delivery model' (EDM) toolkit to analyse the CB-GEP greenhouses project as it seems a highly appropriate tool for reviewing the process for designing and implementing the energy service, as well as the ultimate outcomes. The EDM is a systematic and participatory approach to designing energy services for people living in poverty developed by CAFOD and IIED in 2013 – building on the insights of previous practice and research undertaken by Practical Action, IIED and other groups delivering energy services to poor and marginal groups.

Delivering energy services to poor and vulnerable people is particularly challenging. Globally well over 3 billion people – mainly women and children – cook with polluting fuels and stoves, leading to major health impacts. Over 1 billion do not have access to modern electricity. Almost 90 per cent of these people live in remote, rural areas that are far from electricity grids.

Energy-poor people are not only marginalised geographically but are usually disconnected from services other than electricity from wider social and economic opportunities. These multiple forms of disconnection are also often present where poor people live in the middle of cities, in informal settlements with little or no access to services enjoyed by other city dwellers.

Thus a 'pro-poor' approach to delivering energy services would be one where the energy service has a wider 'development impact' – ie it helps to lift people out of poverty by increasing their opportunities to improve their well-being in a way that is financially, socially and environmentally sustainable.

3.1 A customised, participatory approach

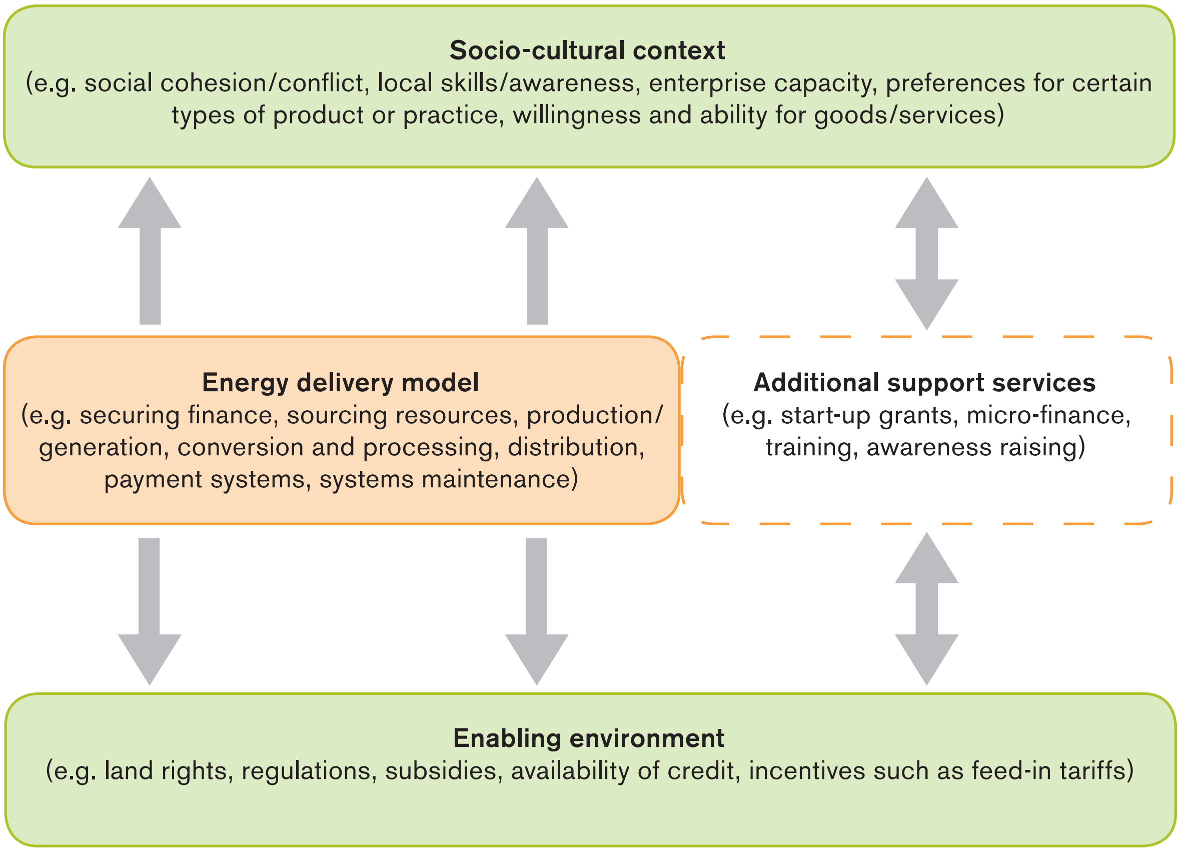
The rationale behind the EDM is that, as research and practitioner experience shows, a 'one size fits all' approach cannot meet the electricity and cooking needs of the world's billions of poor men and women, who live in a range of different geographical locations and socio-cultural contexts. If energy services are to enable people living in poverty to meet their needs and wants, and maximise development benefits, they must be customised to these different needs and contexts, and be financially, socially and environmentally sustainable.

The delivery model uses a combination of the technology, finance, management activities, policy support, legal arrangements and relationship types required to supply energy to a group of people or end users (who are affected by income poverty and/or energy poverty (CAFOD & IIED, 2013).

The term 'energy delivery model' also highlights the crucial role played by *other kinds of activities and support* that are not necessarily part of the energy delivery model but are critical to delivering a successful energy service. So, for instance if a community has identified a priority development *need of a better primary school education for their children*, when other kinds of support (books, teachers etc.) may be needed in addition to an energy service for lighting the school, to ensure that the need is met. Or it might include obtaining a certain permit is required for energy equipment: in this case, solar panels for the school.

Finally, the important role played by socio-cultural factors in helping or hindering the delivery of the energy service is often overlooked. This refers to the norms, values, expected ways of doing things and attitudes of a group of end users and the wider stakeholders. For instance, in one community, people may not feel comfortable in participating in activities unless certain community leaders give the go-ahead, or they may prefer doing activities in a certain way. Understanding these preferences and getting community or certain actors' buy-in could be just as crucial to the success of the energy service as having the right permits and sourcing the right equipment.

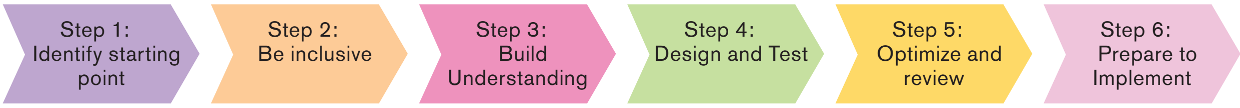
Figure 1
Map of the pro-poor energy delivery system, showing the four building blocks of the delivery model and their inter-relation.



Source: Wilson *et al.* (2012)

The EDM toolkit consists of a practical six-step design process (see Figure 2) combined with two innovative 'delivery model tools', the Delivery Model Map and the Delivery Model Canvas, which help the designers and end users of an energy service develop a potential solution (or solutions) (Garside and Wykes, 2017). It is aimed at fully involving end users in the design of the energy service so that it meets their priority development needs and ensures their buy-in to the final service.

Figure 2
The six steps of the energy design model.



Source: Garside and Wykes, 2017)

Needs and gaps

The starting point is understanding the **wider development needs** and wants of the particular end users, as well as the specific **socioeconomic and cultural context** in which they live. The end users then prioritise the needs identified.

The next step is working with end users to determine what role an energy service could play in meeting their priority needs: in other words, **is there an 'energy gap'**? For instance, a community might want an energy service to light their homes so that they can carry out activities at night; or to provide lighting and heating for their school, to improve the lives and educational outcomes of students and retain teachers; or to refrigerate medicines in the local clinic so children can be vaccinated; or to provide power for farming activities so farmers can generate more income for their families.

However, providing an energy service may not meet the development need identified – or may not do so in isolation. There will be other **non-energy gaps** and these can only be addressed when **other services and resources are put in place** (see below). As above, if the development need identified is for children to get an education, supplying light to a school will not fulfil this need by itself, especially if the school does not have other infrastructure or resources in place – such as books, desks or chairs, trained teachers and so on.

In addition, an energy service must be appropriate to the local context to produce development impact over the long term. **Factoring in the social and environmental costs and benefits** that an energy service would involve is just as important to its long-term viability as sufficient financing for the delivery infrastructure and a workable payment scheme.

Stakeholders and supporting services

A range of different people and organisations – **the stakeholders** – will be needed to deliver the energy service successfully. The stakeholders can include, for instance: the businesses or organisations who will supply, install and repair the delivery infrastructure; the banks or other institutions who will finance this equipment or administer the payment systems; and the local government officials who will give the legal permits.

When designing the service, it is crucial to understand what interests these different stakeholders have in participating in the energy delivery model, in order to **address any potential challenges or opportunities** that could arise. For instance, delivering the new energy service could be seen as a potential threat or benefit to an existing energy or other business.

Apart from mapping the stakeholder and their interest in the success – or failure – of the energy service, it is vital to identify not just the energy infrastructure itself but all the **activities, inputs and outputs** required to deliver the solution designed to meet the overall development need.

The other activities and support outside the actual energy service itself that are needed to deliver the solution can be summarised under the following categories (see **Figure 1** above):

- **The enabling environment** – the formal policies and legal frameworks, and also the existing infrastructure, that support the delivery of energy services.
- **The socio-cultural context** – the social and cultural values and capacities of the community and other actors in the supply chain, linked to their articular local context.
- **Supporting services** – any additional support needed to address weaknesses in the enabling environment or specific issues in the socio-cultural context required to make the service work (in its local context).

The Delivery Model Canvas tool (see **Figure 3**) enables individuals or groups designing projects/services – including the intended end users – to articulate what need or gap the project/service is trying to address, and what solutions and impacts it will deliver, and for whom (its value proposition). It helps designers to break down a project or service into its component parts: end users, delivery infrastructure, accounting (which includes not only financial but also environmental and social costs and benefits). The detailed questions in the canvas can then be used to systematically explore the activities, outputs and relationships needed to deliver the solution/impacts, as well as the wider supporting services required and the socio-cultural factors that will help or hinder project success.

Figure 3
Delivery Model Canvas. Source: Garside & Wykes (2017)

The Delivery Model Canvas

Delivery infrastructure

Key activities

What are the activities we need to carry out to deliver our value proposition, and to make sure that we are reaching our end users and generating sufficient revenue?

Which of these activities are the most important to fulfil our value proposition and which would be 'nice to have' but not essential?

Would any of these activities disrupt existing businesses or upset power relationships?
Is there the potential for conflict?

Example: Firstly, there are problem-solving activities eg how to connect and build different ways of distributing the energy services & products, how to build trust with end users. Then there are activities related to the 'nuts and bolts' of running the energy service: for example, acquiring SHS and appliances & physically selling them; assembling & customising them; and training and managing the technicians who will maintain & repair them. There could potentially be issues with existing energy providers such as kerosene sellers.

Key stakeholders

Who are our key stakeholders? Eg partners, suppliers, repair & maintenance, local authorities, end-users etc.

Which key resources are we acquiring from them?
Which key activities do they perform? What do they expect from us?
What do we expect from them?

How do we add value with all the other stakeholders, including with the end users?

How does the value proposition fit with government strategies and public policies?

Example: International suppliers provide products (SHSs and appliances). Retailers of appliances and gadgets (TVs, radios, phones) sell devices that enable end users to use energy services, and retailers provide repair & maintenance. National and local authorities give import permits, tax and other incentives etc and provide other subsidies and establish policies. Local bank manages micro-loans. International organisation provides funding for loans to farmers and supports training, as does the farmers' association, which is a trusted source of information.

Key resources

What resources do we need to deliver our value proposition, reach our end users, generate revenues and build our partnerships?

Can we easily obtain all the resources (natural, financial, human, physical, institutional etc.) that we need?
Do we need any extra supporting services? How will we obtain these?

Example: The following resources are available. Physical resources: the business has its shop premises in the town & storage for imported goods. Human: the business employees, and other actors involved in awareness-raising. Financial: funding from the international organisation to start revolving loans, and micro-credit & subsidies from the government to buy bigger SHSs and appliances, plus a reduction in import taxes for solar products.

Constraints: replacement parts for the SHSs and appliances need to be imported from abroad. Also, there is no electric grid connection and no plans to expand in the local region. There is poor transport infrastructure and the solar business will need to build a local distribution channel.

Supporting services: Funder to provide revolving fund start-up capital and to build relationships with local banks so that they will manage fund and eventually be willing to provide micro finance loans themselves. Awareness-raising for the farmers on SHSs and appliances; training on using appliances and also on improving agricultural techniques and enterprise development; training for technicians to do installation and maintenance of systems; lobbying government to improve transport infrastructure to improve access to markets.

Value proposition

What value are we adding to the end user's life?

What problem are we helping the end user to solve?

What needs of the end user are we helping to meet?

What collection of products and services are we using to add value or solve a problem or satisfy the end-user's needs?

What are the social and/or environmental problems we are solving? Are we creating any risks?

How is the wider community beyond the specific end users going to benefit?

By doing * activities with *** people/ organisations, we will deliver *** impacts and/or meet *** needs and/or solve *** problems.**

Example: The additional value delivered by the proposition is the following: the ability of the farmers and their families to access electric lighting for the first time, along with (improved) access to modern communications (TV, radio); the improvement of livelihoods by using appliances such as processors, refrigerators and water pumps; more educational opportunities for children and adults due to the availability of light at night for studying. There are also other benefits from actual and potential uses of electric appliances (eg labour-saving for women, health benefits from reduced kerosene use etc). Another co-benefit is the decreased use of diesel generators, leading to lower fuel costs for the farmers and also more environmentally sustainable fuel use. The SHSs and some appliances are imported but the rest of the value chain is local.

End users

Target groups

Which individuals or groups is the service creating value for? (eg services/ products for all users or targeted by gender/ age/ income etc.)

Who are our most important end users? Why?

Are there local behaviours/attitudes towards innovation and risk that could affect the value proposition?

Are there preferences and customs that could affect the value proposition?

How do gender relationships affect the value proposition?

Example: The target group is subsistence farmers. This group can be further divided up by income. The farmers with lower incomes are most concerned about the affordability and durability of the appliances and they are likely to be interested in solar lamps with a phone charger. Farmers with higher incomes could be looking at SHSs and water pumps and potentially some kind of processing equipment. Crops are currently sold directly after harvest, and people are not used to processing them. Women are generally the ones who grow crops, but men are more likely to visit town and sell crops.

Relationship with the end-users

What type of relationship does each of our groups of end users expect us to establish and maintain with them? (eg individual service, people expect to be involved in creating the service etc.)

Do end users expect services to be delivered by the private or public sector (eg private business, governmental agency, cooperative, intermediary such as international NGO, local NGO, church etc.)?

Example: Solar business with a shop in county capital does customised outreach to the farmers with the support of government incentives and working with the farmers' association. Micro-finance loans are made available from a fund supported by the international organisation but managed by the local banks. The farmers' association also acts as a trusted intermediary. Maintenance services are offered by the business through local technicians.

Ways of doing outreach & delivery

Do the end users have preferred ways of being reached when it comes to: awareness-raising, purchase, delivery of the energy service?

How can we make sure our ways of reaching end users fit with their preferences/routines?

How much do people use informal channels to build their understanding of services & products?

Example: Most farmers visit stores in the market town to buy products directly but they also swap information through informal channels such as the farmers' association and they do not often make big purchases or try new products. Women trust information they get from their women's group & feel comfortable asking questions in this environment.

In this case, the farmers and the village as a whole are given demonstrations of products (appliances and SHSs) by local business (supplier) during awareness-raising and promotional campaigns. These are carried out with local associations (farmers' association, women's groups) with the support of trusted development partners. Examples of other similar products being used in neighbouring communities are also used for demonstration and, because evening radio soap operas are popular and used to transmit information, the government pays for awareness-raising through this channel.

SHSs are customised according to the farmer's needs, then delivered & installed by the business and maintained by locally trained agents.

Accounting

Revenue streams

Where will the revenues come from to pay for the service? What are the different sources? Eg from selling products or assets, fees, lending/ renting/ leasing, etc.

Can the end users pay for the service? In full or in part?
How much does each source/ stream of revenue contribute to total revenue? Do donors or the government offer any subsidies or incentives that could be used? Can civil society offer any 'in-kind' resources (physical eg equipment or financial)? Can the end users offer any 'in-kind' resources that could be used?

Example: Revenue stream comes from end-users selling crops. In addition, there are subsidies for the appliances from the government and funding from the international organisation for the payment schemes.

Other costs/ benefits

What are the most important social & environmental costs that this particular service will have?
What are the benefits?

Types of costs/ benefits:
Social – Increasing conflict or cohesion among social or ethnic groups. Impacts of the EDM on gender relationships, job creation, health and well-being and empowerment.

Environmental – Increased pollution or energy sustainability. Restoration/degradation/exhaustion of the natural resource base. Impact on eco-systems services and contribution to resource management (positive/negative).

Example: Increased information/educational opportunities & increased income for farmers. Strengthened resilience through more sustainable energy use, enhanced energy security. Also improved resilience to increasing drought due to the possibility of pumping water. Job creation. Substitution of kerosene lamps & diesel generators mean possibly decreased CO² emissions & improved health outcomes.

Cost structure

What are the biggest costs of delivering the energy service? Eg Fixed costs (salaries, rents and utilities); variable costs (depending on the amount of goods produced); economies of scale; economies of scope (incorporating other businesses)

Which resources required are the most expensive?
Which activities are the most expensive?

Example: The most important costs are supplying the SHSs and appliances, and ongoing repair and maintenance.

4. Objectives and methodology

4.1 Research objectives

The broad objective of the research was to evaluate the effectiveness and impacts of the greenhouse project carried out in Kitui county; identify the critical factors for project effectiveness and impact, and understand how this linked to project design and implementation; and reflect on the learning to improve future project design and implementation. The objectives of the research were as follows:

- **Understand** the project design approach, the value proposition, delivery infrastructure and delivery model(s) used for the greenhouses project that aimed at increasing the income of the target end users (based on evaluating a sample of 11 of the 28 groups in the region).
- **Identify and evaluate** the factors that have appeared to contribute to the success – or otherwise – of the projects (including their ongoing financial, social and environmental sustainability), as well as the challenges faced. This included to what extent the enabling environment was important in determining the project impacts, as well as any sociocultural factors which influenced the design and implementation of various greenhouse projects and/or are currently contributing, or hindering, their success.
- **Reflect** on the design and implementation process used in the greenhouses project, and determine if, and how, these could be improved in future programming.
  The research aimed to address the following questions about the greenhouses project' design and implementation in Kitui county:

Design:
- What project design approach and delivery models were used for the greenhouses project in the target locations?
- What was the entry point? Who was involved and why?
- What value was being added, and for which end user or stakeholder groups?
- What were the perceived risks associated with the project?

Implementation and impact:
- What aspects of the model have been critical to its operation (successful or otherwise) and its sustainability in the target location?
- What are the main benefits and impacts of the project on the community? To what extent were these intended impacts, identified at the design phase?
- What are the key challenges? What risks did the project face regarding its socioeconomic, operational or environmental sustainability?
- What lessons can be learnt, and what opportunities are there to improve the design and implementation of future projects?

4.2 Research methodology

There were two stages to the research. First, understanding the original CB-GEP project design and identifying its intended impacts using the EDM approach. Second, gathering field data and using the questions from the EDM canvas to determine whether the intended results and impacts were achieved.

Key stakeholders of the greenhouses project of the CB-GEP were included in designing the research to better understand the original objectives, the activities undertaken, and stakeholders involved. This exercise was also essential to identify major challenges and issues faced by the project that could be further explored in the field work.

Stage 1: EDM workshop

A research design workshop was organised in Nairobi on 6 – 8 September 2017 with stakeholders involved in the original design and implementation of the greenhouses project and the research team. This included CAFOD staff and partner representatives who were familiar with the EDM approach. The aim was to analyse existing CB-GEP documentation, and to build participant understanding of the EDM approach as a research tool. It included detailed discussion on the original greenhouse project objectives, value proposition, stakeholders, project design and implementing activities. While only a sample of sites were selected for the fieldwork and in only one county, Kitui, the sociocultural context and enabling environment were seen to be similar across all project sites in Kitui county, and the concomitant challenges, and in the other two counties involved in the greenhouse project delivery.

Stage 2: Field research to evaluate impact

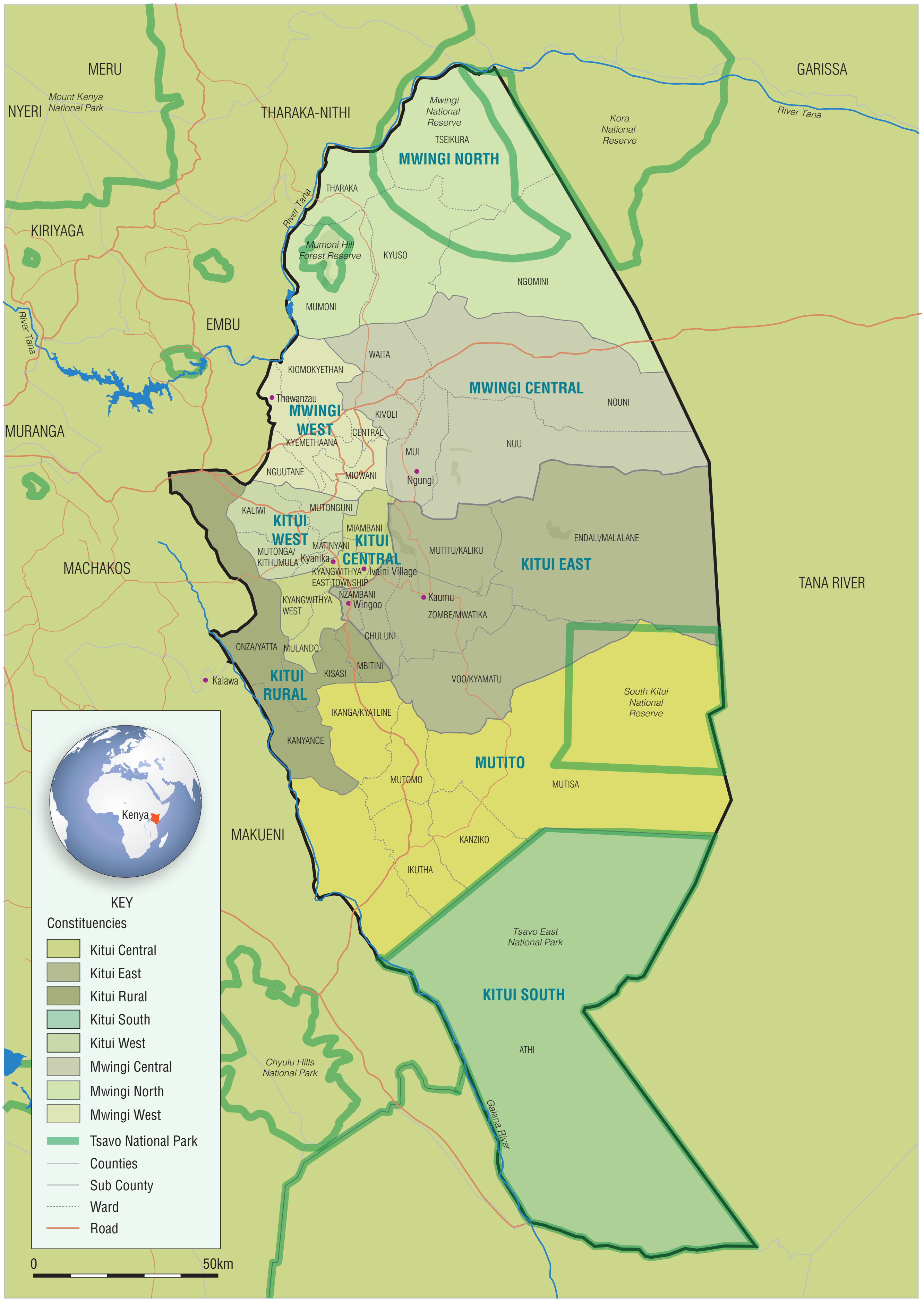
To analyse how the project value proposition and activities were implemented and their impacts, field data were gathered using interviews and focus group discussions with end users, delivery partners, and other stakeholders. The fieldwork also explored participants' perspectives on the project process and outcomes, and captured any unanticipated outcomes. The issues identified in the Stage 1 research workshop were also explored in greater depth.

The research identified a sample set of the CB-GEP beneficiary groups within Kitui county, representing: (1) groups continuing to practise horticulture, using either diesel or solar pumps; (2) groups continuing to exist, but no longer practising horticulture; and (3) groups that no longer functioned, owing to various challenges. The sample set consisted of 11 of the 28 groups in Kitui county.

Semi-structured interviews and focus-group discussions (FGDs) were undertaken with the groups. Interviews were also conducted with selected government representatives, namely agricultural extension officers and chiefs. **Annex 1** provides an overview of the questionnaire used in the interviews, which was used the EDM canvas tool questions, and a list of all stakeholders involved in the fieldwork.

The interviews and FGDs were supplemented with information from previous project evaluations and other documentation, discussions with former project co-ordinators within CAFOD, and project partners such as the Catholic Dioceses of Kitui and private sector supplier Solar Works. **Figure 4** provides an overview of the locations covered during the field research.

Figure 4
Kitui county, Kenya



4.3 Limitations and gaps

The main limitations of the research were as follows:

- **Sample size:** A total of 56 greenhouse systems were implemented across three counties as part of the CB-GE project, 28 in Kitui county. However, time and resource limitations meant that field research and focus group discussions involved 11 groups who had benefited from the systems. These groups are concentrated in five sub-counties within Kitui. The research findings have attempted to identify any specific factors linked to geographical location that may affect some groups of target beneficiaries more than others. However, owing to the small sample size, this cannot be considered a comprehensive and scientific analysis of all the projects.

- **Retrospective nature of the research:** The CB-GEP ended in 2014. The time elapsed since the project closure allows for a clearer understanding of the outputs and outcomes that have been achieved; however, there are some gaps in data on the horticulture businesses, training and timelines. The research prioritises verbal data from partners and end users that has a reasonable level of accuracy, or where there is documentary evidence of an activity or timeline.

- **Lack of clear distinction between greenhouse horticulture and open cultivation, individual and group farms:** Identifying data relating to costs, farm inputs, produce or yield from the greenhouses was complicated because the target groups undertake both open cultivation and greenhouse cultivation on the same plot of land. Individual group members also undertake individual cultivation in addition to working on group land. These aspects, combined with language barriers, made it difficult to identify and capture greenhouse-specific data. In addition, due to the time that has elapsed since the closure of the projects, records of group revenues could not be reviewed. The research relies on self-reported information, but compares it across groups located in similar geographies to try to correct any obvious inconsistencies in data gathered.

Table 2. Stakeholder mapping in the greenhouse project

Stakeholder	Type	Potential influence	Interest (positive)	Concerns (negative)
Women's farmer groups	Producers (target end users of the project)	High	• Increase in income • Improved access to water and efficient water usage • Increased food security	• Time or cost implications in horticulture
Consumers - Local community and institutions - Local market	Immediate consumers	High	• Local availability and accessibility of vegetables	• Price of produce
Technology partners: - Greenhort Gardens - Solar Works - Power Point	Technology providers – solar, greenhouse	High	• Business opportunity • If successfully implemented, possibility of replicating the model in other regions	• Breakdown of systems • Costs of meeting warranty and maintenance
Government entities: - County government - Agriculture extension officers	- Policymakers - Potential donors - Training providers	Medium to high	• Possibility of replicating success in other regions • Increased agricultural produce and income in local regions, meeting their own deliverables • Taxation opportunities	• Time and cost implications (fuel and travel) of meeting with groups and addressing concerns (eg land rights, disease and pests)
Implementation partners: - Caritas Kitui - CAFOD	Donors and community mobilisation partners	High	• Meeting developmental objectives • Increased incomes and food security at community level • Reduced environmental degradation	• Overdependence on grant model with limited local capacity • Shutdown of horticulture after project closure • Change of community priorities or other risks
Others: Middlemen in the horticulture business Motorbike riders	Wholesale buyers – sell at a profit Transport produce	Medium to high (some have local markets that are accessible, lower dependence on middlemen) Medium to high	• Profits to be made in selling at more established markets at higher prices • Income from transporting produce	• Groups managing their own marketing and sales • Low production: low volumes to transport • Poor road network • The groups' own vehicles undercut their business

5. Findings from the analysis of the original CB-GEP design

This section summarises the findings of Stage 1 of the research: analysing the original value proposition and design of the CB-GEP greenhouse project, based on discussions at the workshop in Nairobi. The EDM toolkit, using the **six-step design process** (see **Figure 2**) was used – apart from the last step, 'prepare to implement'. The analysis used questions from the EDM **Delivery Model Canvas**, primarily those relating to the value proposition, end users and delivery infrastructure.

5.1 Steps 1 and 2: Identify the starting point and be inclusive

The first two steps of the EDM approach aim to understand the **intent** and **entry point** for designing any energy service, gathering information about the target end users and their context and mapping any **stakeholders** who could affect the success of the project.

For the CB-GEP greenhouses project, the main intent was to increase local incomes and improve food security, reduce environmental degradation and improve natural resource management. The entry point to enable this was the provision of energy services, as well as building local capacities to ensure their long-term sustainability. The target end users and other stakeholders are identified in **Table 2** along with a summary of their potential influence, their specific interest in and their concerns about the project.

5.2 Step 3: Build understanding

Step 3 of the EDM process identifies the specific end users' **needs** that the project will aim to address, before focusing on the **energy and non-energy gaps** that prevent end users from meeting these needs. It then decides what the intended **development impacts** of the energy project are. Building on these, the step culminates with developing the project's **value proposition.**

For the greenhouse project, the workshop discussions focussed on Step 3 in detail – the energy needs, gaps and intended impacts identified are recorded in **Table 3**. This helped a more detailed value proposition to be articulated.

Table 3. Energy needs, gaps and intended impacts of the greenhouse project

Intended impacts	Energy need	Energy gaps	Non-energy gaps
Primary impact: Higher incomes for women and youth groups and better food security Secondary impact: Increased use of energy systems that reduce environmental degradation and emissions	Power and equipment to pump water and irrigate crops in the greenhouse efficiently and cost effectively	• Manual irrigation without power is time-consuming, labour-intensive • Diesel-powered generators are expensive to operate and cause environmental harm	• Lack of accessible and reliable water sources • Lack of equipment to grow crops in dry conditions • Limited knowledge of agricultural practices, group leadership and management • Limited/no knowledge of group management and horticulture business • Lack of clarity around land rights and ownership • Poor road network affecting access to market

As **Table 3** shows, the project's intended impacts were to increase rural incomes and improve food security for women and youth groups, while reducing environmental degradation and emissions from unsustainable energy systems, such as diesel pumps. To achieve these impacts, the project sought to work with stakeholders including the target end-user groups themselves, the wider local communities, technology providers, government representatives and implementation partners (eg CARITAS Kitui) to address the energy and non-energy 'gaps', by carrying out the following activities and outputs:

1. **Identifying end users**
   - Mobilising target communities and sensitising them to the impacts of energy systems, particularly environmental protection/reduced pollution
   - Identifying and selecting (women's) farmer groups that were already registered and had access to sustainable water sources
   - Ensuring groups had land rights and use agreements
   - Creating producer marketing groups.

2. **Providing technology and solutions**
   - Installing mobile solar water-pumping systems with drip irrigation
   - Installing greenhouse technologies.

3. **Offering capacity building and training**
   - Working with the Ministry of Agriculture so end users could access extension services on crop management
   - Training groups in agronomical skills, business management (including book keeping, enterprise management), system operations
   - Training for local technicians on pump repair and maintenance.

4. **Promoting sustainability and marketing**
   - Assessing the market and strengthening market linkages by creating producer marketing groups
   - Establishing direct links between groups and service providers for after-sales servicing.

The greenhouse project's original value proposition could be expressed as follows:

- ***By [doing activities]:*** *identifying farmers groups and providing them with technology solution packages (solar water panels and pumping systems and greenhouses); giving them capacity building and training on horticulture, marketing, business management, equipment safety and maintenance, and sustainable environmental management and helping them to set up/enhance credit and savings mechanisms; training local technicians to install the equipment; identifying an after-sales service provider for ongoing system maintenance and repair;*

- ***Working with [stakeholders]:*** *the wider local community; technology providers (Solarworks, Greenhort Gardens), government representatives and other implementation partners (Caritas Kitui, Caritas Isiolo, Dupoto-e-Maa);*

- ***The greenhouse component of the CB-GE project will [deliver outcomes and impacts]:*** *increase marginalised farmer incomes and improve food security for the 56 target women's groups, while reducing environmental degradation/ emissions from current energy systems in use and improve natural resource management.*

5.3 Step 4: Design and test

In Step 4 of the EDM, the **Delivery Model Canvas** tool is used to test the value proposition and refine the proposed solutions. The canvas poses a series of questions, such as "Who are the end users?" and "What value is the proposition adding to the end user's life?" These questions help to refine the value proposition and associated solutions by analysing in greater depth aspects related to the end users, delivery infrastructure, and the overall costs and benefits of the proposed delivery model.

The canvas questions and the answers developed in the research workshop are as follows:

End users:

- Who are the target groups for whom the service is creating value?
- How does gender affect the value proposition?
- What types of relationships need to be maintained with end users?
- What methods for delivery and outreach are the most effective to use with the target end-user groups?

1. **Target groups:** Marginalised, vulnerable women in women's farming groups; women are the primary beneficiaries, however, almost half the members in the majority of groups are men.
2. **Gender dynamics:** This could affect the use of income at the household level (ie who decides how to use it); women are often seen as more suited to work on local farms within the village while men engage in waged labour outside the village.
3. **Social dynamics and relationships:** Group dynamics and land issues within the local community affect group functioning and production; implementation partners regularly call end users to ensure systems are functioning and no additional hurdles have come up.
4. **Outreach and delivery:** Public forums are used to disseminate general information; a group approach is ideal for higher impact products and services; training modules are provided through agriculture extension officers and technology partners; the field partner is responsible for group and business management training.

Value proposition:

- What value is being added to end users' lives?
- How are they benefiting from the value proposition?
- What benefits are being created for the wider community?
- Are any social and environmental problems being addressed?
- What collection of products and services (including training) are used to solve the problem?

1. **End-user benefits:** Higher incomes, higher volume and quality of production, better food security, reduced labour and reduced crop failure.
2. **Group and community benefits:** Sharing of group income, table banking facilities within the group, reliable access to vegetables at reasonable prices for community members and local institutions.
3. **Socio-environmental benefits:** Increased income and nutrition for end users and wider community, social capital and increased savings through the groups, positive environmental implications from replacing or avoiding diesel use with solar-powered water pumping systems.
4. **Products and services used:** Solar water pumping systems with drip irrigation, greenhouse technology with hybrid seeds, training and capacity building for group members.

Delivery infrastructure:

- What are the key activities required to deliver the value proposition?
- Who are the key stakeholders and what role does each play?
- What resources are required to deliver the value proposition?

1. **Key activities:** Mobilising the community and identifying groups, installing pumps and greenhouses, training and building group capacity to ensure long-term maintenance of technology and sustainable access to markets for groups.
2. **Stakeholders:** Technology partners (Solar Works, Greenhort Gardens), community partners, Caritas, other NGO partners. Additional stakeholders required to deliver the value proposition are agricultural extension officers and county government.
3. **Resources:** Technology components are solar water pumps, drip irrigation systems, water tanks, greenhouses, other fixtures; training components are specific training activities on the three main types required – technology, agronomy and business management; financial resources are funds to purchase the above and provide for agricultural inputs, human resources and consultancy, travel and logistics.

Accounting:

- Where will the revenues come from to pay for the service?
- What are the types of costs and benefits that are likely to accrue?
- What are the biggest costs of delivering the energy service and what resources cost the most, including human resource allocation?

1. **Revenue streams:** EU funds (75 per cent) and CAFOD funds (25 per cent) as part of the CB-GEP proposal; no direct end-user financial contribution as end users mainly contributed in kind, through labour and basic raw materials to install the systems.
2. **Costs and benefits:** The project will result in a revenue stream for end-user groups but project design does not provide for any return of funds spent to CAFOD or Caritas.
3. **Highest cost resources:** Technology and equipment incurred the highest costs but considerable time and human resources also involved in project implementation activities; post-project implementation, monitoring, following up and ensuring the sustainability of the projects are probably the most resource-heavy activities.

5.4 Step 5: Optimise and review

Step 5 of the EDM involves further refining the value proposition by identifying the supporting services, the risks and how to mitigate them. Risk mitigation tools are typically used to outline the probability of occurrence and the likely impact on the project.[3]

Table 4 outlines the main risks, their probability and impact, as well as mitigation measures considered as part of the greenhouses project design. It then outlines those risks and mitigation measures that were not identified in the original project design, but only identified subsequently as part of this research (these are blue in the table below).

Table 4. Summary of risk assesment for the project *(continued on the following page)*

Risk	Probability	Impact of risk	Mitigation measures
Technology: • Theft of equipment • Electrical shocks and fires • Exposure to dead batteries • Shading of solar panels	High	High	• Designing the system to enable pumps to be moved (later became a risk in itself – regular movement affecting equipment) • Creating awareness within target groups about ownership and responsibility for safeguarding systems

3. For example see Mindtools risk/impact probability chart www.mindtools.com/pages/article/newPPM_78.htm which can be adapted to the tabular form used in the case study.

Table 4. Summary of risk assesment for the project *(continued)*

Risk	Probability	Impact of risk	Mitigation measures
Lack of community co-operation	Low	High	• Creating awareness • Ensuring registration and legitimacy of groups • Working with local chiefs to address group dynamics Lessons from post-project review: • Improving the understanding of group dynamics • Creating project champions • Making group management more professional and accountable • Creating grievance redressal mechanisms for group members especially when the community's priorities or challenges change eg where drought leads to water availability problems for the project or alternative sources of employment disincentivise farmers • Ensuring some end-user contribution before the intervention to increase buy-in and ownership from end-user group
Changing community priorities	Medium–High	High	• Creating awareness • Working with local chiefs to address group dynamics and priorities Lessons from post-project review: • Building a greater choice of activities and interventions for the community to decide on/choose • Improving the understanding of group dynamics • Creating project champions • Creating grievance redressal mechanisms for group members – especially when the community's priorities or challenges change (see above) • Ensuring some end-user contribution before the intervention to increase buy-in and ownership from end-user group
Land ownership or lack of safeguards for the community	Medium–High	High	• Ensuring legal land documents or agreements • Creating awareness within the community about tenure and land rights • Developing processes for enforcement
Water quality issues affecting production or system functioning	High	High	• Ensuring better site assessment and understanding of water quality • Appropriate system design • Piloting proposed solution on a small scale before larger scale deployment
Equipment failure and lack of maintenance and repair service	Medium	High	• Technician training • Ensuring better site assessment and site-specific technological specs • Developing a maintenance plan with clear payment model – ie funding from community/partners/donors • Engaging local/existing equipment and service providers – to increase accountability and accessibility

6. Outcomes and impacts identified by the field research

Stage 2 of the research consisted of investigating the outcomes and impacts of the greenhouse project in the field, using interviews and focus group discussions with end users, implementation partners and other stakeholders. The research team met with members of the 11 farmer groups who had participated from the start of the greenhouse project across five sub-counties in Kitui county.

The groups have 15–30 members, each with a slight majority of female members. Each group has a chairperson, a vice chairperson, secretary and treasurer, among other management positions. The groups were selected to be representative of the project's beneficiaries, covering three categories: (1) those groups still carrying out horticulture, using both diesel and solar pumps; (2) those groups that still exist but no longer practise horticulture; and (3) those groups no longer functioning owing to land rights, leadership or management challenges. A snapshot of the groups and their current status is provided in **Table 5** below.

More than 50 per cent of the 11 groups are still functioning, with horticulture as their primary activity – using both the greenhouse and open cultivation methods. Typically, each of the members also has an individual farm on which they cultivate cereals or vegetables. Most of the active groups undertake 'table banking', an informal group strategy to enable savings and offer credit facilities for members, and seen as one of the main benefits of membership. Most groups were set up between 2010 and 2012 and had begun horticulture production or small credit provision activities as a group prior to the greenhouse project.

The groups that have stopped functioning in the last two years are all located by the Tana river, one of the few perennial water sources in the otherwise arid region. The groups were disbanded primarily due to land rights, management and leadership issues (see below).

Table 5. Snapshot of groups visited and their status

Sample set of 11 farming groups in Kitui county						
6 active groups					5 non-functional groups	
3 groups: horticulture with table banking		2 groups: horticulture without table banking		1 group: no horticulture, table banking only	5 groups: horticulture by individual farmers	
1 group using solar pump	2 groups using diesel generation/ manual	1 group using solar pump	1 group using diesel generation/ manual	Reconsidering horticulture, especially if pump issues resolved	Group members working on individual farm land, using own equipment	1 individual member, using group equipment

Based on the canvas, our field research set out to find whether the greenhouses project's intended impacts had been achieved. We used the canvas's main categories to analyse the value proposition, end users, delivery infrastructure and accounting. Aspects of the sociocultural context and the enabling environment were also analysed.

The findings identify factors that were critical to the project's success – or otherwise. Some factors were not identified or explored in detail in the original project design phase, but subsequently became challenges.

6.1 The greenhouses project value proposition

The greenhouse project's original value proposition was discussed in Section 5 (see **Box 1**). Questions relating to this were then used to analyse whether it had been delivered such as "What value did the greenhouse project add to end users' lives?" and "What social and environmental problems is it solving?"

Box 1: The value proposition of the original greenhouse project

- ***By [doing activities]:*** *identifying farmers groups and providing them with technology solution packages (solar water panels and pumping systems and greenhouses); giving them capacity building and training on horticulture, marketing, business management, equipment safety and maintenance, and sustainable environmental management and helping them to set up/enhance credit and savings mechanisms; training local technicians to install the equipment; identifying an after-sales service provider for ongoing system maintenance and repair;*

- ***Working with [stakeholders]:*** *the wider local community; technology providers (Solarworks, Greenhort Gardens), government representatives and other implementation partners (Caritas Kitui, Caritas Isiolo, Dupoto-e-Maa);*

- ***The greenhouse component of the CB-GE project will [deliver outcomes and impacts]:*** *increase marginalised farmer incomes and improve food security for the 56 target women's groups, while reducing environmental degradation/ emissions from current energy systems in use and improve natural resource management.*

Income generation and use of profits

The baseline survey for the original project carried out in 2010 – 11 indicated that 52 per cent of those interviewed reported earning less than 3,000 Kenyan shillings (EUR27 or USD30) per month. At less than USD1 per day, this income falls well below the international poverty line.[4] Only 2 per cent reported monthly incomes above KES25,000 (EUR255 or USD250).

In our field research discussions, all the end-user groups indicated that they were making or had made a profit. However, it was difficult to distinguish clearly between profits accruing from greenhouse produce and the profits accruing from the group's open cultivation beyond the greenhouses. Each year typically includes 3–4 cropping seasons of 3–4 months each. For groups, consisting of between 15 and 30 members, sharing profits yearly or biannually, the annual profits for each individual farmer (after considering reinvestment requirements and so on) were in the range of KES5,000 (USD50) and KES20,000 (USD200).

Profits are used differently in each end-user group, usually in one or more of these ways: sharing them equally among members (after every season or twice a year, or during Christmas celebrations in December); reinvesting them into the greenhouse business; or reinvesting into the table banking facility to increase core capital/the group fund. The way profits are used depends on several factors, including suggestions from the management of the group; the sources of group income and their profitability; the size of the group's core capital/fund; any outstanding loans; the benefits accrued from previous harvests; and the group's confidence in continuing the horticulture business in the future.

Market linkages

The main consumers for greenhouse produce are within the local community. The market linkage for most groups is a combination of the weekly marketplace in the nearest town, villagers and wholesalers who come directly to the farm, and in rarer cases, supermarkets or marketplaces outside of Kitui county. Producer marketing groups were created as part of the greenhouses project to improve access to markets for groups in each location. However, there is little data on how they performed.

Group members are also allowed to buy from the group produce, usually at a discounted price. However, few groups sold produce to members. Since most groups are operating at a relatively

4. The international poverty line has a value of USD1.90 purchasing power parity (PPP) while the lower middle-income class poverty line has a value of USD3.20 PPP.

small scale with limited volumes of produce, the local market is adequate to sell their produce. No group explicitly expressed a concern about market linkages or middlemen and wholesale prices. However, this could be a 'chicken-and-egg' problem – groups perhaps do not consider this an issue given the current low volume of produce and their limitations in accessing larger markets. If there were additional efforts to create market linkages, perhaps they would consider expanding their operations to meet the demand.

Food security

The project had clear impacts on the quantity and quality of crops produced, although the impacts on food security were less certain.

Using greenhouses and hybrid seeds have resulted in larger vegetables and bigger harvests. The advantage of greenhouse production is that it can carry on all year round and results in a higher yield per hectare, with lower water usage. Although the shelf life of the produce is shorter, vegetables are more attractive to market customers in size and colour. Several factors affect production quantity, including how well the pump functions; group capacity to understand and apply agricultural and other training; group interest and buy-in to the project; and the extent to which the income generated is of value to individual members (as direct income for individuals or added to the group fund).

Greenhouses have almost eliminated crop failure due to lack of rainfall. The main dependence is on a reliable source of water for irrigation. Pest-related crop failure has also reduced, where groups have adequate knowledge of good practices for greenhouse cultivation. The main concerns expressed by end-user groups concern soil-borne diseases such as bacterial wilt or nodes, which all 11 groups had experienced. Tomatoes are particularly prone to bacterial wilt and once infected, the enclosed space of the greenhouse aggravates and accelerates the spread of the disease. In terms of labour, groups indicate that each person needs to spend fewer hours tending to the greenhouse. This is mainly due to the drip irrigation system which significantly reduces the time and labour involved in irrigation.

While improved food security in the region was an intended outcome of the project, there is little evidence to suggest that this target was achieved. The current small scale of the project means that the volume of produce from the greenhouse is too small to address this ambitious target. However, the greenhouses enable groups to produce vegetables during the dry season (May to September) and adds to the nutritional value of food sources consumed by group members and their wider community.

Finally, as mentioned above, most groups gave members the option of purchasing vegetables from the group, but few used this opportunity – members in several groups were growing similar vegetables on their individual farms, albeit in smaller quantities.

Socioeconomic benefits of group membership

An important benefit of the project has been the enhanced access to credit facilities through farmer group membership. Members expressed a high level of satisfaction from group membership primarily due to better credit access through 'table banking' and 'merry-go-round' (more popularly known as *chama* in Kenya facilities).[5] This benefit, regarded as important to end users, was not articulated explicitly in the original value proposition.

Table banking requires members to contribute a certain amount on a weekly basis into the group fund – groups under the greenhouse project typically contribute between KES50 and KES200 (USD0.5–2) per week. It allows individual members to borrow amounts ranging from KES5,000 to KES20,000 (USD50–200) for one to six months at approximately 10 per cent interest. Some groups have more sophisticated rules for table banking than others and have been able to access government funds such as the Uwezo Fund or Youth Fund, to lend on to members on more flexible terms.

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5. 'Merry-go-round' or *chama* involves fixed contributions by members at each meeting for a certain period of time, where the lump sum of all contributions at a specific meeting are collected and given to one individual member on a rotational basis. This enables individuals to have access to a relatively large sum of money at a specific point of time.

A range of loan products are available with different terms depending on the source of funding. Those groups that reported difficulties in running table banking cited collections as the primary problem. This was linked in turn to irregular savings contributions or lax enforcement of repayment rules in the initial stages. Thus, for table banking to function well, there should already be a regular savings habit among group members and strong enforcement of repayment schedules by the group management.

In general, these savings-credit facilities are highly valued among these communities, since the formal banking system in Kenya has restrictive rules on borrowers' eligibility and microfinance institutions have extremely high interest rates – upwards of 27 per cent per annum. All the greenhouse project groups interviewed have opened accounts in commercial banks for their group savings, with the treasurer in charge of keeping records and managing transactions. Members use the money primarily for household needs, such as school fees and unforeseen medical bills, and for investment into their individual farms such as buying seeds.

Members also identified the social support that being a part of the group gave them as an important benefit. In addition to credit facilities, they believe they can rely on group members for psychological and other forms of support in times of difficulty or distress. This was not an intended outcome of the project, but came up in response to questions in the EDM canvas about the value being created for end users and the social benefits accruing from the provision of services.

Environmental impacts

The main environmental impacts of the projects analysed relate to use and availability of energy and water. Prior to the installation of solar pumps, groups used a combination of diesel and manual irrigation. Following installation, diesel use dropped as the groups used solar energy alone to power the greenhouse irrigation pumps – avoiding all the environmental and financial costs associated with diesel use. However, the pumps began to break down six to ten months after installation, causing almost all groups of the 11 covered in the research to switch back to diesel generators or manual methods for pumping. The pump breakdown was mainly attributed to mud in the water entering the pumps, causing the shafts to break (see details in Section 6.3). Only one group of the 11 purchased a new solar pump when they had enough funds to replace the broken system.

For the three groups that used manual irrigation before the greenhouse project but moved to diesel-powered irrigation after the solar pumps broke down, the environmental impact was negative.

A notable positive environmental impact of the project was the use of drip irrigation systems. By using water more efficiently, these systems demonstrated their own value to the community; and judicious water use for cultivation in arid and semi-arid areas is of considerable environmental significance. While one or two groups had used these systems before as part of projects supported by other foundations or government, for most farmer groups participating in the CB-GEP greenhouse project, it was their first time. Combining drip irrigation with solar water pumping is effective, since by itself solar pumping may encourage over-use of water: there is no additional cost for running the pump longer. The four groups covered in the research with functional water tanks that continue to grow vegetables also continue to use drip irrigation systems, showing end-user understanding of the importance of using drip irrigation in these water-scarce regions.

6.2 End users

The canvas questions relating to end users include "Which individuals or groups is the service creating value for?"; "Who are our most important end users?"; and "How do gender relationships affect the value proposition?". These questions were used to explore the impacts of the greenhouses project in relation to end users, their engagement as a group, the gender dynamics, training and capacity building and their access to land.

Group management

Clear group management structures that function effectively have been critical to the success of the groups' horticulture business, investments made, and the progress of the group in general. Groups where the project has had the most positive impacts, despite challenges, have strong and proactive leaders.

In addition to enforcing group rules and managing internal processes, including any conflicts, the leadership has been proactive in addressing concerns about delivering the horticultural activities successfully. This has included finding alternate mechanisms for water pumping; liaising with agricultural extension officers and local government to access relevant programmes and training; addressing pest infestations through soil testing; observing other farmers who have tried different methods or solutions; or changing the varieties of vegetables grown in response to market demand. Other factors contributing to group success (both absolutely and relative to others) were existing expertise within the management or group members on relevant aspects of agronomy, business management or technology. These factors also strengthened groups' ability to overcome challenges (see more on capacity building below).

In terms of group versus individual farming models, end users' views differed on their comparative utility and value. Some end users suggested that the group farming model enabled better access to agricultural extension services and other government schemes. As the model is promoted by the government, there is more likely to be support for groups. Those farmers participating in a group have also been resourceful in finding solutions to overcome challenges relating to solar pumps, pest control, and water access – despite limited financial resources, technical knowledge or access to repair and maintenance. In addition, as above, the access to credit facilities and social capital offered by farming groups are greatly valued by members of most of the groups interviewed.

However, concerns were also expressed about the lack of individual ownership of and accountability for equipment impacting on the upkeep of this equipment, since it was perceived as belonging to the group. This risk was not fully identified and mitigated in the original project design (see below on delivery infrastructure), causing problems with repair and maintenance. In addition, the primary field partners, Caritas Kitui, suggested that the ideal way to promote the profitability of the horticulture enterprise would be a hybrid model combining group training, shared equipment and marketing facilities with individual greenhouses for farmers. This way, shared resources and supporting services can benefit a larger number of farmers, while individual greenhouses would incentivise individual enterprise to boost yields and profits. Representatives from Caritas Kitui also said that the county government is learning from the challenges of the group farming model and is contemplating working more with individual farmers. Despite optimism among field partners and county government about the hybrid model, it is worth questioning whether it would cause similar challenges with regard to repair and maintenance of what would still be shared equipment.

How and why farming groups come together is also an important determinant of their long-term sustainability. The most successful groups, according to those interviewed – not solely in the CB-GEP projects studied in this research, but also more widely among other horticulture projects in Kitui – were those in which farmers took the initiative to create groups, in comparison to those that were created as part of donor-funded projects. The self-initiating groups developed their own rules and ways of working, independent of any external funding or supporting services. They have clear processes for dealing with group disagreements or conflicts, which are resolved through regular group communication (such as meetings) or sanctions (such as fines).

Gender issues

According to the Ministry of Culture and Social Services of the Government of Kenya, 'women's groups' are defined as "a voluntary self-help group with fifteen or more members made up of exclusively of women or whose membership consists of an overwhelming majority of women". Their definition also emphasises that the women should have the power to make decisions (Nyataya, 2016). The original intent of the CB-GEP greenhouses project was to work with women's groups to target marginalised and vulnerable women. Most of the groups visited for the CB-GEP projects research had a majority of women, albeit not a large one, in both membership and management positions. However, in most of the focus group discussions men were more active speakers, and in five of the six active farming groups men held the highest management post (chairperson).

The CB-GEP field partner, Caritas Kitui, has experience of multiple community mobilisation projects and observed that projects on livelihoods and other development-oriented goals tend to have a larger number of female participants and leaders. In contrast, men tend to dominate participation in projects linked to advocacy or community leadership. The criteria for participating in the latter kind of projects usually includes "individuals who can lead and make decisions". From Caritas's perspective, decision-making is still seen as male-dominated, resulting in men taking the lead in such community projects more often than women.

Gender issues were also prevalent in decisions on household expenditure and income. Most male group members interviewed suggested that, in keeping with social norms in the region, they were the key decision makers on how the money was spent. Some women reported joint decision-making on matters of expenditure, but only women-led households (where the husband worked in a larger city or was deceased) reported decision-making by the woman alone.

Training and capacity building

Training and capacity building took place throughout the life of the project, both before and after installing the technology. **Table 6** summarises the training delivered as part of the greenhouses project.

Groups in this project received training more than once and all group members interviewed agreed that it was useful, particularly those on agronomy and business management. Many of the groups that continue to engage in horticulture only began growing vegetables at the start of the greenhouse project. This demonstrates the value and impact of the training delivered as part of the CB-GEP and also the value of the support from agricultural extension officers, suggesting that agricultural extension services are an important aspect of ensuring long-term project sustainability.

The greenhouse project capitalised on the local presence and expertise of agricultural extension officers by making them an integral part of project delivery, ensuring that they became the key contacts on horticultural issues for farmer groups, particularly after project closure. A key finding of the research is that additional efforts may be required to engage the county government to address some of the logistical challenges faced by these officers (such as fuel and transportation costs) if they are to visit project sites and provide hands-on support. This has been particularly challenging over the last six months (April to September 2017) owing to the Kenyan electoral process and the

Table 6. Training and capacity building in greenhouse project

Training module	Details	Time frame	Primary trainers
Business management	• Group rules • Table banking practices • Record keeping • Costing and pricing of produce • Sorting and marketing	Pre- and post-installation	Caritas Kitui
Agronomy	• Greenhouse gardening, mitigating risks of pests and disease, crop management	Post-installation	Agricultural extension officers
Technology	• Operating and maintaining solar-powered pumping system and greenhouses	Post-installation	Greenhouse: Green Hortgardens Solar systems: Solar Works

start of the new financial year in July 2017, which affected budgetary allocations.
The impact of the training appears to have been greater in groups that had access to local expertise on relevant subjects so that ongoing support was available to members after training. For example, in four of the groups – almost a third of those visited – one or more members had a background in small-scale vegetable production and agronomy, and could support the group in horticultural production despite challenges with the irrigation system. In two other groups, members of the management structure had taken courses on business administration and were able to apply this knowledge directly to group operations. In one of the groups, a younger member is a trained electrician who carried out regular checks on various components of the delivery infrastructure, such as the electrical wiring, pump, drip system, addressing any problems as they arose. The training was also more beneficial for those attending repeat or refresher training, and for those who had a good relationship with the agricultural extension officers, since the officers were more likely to provide timely feedback or additional information.

In addition to the CB-GEP training between 2012 and 2015, all groups expressed an interest in additional training on pest and disease control. Growing crops like tomatoes requires significant farmer knowledge and skill given that these crops are highly susceptible to soil-borne diseases such as bacterial wilt and root nematodes.

Those groups with proactive leadership also saw an improvement in group capacity, despite no direct input from the greenhouse project. One group has been particularly successful in using technology for group and business management (eg using an electronic tablet and software for record keeping) and to build their knowledge of agronomy, particularly of pests and pest control. This is primarily because the chairperson owned a tablet. A leadership committee member from another group attended advocacy training organised by Caritas Kitui and put it into practice by lobbying the local government authorities to have a tarmac road constructed to the village. This has improved the group's access to transportation, which also improves their access to markets.

Given the issues with the pump technology, one key question is whether the groups received adequate training on using and maintaining the pumps prior to project implementation. Only one group used a filter to prevent muddy water damaging their pump, and no other group reported being trained on water quality and pump maintenance. Given the poor quality of water sources in the target regions and the technical specifications for pump use, a key question is whether the end users received sufficient technical training by the implementing partner as this may have aggravated the situation on the ground and led to the technology breakdown. According to the implementing partner (Solar Works), training was carried out for all groups on basis operation and maintenance; but its effectiveness and the application of the training varied from group to group due to differing levels of literacy and skills within groups.

Finally, end users reported that they would have found more intensive training on new areas of skills or knowledge useful – namely on solar energy systems and greenhouse horticulture. Overall, the research highlighted a need for ongoing training to specific groups beyond the original project training. In addition, agricultural extension officers, technology partners and other community partners could have supported or delivered an assessment of additional post-project training needs as part of the project final evaluation. This could have helped ensure project sustainability.

Land rights issues

In terms of the research sample, land rights only came up as a challenge for the five groups operating in the Tana river catchment in the Mwingi region. With good water access from the Tana river, demand for land in the region has increased, driving up land values. The attendant risk is that landowners may not renew three to five-year leases with farmer groups, preferring to lease their land to new clients who are willing to pay more. This was true for four of the five Tana river groups. Although the CB-GEP greenhouses project required leasing documentation to be signed in the presence of a lawyer to ensure the legality of the lease agreement, one group was evicted from the land before the end of the lease tenure. Group members brought the eviction issue to the attention of the local chief, who recommended mediation as the best way to address the conflict.

For the six farming groups in our study outside of the Tana river area, land owners were mostly part of the management structure – as part of the leadership in four groups. Their motivation for leasing out their land to the group included learning the benefits for their own farming of using systems such as solar pumps, water tanks and shallow wells. In addition, some group members who are also land owners are given a token remuneration of KSH1,000 (USD100) per year for the period of the lease agreement.

6.3 Delivery infrastructure

Delivery infrastructure is another main category of the EDM canvas. The research used relevant questions including "What activities are required to deliver the value proposition?" and "What resources do we need?". This section focuses on the technologies or systems used in the greenhouses project, analysing the challenges and issues faced in the process of designing and using the delivery infrastructure. A key finding was that a lack of technology assessments for the system design and an inadequate consideration of after-sales service and maintenance during the project design phase impacted on the implementation of the projects.

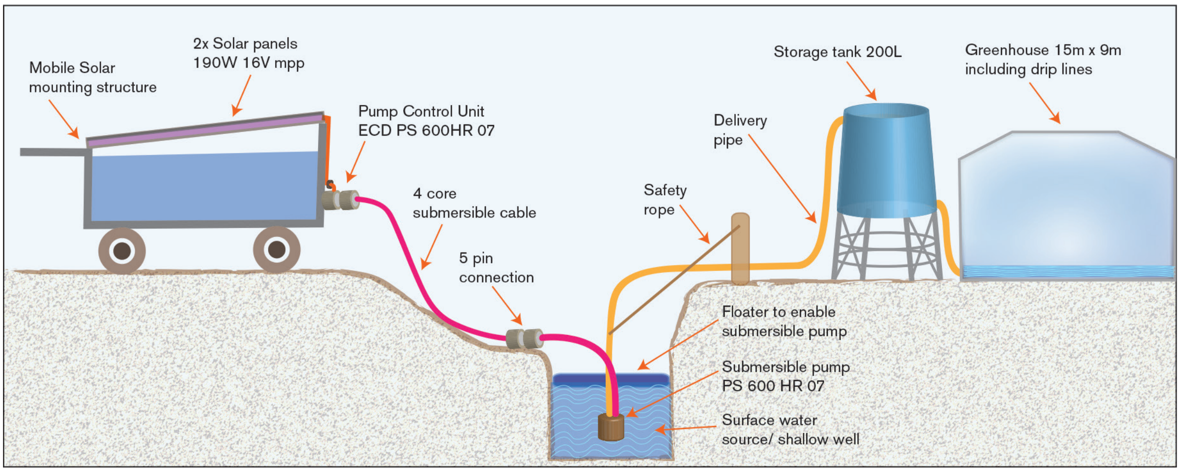
The technology for the greenhouse project consisted of the following:
- A greenhouse with a floor space of 15 by 9 metres from Green Hortgardens, Kenya.
- A water storage tank of 2,000 litres and a drip irrigation system.
- A solar water-pumping system consisting of a submersible water pump (PS 600 HR 07) and two 190Wp solar panels procured from Power Point systems.

Using and maintaining the solar pumps

Of the 11 groups interviewed as part of the research, only two groups still had functional solar water pumps. The rest had encountered problems with their pumps about six to eight months after installation. The most common issue was mud entering the pump and causing the shaft to break.

One group with a functional pump had used their own resources to replace the original pump, which began indicating an overload within six months of installation. They approached Davis and Shirtliff, a pump supplier in the region with a local presence in Kitui county, who assessed the solar panel capacity and suggested a replacement that would meet the needs of the group. The cost was covered by the group's pooled funds. The other group managed to keep their solar pump operational primarily because the group leader had a diploma in agronomy and was familiar with this specific pump design. The group added a filter (muslin cloth) to prevent mud from entering it.

Figure 5: The technology components of the greenhouse project.



Source: CAFOD documentation

Water availability and quality were crucial success factors in the outcome of the greenhouse project. While every group has access to water, its availability and accessibility differs depending on the season. Water sources include a combination of shallow wells, scooped out ponds on the dry river bed during the dry season and a perennial river (during the rainy season, scooping may not be necessary). Muddy water is characteristic to this region, particularly during the dry season. The groups required supporting services or training in pump maintenance and use. Systematic evaluation of the water availability and quality during the project design phase would have ensured that the pumps were suitable for the conditions in each region – in this case, the pumps' instructions stated that they should not be used in muddy waters.

Assessments and system design

Caritas Kitui's criteria for selecting the target farming groups included the availability of a water source in the project location and the group's previous experience in horticulture farming. Solar Works, the technical partner who supplied the solar water pumping system, undertook a limited number of site visits to determine the technical specifications for the system. However, there was no provision within the project to do detailed site surveys including water quality assessment.

The decision among project partners was to develop a uniform design pitched between the maximum and minimum requirements to achieve the project objectives, and taking into account various parameters – in particular the delivery head (the height to which the pump can raise water) and distance from water source. The decision to use a uniform design was driven by the procurement criteria specified by the EU as CB-GEP main funder. The supplier was chosen following a procurement process that included advertising the technical specifications and identifying the lowest bidder. As a result, the final pump design was not site-specific or customised for each group's needs and location: it was over-designed for some groups and under-designed for others. The greenhouse was designed in the same way. As a result, in some locations the internal temperature became excessively high, particularly during the dry season. In one case, this caused the greenhouse to break, rendering it unusable. Many groups reported problems with the drip irrigation system; some groups had to replace the pipes because of clogging or breakages due to muddy water or upgraded their systems as they expanded their businesses.

Another failure of the original site evaluations relates to the assessment of water quality. The Lorentz pumps procured through the local vendor, Power Point Systems, contain clear instructions that they are not to be used in muddy water (as discussed above). Yet the water sources for all the group sites visited in the field research were muddy shallow wells or pools scooped from the river bed.

All these challenges highlight the lack of site-specific design and the problem with bulk ordering. The 'one size fits all' approach used in the design of pumps and greenhouses, with limited attention to site-specific needs and characteristics, adversely impacted the intended outcomes of the project.

After-sales servicing and maintenance

Although the water pumps came with a one-year warranty from Power Point Systems, the time taken in procurement and installation of the pumps for all the projects meant that by the time some groups received their pumps, the warranty cover had expired. These delays were mainly attributed to complicated procurement processes and hence an underestimation of the time required for procurement, plus the time needed for purchasing, transporting and installing the equipment, including identification of trained technicians to carry out installation in each region. Based on the original agreement, Solar Works' role was to carry out the servicing of the pumping system, with the initial diagnosis undertaken by the local technicians trained in installation and maintenance. However, both the local technicians and Solar Works were unable to repair the systems.

Although Solar Works gave the groups their contact details, the groups approached Caritas Kitui whenever problems with the pumping systems arose. This was perhaps motivated by a desire on the part of the groups to keep Caritas informed as the provider of the equipment (the pumping system did not involve any direct cost to the group itself), or the hope of additional support in replacing or repairing the pump. Soon after the pumps began to break, Solar Works indicated their inability to service the systems. Without a warranty cover or a maintenance agent, the implementation partners were forced to approach a local pump supplier, Davis and Shirtliff, who had the local networks and knowledge to address the issue, and who were able to give an estimate for the cost of replacement pumps.

All groups indicated a willingness to set aside a certain percentage of group income to undertake regular maintenance of any new solar pump. However, apart from the one group mentioned earlier, all the groups that received an estimate of pump replacement costs have still not purchased a replacement. The reason given was that the replacement pumps cost in the range of KES80,000 and KES150,000 (USD800–1,500) and groups are still building up their savings to make this relatively large one-off payment.

It is worth noting that where the pumps are no longer functioning, the solar panels continue to be safely stored in the house of a member of the group or group leader. None of the groups interviewed had connected the solar panels to batteries or loads for household or community use due to the project requirement that the panels belonged to the groups not individuals and could not be used for their personal energy needs. Any equipment not being used by groups – particularly where the group was no longer functioning – was supposed to be returned to the implementing partner for use by active groups. However, implementing this in practice was difficult for both end users and the implementing partner.

These findings demonstrate that in the design phase, the project must consider and identify how the long-term maintenance and servicing needs of any delivery infrastructure will be met, including the need for replacement equipment and parts. It is essential to identify local maintenance providers that end users can contact directly, and have a fully-costed payment plan (such as an annual maintenance contract and fee that may vary for each location). In the case of the greenhouses project, the local technicians appear to have had inadequate training while the other technology partners/service providers were based in the capital, Nairobi – too far to support groups operating in rural parts of Kitui county. This meant that Caritas Kitui became the default point of contact for the farmer groups, which undermined Caritas's longer-term exit strategy.

6.4 Accounting

The final category of the EDM canvas is accounting, including the following questions: "Where will the revenues come from to pay for the service?"; "Can the end users pay for the service?" and "Do donors or the government offer any subsidies that could be used?" In this case, the research analysed the potential revenue streams that could pay for future energy solutions or greenhouse projects, as well as the accounting for the current CB-GEP greenhouses project.

Willingness to pay for similar projects in the future

All groups that are still active in the horticulture business indicated a willingness to take loans, albeit at lower interest rates, to continue the business. Some have accessed government funds (low-interest loans) but mainly use these for lending on to members. In addition, the groups that are still active have been able to access programmes from the National Irrigation Board, which provides water tanks and greenhouses, or government funds such as the Uwezo Fund, the Youth Fund and the Women's Enterprise Fund.

Greenhouse cultivation costs

Tomatoes, the main greenhouse crop, are affected by bacterial wilt in most of the project greenhouses. Farming groups therefore only produce this crop for a limited number of seasons, harvesting between 5 and 20 crates of tomatoes per month. Depending on the time of the year, the quality of the produce and the demand, each crate of tomatoes can fetch between KES1,500 and KES6,000 (USD15–60). Since the bacterial attack, most groups have diversified the crops grown in the greenhouse to include kale, spinach, capsicum, cabbage and onions. Each of these crops are priced differently and the group decides which to grow in each season.

Profits are contingent on several factors, including the volume of vegetable supply and market price, the number of group members, the choice of vegetables grown in a season and cost of inputs such as seeds, pesticides and fertilisers. Fuel costs are of great significance, when considering both the intended and actual impacts of the project, since the inability to operate the solar pumps has forced most groups to resort to diesel generators to pump water to the tanks for irrigation. While the groups had no fuel costs when the solar pumps were functioning, they now spend between KES1,500 and KES3,000 (USD15–30) per month on diesel and petrol to run the generators, which adds significantly to the input costs of greenhouse farming. The only other comparable cost that is that of hybrid tomato seeds. Yet the greenhouse production still returns profits; individual group members are earning between KES5,000 and KES20,000 (USD50–200) per year from their share of the profits.

Larger cost components

For the four CB-GEP partner organisations, the largest cost head incurred by the project was the delivery infrastructure – the greenhouse, solar water pump, water tank and drip irrigation system – at nearly KES770,000 (USD7,700) per group. The solar water pump accounted for nearly a third of the costs. In terms of next steps, it is critical to ensure that this investment is not a sunk cost. The other capital costs included the cost of human resources for the four partner organisations implementing the project, and the cost of logistics and communications, as well as of developing and delivering training modules.

For the farming groups, their operational costs, fuel (diesel/petrol) are among the highest, at USD15–30 per month to pump water in the absence of functional solar pumps. Other expensive inputs include hybrid seeds, insecticides and pesticides to prevent crop infestations. Most groups have also incurred costs for the diagnosis, repair and/or replacement of specific technology components. A few groups spent KES8,000–9000 (USD80–90) on replacing the drip irrigation pipes 7–12 months into the project. Others have spent KES5,000 (USD50) to have pump supplier Davis and Shirtliff make a site visit to check their non-functional solar pump and estimate the cost of replacement. The quotations provided for repairs and replacements are in the range of KES80,000 and KES150,000 (USD800–1,500).

As reported above, only one group has replaced the broken pump with a new one and the group is satisfied with its performance. Some other groups are beginning to save money for pump repairs/ replacements. Based on the quotations, it appears that the repairs or replacement would cost between 30 and 70 per cent of the original cost of the pump. Considering the pump's value for horticulture, and the groups' high expenditure on diesel, it may be worth the original CB-GEP project partners considering allocating additional resources or creating new instalment-based payment models to help the farmers groups buy a replacement pump or undertake the required repairs to the existing pump.

Figure 6 shows how the canvas questions were used/adapted to review the project and the findings/ key lessons learned from the field work.

Figure 6
Kenya Delivery Model Canvas

The Delivery Model Canvas

Delivery infrastructure

Key activities
What activities are required to deliver the value proposition?

Original design:
- Installing mobile solar pump systems with drip irrigation.
- Installing greenhouse technologies.

Lessons to be incorporated:
1. Undertake detailed site surveys and needs assessments
   - Technology specifications based on site requirements, particularly for energy systems and greenhouses.
   - Analysis of usage dynamics that effect the design – these may be technical (eg muddy water) or social (eg security of equipment).
2. Determine end user willingness to pay for technology, developing a financial model for repayments.
3. Enter into maintenance contracts for energy systems.

Which of these activities are the most important?
Site-specific surveys and installing technology based on site requirements.

Key stakeholders
Who are our key stakeholders? Which key activities do they perform?

Original design:
Farmer groups (producers); local community (consumers); solar company and greenhouse manufacturer (technology providers); government officials and agricultural extension officers (enablers); middlemen (market channels); community partners.

Lessons to be incorporated:
- Need for incentivised local technicians and local service providers, including after-sales support.
- Use local credit providers for groups to contribute towards technology purchase (e.g. SACCOs, local MFIs and co-operative banks).

Stakeholders key to project success:
- Agriculture extension officers (could benefit from additional training on solar energy systems and greenhouses).
- Field partners Caritas Kitui (could become repositories of maintenance and repair fund for immediate redressal).

How does the value proposition fit with government strategies and public policies?
- In line with strategies of the Ministry of Agriculture, National Irrigation Board and County government.
- Groups are able to capitalise on government programmes.

Key resources
What resources do we need to deliver our value proposition, reach our end users, generate revenues and build our partnerships?

Original value proposition:
- Technology systems: solar pump system, drip irrigation, greenhouses.
- Knowledge on agronomy, business, technology.
- Human and financial resources to mobilise the above.

Lessons on additional resources:
- Financial contribution from the local community/end user beneficiary towards the energy system: to ensure ownership within the group and accountability from service providers.
- Allocate finances for a maintenance and repair fund: through group internal resources and/or main funder.
- Land ownership: ideally from within the group with the remuneration or benefits accruing to land owner, decided well in advance, or church involvement in land leasing and enforcement process.
- Additional training material on newer components of the system: solar pump, greenhouse production.

Can we easily obtain all the resources (natural, financial, human, physical, institutional etc) that we need? Do we need any extra supporting services? How will we obtain these?
Procurement processes for technology: if these were simplified by the donor agency to allow the procurement of varied products and components based on the needs of specific sites, there may have been more success on infrastructure delivery.

Value proposition

- **What value are we adding to the end user's life?**
- **What collection of products and services are we using to add value, or solve a problem, or satisfy the end user's needs?**
- **What are the social and/or environmental problems we are solving?**

Original design:
1. Increase income and food security
   Support farmer groups in undertaking horticulture production.
   - Provide greenhouses to cultivate vegetables.
2. Reduce environmental degradation.
   - Provide drip irrigation systems and solar water-pumping systems (to reduce water usage and diesel consumption for irrigation).
3. Improve partner and community capacity to maintain energy projects.
   - Train groups in technology use and basic maintenance.

Lessons to be incorporated:
1. Ensure long-term sustainability of projects: financial, technical, operational.
   - Encourage savings/credit facilities as part of group's core activities.
2. Determine financial contribution from end user towards product/service (based on willingness to pay).
   - Local supplier to manage energy system servicing and contracts.
   - Determine the value of social support benefits for end users, as a consequence of group farming approach.
3. Explore alternate channels for market linkage – to provide for increase in production and sales.
4. Pilot innovative models for interventions in agriculture: including new technologies and finance models, individual farmer support through shared equipment, training and shared marketing facilities.

End users

Target groups
- **Which individuals or groups is the service creating value for? (eg services/products for all users or targeted by gender/age/income etc)**
- **Who are our most important end users?**
- **How do gender relationships affect the value proposition?**

Original design:
1. Target end users: marginalised women's groups.
2. Design involved mobilising target communities and selecting groups that were registered.
3. Groups needed to have access to water sources and enter into land agreements.

Lessons to be incorporated:
1. **Target end users:**
   - **Marginalised farmer groups:** groups include almost equal numbers of men and women.
   - Innovative models can be tried out with individual marginalised farmers (and shared resources).
2. **Strong leadership:** the background and experiences of management greatly affect group performance.
3. Land ownership from within the group appears to reduce instances of land-related conflicts.
4. **Gender:** only in women-led households do women make decisions on income use; otherwise men decide (based on limited data-set).

Ways of doing outreach & delivery
- **Do the end users have preferred ways of being reached when it comes to: awareness-raising, purchase, delivery of the energy service?**
- **How can we make sure our ways of reaching end users fit with their preferences/routines?**
- **How much do people use informal channels to build their understanding of services and products?**

Original design:
1. Initial mobilisation through public forums-awareness raising to groups prior to visit.
2. Training on agronomy, business management, technology through specific entities.

Lessons to be incorporated:
1. Using the Internet as a method for learning more about soil testing, pest and disease control, maintenance of any energy system (which are all training needs).
2. Creating 'hubs of excellence' on more successful farms to encourage peer-to-peer training and hands-on learning.

Relationship with the end users
What type of relationship does each of our groups of end users expect us to establish and maintain with them?

Original design:
1. Hand technology maintenance over to groups and facilitate direct contact with suppliers.
2. Include agricultural extension officers for agronomy and horticulture support.

Lessons to be incorporated:
1. Field/community partners continue to remain the first point of contact for end user groups on all aspects.
2. Agricultural extension officers have typically become strong support mechanisms on agronomy-related issues.
3. Significant time and resource commitments need to be made from field partner post-implementation to enable handover in the medium term.

Accounting

Revenue streams
Where will the revenues come from to pay for the service? Can the end users pay for the service? Do donors or the government offer any subsidies that could be used?

Original design:
- Fully donor-funded project.
- End-user contribution restricted to labour, small supplies for installation.
- Maintenance to be managed by group income, as required.

Lessons to be incorporated:
- Assess willingness of groups to make financial contributions (and even borrow low-interest loans) for energy systems and annual maintenance, if a 'reasonable' amount; some groups willing to pay for pump replacement as well, after saving enough.
- Revenues from the project go into the group fund: profit-sharing among members/reinvestment into table banking or horticulture.
- Government funds/soft loans available for farmer groups.

Other costs/ benefits
What are the most important social and environmental costs that this particular service will have? What are the benefits?

Original design:
Social benefits: Awareness of environmental issues, development of women groups, food security and income increase.
Environmental benefits: Reduced diesel consumption for irrigation.

Lessons to be incorporated:
Social: Increase in social capital and access to credit facilities, discovery of leadership potential in the region.
Environmental:
- No reduction in pollution from diesel: groups resort to diesel usage owing to breakdown of solar pumps.
- Reduced water usage with drip irrigation system: water scarcity is a visible threat so groups continue to use drip irrigation, replacing pipes as required.

Cost structure
What are the biggest costs of delivering the energy service? Eg fixed costs, variable costs.

1. **Technology the highest cost:**
   - KES770,000 (USD7,700) per group.
   - Solar water pump constituted 30%.
2. **Other costs: HR, transport, training**
3. **Operational costs:**
   - Diesel for pumps (in the absence of solar) KES1,500 – 3,000 per month (USD15-30).
   - Some groups spent KES8,000-9,000 (USD80-90) on replacing drip irrigation pipes.
   - Groups spend significant amounts per cropping season on hybrid seeds and insecticides.

7. Using the research findings to revise the value proposition

7.1 Delivery of impacts against the original value proposition

- ***By [doing activities]:*** *identifying farmers groups and providing them with technology solution packages (solar water panels and pumping systems and greenhouses); giving them capacity building and training on horticulture, marketing, business management, equipment safety and maintenance, sustainable environmental management and helping them to set up/enhance credit and savings mechanisms; training local technicians to install the equipment; identifying an after-sales service provider for ongoing system maintenance and repair;*
- ***Working with [stakeholders]:*** *the wider local community; technology providers (Solarworks, Greenhort Gardens), government representatives and other implementation partners (Caritas Kitui, Caritas Isiolo, Dupoto-e-Maa);*
- ***The greenhouse component of the CB-GE project will [deliver outcomes and impacts]:*** *increase marginalised farmer incomes and improve food security for the 56 target women's groups, while reducing environmental degradation/emissions from current energy systems in use and improve natural resource management.*

In this section, the original value proposition (see **Box 1**) is revisited to examine how successfully it achieved the intended impacts, or not, and the contribution of each of the activities to these results. This includes consideration of the additional risks identified during the review of the greenhouse projects (see **Table 4**).

Intended result: Increased rural incomes for 56 women groups

Success rating: achieved

The research found that in the 11 projects analysed, horticulture using greenhouses has resulted in higher incomes for the farmer groups. Group members are earning between KES5,000 and KES20,000 (USD50–200) per year from the profits accruing to the group from horticulture production. The large size of vegetables and higher yield within a smaller land area contributed to higher incomes. However, it has been difficult to distinguish between profits from the greenhouse produce and those from open cultivation on group land.

In the initial stages of this project, solar water pumps played a key role in enabling drip irrigation with reduced labour, time and cost (in comparison to manual irrigation). The breakdown of solar water pumps affected profits as groups began to use diesel generators for pumping and spend between KES1,500 and KES3,000 per month on fuel alone – the second highest cost after hybrid seeds. However, five of the 11 groups in this study have continued horticulture production due to the higher income for individual members this has resulted in, along with investment in table banking facilities.

Given the relatively low production volume, the potential impact of upgrading product value and increasing market opportunities were not considered in detail in this research. The local market place, local community and institutions form the biggest sales channels for the groups. Two groups that were particularly proactive have built networks to access supermarkets in the nearest town.

Intended result: By increasing income for the target groups, improve their food security

Success rating: not achieved/difficult to identify impact

While improved food security in the region was an intended outcome of the project, there is little evidence from the research to suggest that this target was achieved. The current small scale of the project means that the volume of produce from the greenhouse is too small to address this ambitious target. However, the greenhouses enable groups to produce vegetables during the dry season (May to September) and adds to the nutritional value of food sources consumed by group members and their wider community.

Intended result: Reduced environmental degradation and enhanced environmental protection

Success rating: partially achieved

Overall, the project was partially successful in introducing distributed renewable energy interventions where no energy source was available, but encountered technical problems that could have been avoided if they had been more carefully considered during the design phase.

Water and energy supply and use were two critical factors for the projects' success from an environmental perspective. The drip irrigation systems enabled efficient water use – a significant benefit in arid and semi-arid areas. For most farmer groups taking part in the greenhouse project, the project was a valuable introduction to drip irrigation.

In terms of energy supply and use, however, the project results were more complicated. Prior to the installation of solar pumps, groups used a combination of diesel and manual irrigation. Immediately after the installation, their use of diesel dropped significantly as they switched to solar energy for pumping, avoiding all the environmental and financial costs associated with diesel use. However, given that all but one of the pumps broke six to ten months after installation, groups were forced to switch back to diesel generators or manual irrigation. As a result, while the solar pumps initially reduced environmental degradation, the tendency to revert to diesel among most groups means that this impact was not sustained – and for those groups who had previously used manual irrigation but switched to diesel after the solar pumps broke, the environmental impacts were negative.

Intended result: Improved partner and community capacity to manage and maintain energy services in target areas

Success rating: not achieved

While the project design included activities to enable longer-term partner/community capacity to maintain the solar pumping systems after project closure, the challenges and potential hurdles appear to have been underestimated. All the stakeholders interviewed acknowledged that building the community capacity to manage and maintain such energy services requires: (1) sufficient time; (2) intensive training; and in this case (3) additional external expert support and resource allocation to ensure regular maintenance and timely repair.

The research highlights the inadequacy of group training on using the pump systems, together with the lack of an adequate maintenance and repair function. While local technicians were given basic training on system maintenance, most groups were unable to prevent the pumps from breaking down. The delays in installation caused the warranty period from the pumping system supplier to lapse and the service provider tasked with ongoing maintenance had neither the local networks nor the capacity to address multiple solar pump failures and provide a sustainable service. The implementation partner was then forced to source a technology provider with local networks who could offer pump replacement and repair options, but at extra cost. The lack of identification of a viable repair and maintenance function at the design phase, combined with lack of resource allocation for future equipment repair and replacement, has prevented timely system repair and replacement from being undertaken.

Box 2. Group innovations during the greenhouses project

Delivery infrastructure: adapting key resources
Tiwa Environmental Youth group replicated the original greenhouse project by building two more greenhouses. To reduce the costs and address the challenge of the greenhouses overheating, they modified the materials used for the new greenhouses. They used timber instead of steel for the frame and 'shade net', which limits the heat and humidity inside the greenhouse, instead of polythene for the cover.

Mbooni youth group used muslin cloth as a filter for the submersible pump. This stopped mud from entering the pump with the water, preventing it from breaking down.

Soon after installation, the Wingoo small-scale farmer group used their existing skills and previous experience to identify blockages in the drip system's pipes and replaced them with a new set of pipes of the right dimensions and quality to allow for the flow of muddy water.

End users: new ways of accessing information
The Wingoo farmers group used the Internet to access information on pests and diseases affecting greenhouse produce. Based on this information, they carried out soil testing and identified potential solutions. They contacted a local farmer with experience of using one of the solutions and visited his farm to understand how to implement it. Using multiple information sources and field visits, they are equipping themselves with the right pest control methods and solutions.

Accounting: Increasing revenue sources
The Kateiko group and Tiwa river environmental groups have worked to increase their group fund by accessing government schemes and low-interest loan facilities. They have accessed the UwezoFund, Youth Fund and Women's Enterprise Fund. These funds are used primarily for table banking. However, they are also willing to consider using these funds to maintain energy systems and expand their horticulture business.

The Thua vegetable growers group have also accessed additional support from the National Irrigation Board in the form of water tanks and new greenhouses as part of the scheme. These additional resources have enabled to the group to expand their business. They have also used their training in greenhouse cultivation and water management on larger plots of land.

7.2 Revised value proposition

We can now revise the original value proposition by integrating the learning from the field research and analysis of the greenhouse project to suggest a new, retrospective value proposition, as follows. The revisions are in blue.

By doing [activities]:

1. Identifying end users and stakeholders

- Identifying and selecting farmer (women's) groups that were already registered and had access to viable water sources.
- Mobilising target communities and sensitising them on energy systems and environmental protection, and natural resource management.
- Ensuring legal land leasing agreements for the groups.
- Creating producer marketing groups.
- Working with local government to build their understanding of the project.
- Identifying technology providers (Solarworks, Greenhort Gardens).

2. Providing technology solution packages (solar water pumping & greenhouses):

- Undertaking detailed site surveys to ensure the proper technical specifications for the solar water pumping systems.
- Undertaking a detailed site analysis to understand the water quality and availability at each location.
- Designing customised/tailored technology solutions for each location (water pumping system and greenhouses).
- Determining the willingness of end users to (part) pay for technology solutions and developing a financing model to allow instalment-based payments.
- Installing mobile solar pumping systems with drip irrigation.
- Installing greenhouse technologies.

3. Supporting services for the energy delivery infrastructure (water pumping system/greenhouses)

- Training farmer groups in equipment safety and maintenance.
- Training farmer groups in renewable energy technologies and services.
- Determining the willingness of farmers to pay for maintenance over the life of the asset or technology solution and develop a sustainable payment model.
- Identify a maintenance and repair service provider for the technology solutions installed – water pumps and greenhouse.
- Training for local technicians on pump repair and maintenance.
- Creating incentives for local technicians to ensure regular maintenance and monitoring of technology.

4. Supporting services for the horticulture business

- Working with the Ministry of Agriculture to access extension services on crop management.
- Building/maintaining relationships with agricultural extension officers and ensuring they have sufficient resources to do regular site visits.
- Training farmers groups in agronomy and business management (including savings-credit facility management).
- Carrying out value chain analysis and strengthening market linkages through the creation of producer marketing groups.
- Establishing direct links between groups and service providers.
- Explore value addition for vegetables that are easily perishable (once the group production volume is high enough).
- Carry out post-implementation training review.
- Develop a best-practice hub to help provide regular training, review and peer-to-peer support after the implementation phase is over and allocate resources.

Working with [stakeholders]: the wider local community; technology providers (Solarworks, Greenhort Gardens), local technology and maintenance support providers, government representatives and other implementation partners (Caritas Kitui, Caritas Isiolo, Dupoto-e-Maa).

The greenhouse component of the CB-GE project will [deliver outcomes & impacts]: increase rural incomes for marginalised women's farming groups, reduce environmental degradation/ emissions from current energy use and improve the sustainability of water management, through creating sustainable horticulture businesses and providing renewable-powered water pumping systems with drip irrigation, and setting up/enhancing group savings and credit facilities.

It should be noted that although the project did contribute to improved nutrition, it is very difficult to prove a link from a single intervention to overall food security because it is dependent on so many factors. Therefore, food security is not an intended outcome of the revised value proposition, as highlighted by this project review.

8. Conclusions

This section considers how the challenges identified in the project could be addressed going forward, and the key learning from the research that could be integrated into designing and implementing future projects of this kind. It concludes by reflecting on the value of the EDM toolkit as a project review and research tool.

8.1 Recommendations

For the greenhouses:

1. **Rehabilitate or replace the solar water pumping systems for all greenhouses**
    a. Undertake site-specific assessments for each pumping system.
    b. Develop a plan for financing and sourcing new pumps from Davis and Shirtliff (or another local technology provider).
    c. Develop a viable payment model for groups to contribute towards new pumps and/or support further training in pump use and maintenance (see 3 below).

2. **Develop a plan for ongoing maintenance, service and repairs by local technology and service providers**
    a. Identify the type of maintenance and repair contract and a local service provider appropriate for each location.
    b. Develop a viable payment model for this, ideally funded by the groups themselves.

3. **Develop additional training and create a schedule for refresher training**
    a. Develop a plan to provide additional training to groups, including on pump use and maintenance, including identifying resources and delivery partners.
    b. Undertake an evaluation of refresher and additional training needs – particularly on aspects of agronomy/horticulture, disease and pest control, use of renewable energy systems and more in-depth training on table banking, savings and credit facilities.

Recommendations for future projects

1. **Pilot technologies and delivery models at a smaller scale before widespread deployment**
    a. Piloting the technology solutions and monitoring their operation over a 3–6-month period will help to identify any gaps in the solutions proposed, hidden costs and so on.
    b. Include greater choice for end users at the design phase by creating technology solutions and livelihood options that are field-tested and customised for different farmer/end user groups (albeit in smaller numbers).
    c. Explore the value of working with individual farmers, while continuing to support existing group farming, including hybrid group-individual models.

2. **Improve site selection and assessment so that project design can be customised**
    a. Adequate attention must be paid to field assessments and ensuring site-specific designs. Systems and solutions that are dependent on environmental factors – such as solar energy or water availability – need to be custom-designed based on the conditions in specific geographies.
    b. Financing and operational aspects must also be considered during the field assessment to ensure the model and system design is appropriate.
    c. Once the end user need and intended impact(s) are clearly identified, the solution – including technical specifications and delivery model – can be customised for implementation in varying geographies and for varying communities based on different combinations of technological, financial and operational factors.

3. **Develop best practice hubs for farmer groups**
    a. Set up a mechanism for peer-to-peer learning and hands-on understanding of how the challenges were addressed or innovations undertaken, using lessons from groups whose leaders had a certain expertise, and performed better in addressing challenges and innovating around the project delivery model.
    b. Innovation undertaken by groups and relevant interventions outside the CB-GEP greenhouses project should be tracked, documented and monitored so they can be disseminated to the farmer groups.

4. **Integrate enterprise development training into livelihoods projects**
    a. Build end-user awareness of the added value of enterprise development training in all livelihoods projects and include training into design of livelhoods projects an essential supporting service.

5. **Build end users' knowledge of savings and credit facilities and funding sources**
    a. Include training on establishing/enhancing savings and credit facilities in any group management training and ensure refresher or additional training for groups who already have these facilities.
    b. Given the perceived willingness of groups involved in the CB-GEP to contribute towards the horticulture businesses, future projects could train end users on how to identify a range of funding sources and how to access financing, including identifying and managing any risks.
    c. This could include supporting end users to build relationships and make links to micro-finance and savings and credit co-operative organisations (SACCOs) or small co-operative banks. One option could be for soft funding from entities such as CAFOD to be used as guarantees or first loss facilities to reduce risk for financial institutions.

6. **Advocate for change in donor procurement policies**
    a. Current procurement policies, as seen in the CB-GEP research, can prevent customisation of project design by not allowing for split procurements and insisting on bulk orders from a single vendor for a specific product. This can add significantly to the project timeline, reducing the time available for implementation and supplier options, impacting on the sustainability of the delivery infrastructure.
    b. Procurement policies should incentivise the use of suppliers with viable local networks that can ensure longer-term support and maintenance for the product/solution. Both project donors and recipients must ensure that the procurement timeframes are taken into account during the design phase.

7. **Ensure the legality and enforceability of land leases**
    a. Replicate the good practice of providing legal support to communities to safeguard leasing of land in livelihoods projects.
    b. There could also be an opportunity to learn from the success of other Caritas Kitui and CAFOD projects in this respect, including projects where land has been leased or purchased by these entities on behalf of communities for their future use.

8. **Ensure adequate human resources are allocated for implementation and post-implementation activities during the design phase**
    a. Roll out of new technologies and innovative delivery models requires implementation partners and technology partners to allocate additional time and resources for monitoring, review including end-user feedback, and modifications, including post-implementation.
    b. Evaluation of the likely timeframe for the project to 'bed in', along with adequate budget allocation for longer-term monitoring and review, must be included at the design phase to ensure the project's sustainability.

8.2 Using EDM as a research and project review tool

In carrying out this research, the EDM toolkit proved very useful in terms of analysing the original CB-GEP greenhouses project, its objectives and intended impacts and its original design process. One of the toolkit's main advantages is that it helps project developers or reviewers to articulate the original value the project was intended to deliver and the set of activities, outputs and actors that together will deliver the solution (its value proposition).

Using the two innovative tools – the Delivery Model Map and Canvas – enables project developers/reviewers to then systematically evaluate whether the intended impacts of a project have been achieved, and why or why not, including identifying any unintended impacts. The two tools help developers/reviewers break down a project or service into its component parts (the categories outlined in the Delivery Model Map) and the detailed questions in the canvas can then be used to systematically evaluate how a category of project activities and outputs is performing in relation to delivering the overall impacts expressed in the value proposition. The toolkit highlights the need to pay attention to the wider set of supporting services needed to deliver the intended impacts, as well as the socio-cultural factors that are crucial for project success and can often cause failure. This enables developers/reviewers to identify gaps in the original design that may be preventing the value proposition being delivered. In the greenhouses project review, a selection of the canvas questions was selected and adapted in the field research with end users (see **Figure 6**).

Identification gaps in the original project design, including those relating to socio-cultural factors, can help project developers to identify the specific 'tweaks' or more structural modifications needed to address current operational challenges or anticipate future ones. It can also identify the successful components of project design that can be further built on or replicated. In the greenhouse review, the findings are useful both for improving the current greenhouse projects going forward, and informing future project design for similar livelihoods projects.

In summary, the added value of the EDM toolkit is that it enables individuals or groups designing a new project or reviewing existing projects – including its end users – to problem solve in a rigorous and systematic way. It has potential for use beyond designing or reviewing energy sector projects/services in planning projects/services in other development sectors.

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Annex 1

List of interviewees

Women's farming groups

1. Kyanika horticulture and cereal farming self help group (Kyanika, Nzambani ward, Kitui East)
2. Mbooni youth group (Ivaini village, Kyangwithya East, Kitui Central)
3. Thua vegetable growers (Kaumu, Zombe, Kitui East)
4. Tiwa river environmental youth group (Kalawa, Yattakwavonza ward, Kitui Rural)
5. Wingoo small-scale farmers group (Wingoo, Nzambani, Kitui East)
6. Kateiko Muungano Self Help Group (Ngungi, Mui ward, Mwingi Central)
7. Umiisyo group (Thawanzau, Kyomethaana ward, Mwingi West
8. Uwonge group (Thawanzau, Kyomethaana ward, Mwingi West)
9. Muwanzo group (Thawanzau, Kyomethaana ward, Mwingi West
10. Useo group (Thawanzau, Kyomethaana ward, Mwingi West)
11. Taa wa mbuki group (Thawanzau, Kyomethaana ward, Mwingi West)

Others

1. Agriculture Extension officers in Mwingi West and Mwingi Central
2. Local chief from a sub-county in Kitui county
3. Julianna Mwania , CARITAS Kitui
4. Rose Mbatha, CARITAS Kitui
5. Joseph Munyeki, CAFOD
6. Simon Ndoo, Solar Works

Annex 2

Questionnaires used for semi-structured interviews/focus group discussions

Method 1: Focus group discussions

Section 1: Introductory questions about the group

1. What is the name of your group?
2. How many years has it been in existence?
3. How many group members are there
4. How many men and how many women?
5. What management and leadership positions are there and who are in these positions?
6. Region/location (village, ward, sub county):
7. No of management positions/ leaders:
8. What were the reasons for forming the group?
9. Is the group still active? If yes, what are its main current activities?
10. What were the main activities of the individual members/group prior to involvement in the CB-GEP greenhouse project?

Section 2: Specific to greenhouse project: (or other business over the last 12 months)

2.1 Greenhouse economics

		Last 12 months (2016-17)	During project period and after (2011-14 & 2015-16)
1.	Crops grown		
2.	Quantity of production		
3.	Typical price per unit (selling price)		
4.	Typical monthly/seasonal costs • Seeds, fertilisers, pesticides, • Fuel/diesel; litres and KSH • Transportation costs • land costs- donation/lease		
5.	Number of hours worked by all members (per day)		
6.	Typical monthly revenue		
7.	Group profit per month		
8.	Typical profit/person		
9.	Any other information		

10. For a group that is still functioning
- What is the typical market?
- How do you transport produce to the location of sale?
- How did you select the 'market'; how did this connection take place?
- What are the main issues you face? eg: variation in price, distress sales

11. (If the group/business is not making a profit)
- What is the value of the group for the members?
- What motivated them to remain members?

12. Did you access any government support or funding? Loan/ equipment/ grant

2.2 Technology

1. Are the main technology systems (eg solar water pumps, greenhouse) still working? Note the current location of each component: panel, tank, pump and drip, greenhouse.
2. What challenges have you faced with the technology?
3. If the systems are working, what steps have you taken for maintenance?
4. When did it stop working and what did you do (process)?
5. Do you know why the technology/product failed?
6. How much has been spent by the group on the technology (capital costs/replacement of equipment), maintenance of greenhouse and other technology?
7. Who is the technician for your group?
8. Were they able to address the system breakdown/issues?
9. If not, who addressed the issue?
10. Would you be willing to pay for maintenance of the system?

For those groups still doing horticulture:

1. What water source do you use (shallow or hand-dug well etc)?
2. What pump is being used? (technical specs of pump: panel wattage, HP, etc)?
3. Who supplied the pump?
4. If the pump is still working, how many hours is the pump used per day/week?
5. How many litres of water are pumped/required per day/week for the business?

2.3 Crop resilience and quality

1. How would you compare your greenhouse produce to open cultivation (quality, shelf life, size, pest resistance etc)?
2. How many months in a year do you produce for?
3. Are you able to produce during the dry season? What do you produce during that season? (Probe if this is different from before the CB-GEP horticulture business started.)
4. Have you had any crop failure over the last 3 years?
   - In the greenhouse
   - On your own farm
5. What are the main challenges you face? (seeds or other inputs, capital, water availability, technology, market, skills etc)?

2.4 Group operations, cohesion and savings

1. Who owns the land you farm on?
2. Do you face any issues or challenges around leasing the land?
3. If you did face any challenges, what did the group/ leadership do to address it?
4. (In the case of groups that lost land): What was the main reason for losing your land (eg inability to pay, conflict, vested interests, bad management/ leadership etc)?
5. (For groups making profits):
   - What does the group use the profits for?
   - What is the profit sharing model?
6. Does the group practice book-keeping? Who does this?
7. If not, how does the group know when they are making profit and when not?
8. How does the group deal with complaints/conflicts when they arrive?
9. What were the biggest issues that the group dealt with over the last few years?

Savings and credit facilities:

1. Does the group have a group fund?
2. Do all members save?
3. How much is saved per week or per month?
4. Does the group give out loans?

2.5 Training effectiveness

1. What trainings was undertaken?
2. Who conducted the training and how many times did it happen?
3. What content was covered (business management, agronomy, technology operation etc)?
4. What aspects of the training have been put to practice? (give examples of things learnt during training)
5. Are there any gaps in the training you got?
   - If yes, what other training would have been more useful for you?
6. Did you like the way the training was delivered? Why/why not?
   - If no, how could it have been improved?

Section 3: Future sustainability and replication

1. What aspects of the group do you think have worked the best? Why? (group dynamics/ leadership/income generation/labour/social support/innovative practices etc)?
2. What are the main things you have learned from working in the group?
    - Note any innovation or replication mentioned or observed (eg energy service/other technology/group working/farming)

For groups still carrying out horticulture:
1. Are you aware of other markets that you could access to sell your produce?
2. If yes, how did you find out about these other markets?
3. Do you think there would be a benefit in trying to identify other potential markets?
4. Did you have access to any external funding support for this or other projects? From whom, terms and conditions (SACCOs/Govt funding/Other charitable institutions
5. If the same project were to be developed with another group, do you think the members would be willing to use their savings or take small loans to start this business? Why/why not?

Method 2: Interviews with individuals

a. Individual group member questionnaire

	Name	Name	Name
Family size			
Profession before joining group			
Income before joining group (monthly/ yearly)			
How and why did you join the group?			
Was it useful for you to participate in the CB-GEP greenhouse project? Why/why not?			
Did you get additional income from the project? *(if not known, could you calculate it?)* or have you got access to credit via this project?			
Do you undertake other paid activities in the community? If yes, what activities?			
Use of income credit from table banking: What do you use the income/credit for?			
Who controls the household purchases?			
If you weren't part of the group, what activities would you be doing (farming/ business etc)?			

b. Individual group member questionnaire

1. How long have you been in a management position?
2. How were you elected?
3. How easy has it been to manage the group?
4. What happens with group income?
5. What rules and processes for making decisions do you follow the group?
6. How did you decide what processes to use?
7. Who were the innovators or champions in the group?
8. Have government initiatives or processes supported your efforts – in this specific project or beyond this project in your other farming?

c. Land owner questions

1. How was your land acquired (eg donation, lease or other method)?
2. What were the benefits of giving or leasing your land for this project?
3. Have there been any negative effects on your land because of the project?
4. What was the process used to give land for this project?
5. Was there any legal documentation?
6. Have there been any conflicts over land? (What happened and why)?
7. How were these resolved?

Knowledge Products

Toolkit
November 2017

Energy

Keywords: Kenya, energy access, small-scale agriculture

Access to modern energy services is vital for poverty alleviation and human development. In Kenya the agricultural sector has significant potential but is hampered by lack of electricity and water availability. From 2011 to 2014, CAFOD and local partners implemented a Community Based Green Energy Project aimed at addressing some of these challenges by providing energy services for rural and peri-urban communities.

One component involved providing greenhouses, solar-powered pumping systems and supporting services to 56 women farmer groups. This study reviews the project's impact on a sample of farmers groups in Kitui county. It uses the CAFOD and IIED 'energy delivery model' toolkit to analyse the project's impacts, using the learning to identify how challenges can be overcome, and future project design improved.

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