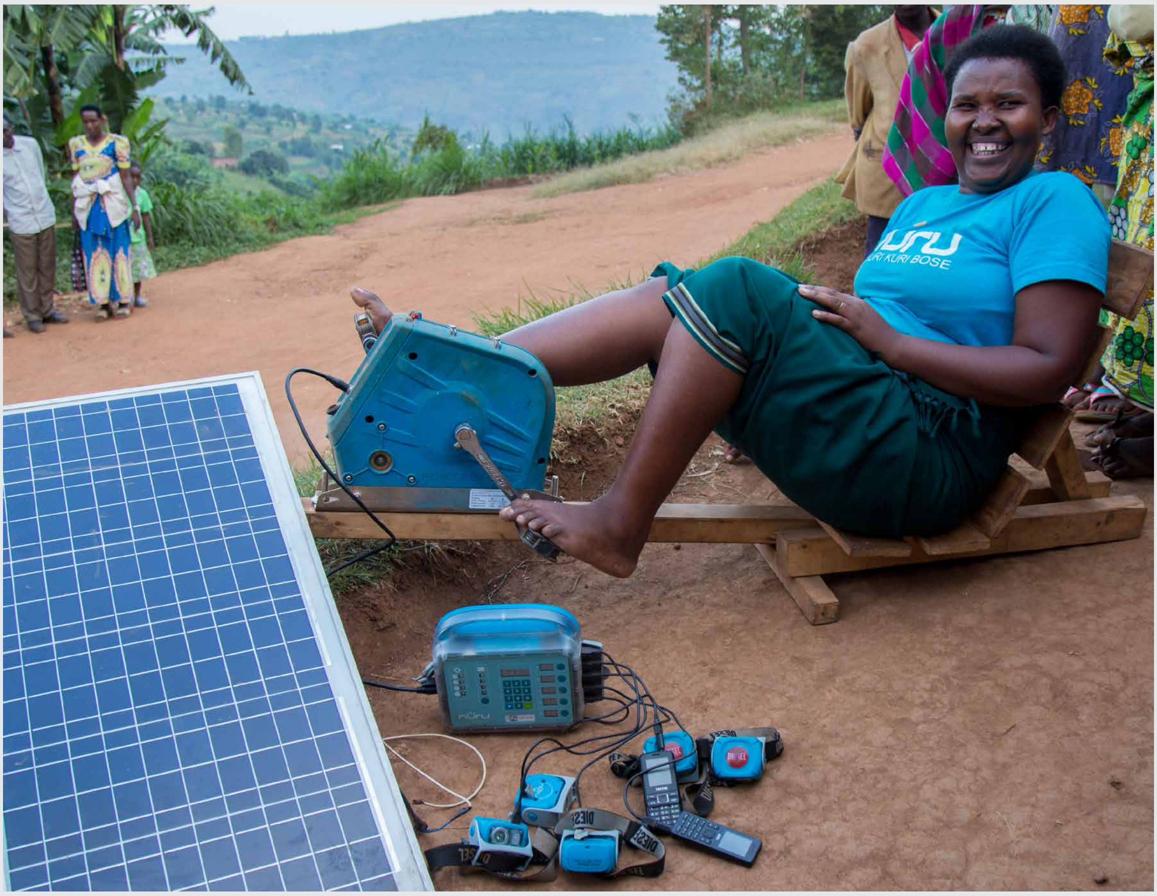
ENERGY AND ENVIRONMENT PARTNERSHIP / SOUTHERN AND EAST AFRICA

The Energy and Environment Partnership Programme Southern and East Africa
PHASE II

28 DECEMBER 2016

ENERGY EFFICIENCY IN EEP S&EA

IN-DEPTH STUDY I



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EXECUTIVE SUMMARY

EEP-S&EA PROGRAMME OVERVIEW

The EEP Programme is supporting a variety of energy efficiency activities in the thirteen countries in southern and east Africa the programme is active in. These activities range from the use of energy efficient lighting technologies like CFL and LED lights in electrification projects, energy efficiency in the building sector, and energy efficiency in the provision of basic energy services as well as improved cookstove programmes.

This report highlights the energy efficiency components of the current portfolio of projects supported by the EEP programme. The purpose of the report is to draw attention to energy efficiency issues relating to different technologies even if projects are not reported under the energy efficiency category.

This report is supported by a number of separate Technical Briefs presenting a broad overview of energy efficiency principles which affect the key areas of energy systems within the portfolio.

Energy efficiency is a major goal of improved cookstove programmes. Cooking uses energy in the form of heat to improve the safety, digestibility and edibility of foodstuffs. In the countries where EEP S&EA projects are being implemented, cooking forms the single main daily use of energy by households. Introducing improved cookstoves can result in significant reduction in energy used, as well as providing important health benefits due to reduced exposure to smoke.

Providing rural communities with efficient lighting technologies, such as compact fluorescent lamp (CFLs) or light-emitting diodes (LEDs), reduces the amount of electricity required by households and increases the number of households that can receive power from solar, wind or hybrid systems, while also reducing the cost of delivering this service.

Improving energy efficiency in existing and new buildings is a major area of development in the EEP region, with Botswana, Namibia and South Africa having made progress in this regard.

Solar photovoltaic (PV) systems form the single largest project category within the EEP S&EA portfolio. This report provides an overview of the operation, technology and efficiency considerations for solar PV.

The total power output of a Solar PV system is affected in two major ways. Firstly, solar PV systems are constructed from multiple subsystems which all have respective efficiency constraints. The total system efficiency is a mathematical product of the respective subsystem efficiencies. Secondly, several design and operational issues affect the energy output of a solar PV system. Where subsystem efficiencies are an inherent technological constraint, yield-related issues can often be mitigated through effective design, management and maintenance.

Solar PV systems are constructed in a variety of sizes and topologies, depending on the desired function and power output. Due to the fact that solar PV technology is inherently scalable, the factors affecting energy efficiency remain the same, regardless of the size and topology of the system. For this reason, the information in this report is equally relevant to evaluate the efficiency and yield of solar home systems as it is to assess large solar PV arrays.

For this report, a case study has been performed on one of the largest solar PV projects within the EEP S&EA portfolio. Conclusions from the case study and the topic overview have been reduced into practical evaluation criteria which will aid in effective mapping and efficiency evaluations for solar PV projects.

ENERGY EFFICIENCY IN THE EEP COUNTRIES

Most of the EEP countries do face energy challenges: in the southern part primarily due to an increase in electricity demand combined with delays in bringing new generation capacity on line, while in the east African region limited hydropower generation due to prevailing droughts has led to energy shortages. In response, energy efficiency measures and regulations have been enacted in the region.

As much as implementing energy efficiency measures and activities is an issue of cost savings; it can be seen as a low-cost energy resource in itself. The rational use of scarce energy sources allows the delivery of more services for the same energy input. Energy efficiency also can reduce the need to install new (peak) capacity and can support the development of an energy supply based on renewable energy.

Particular in off grid situations were all energy requirements will need to be supplied by a local energy source, the deployment of energy efficient equipment can substantially reduce the total amount of energy required. The introduction of energy efficient end uses of energy like CFL and LED lighting have made it possible to supply the needed energy with for example solar PV.

ENERGY INTENSITY

Energy efficiency is typically expressed by using a figure for the "Energy Intensity". Such figure can be used as an indicator to monitor energy efficiency in a sector, country or a region. However, energy intensity can be affected by a number of factors not necessarily linked to pure efficiency such as fluctuations in the volume and sectoral structure of GDP, but it can provide a quick overview of the status and evolution of energy efficiency.

Figure 1 shows the progress on energy intensity for the 13 EEP countries in southern and east Africa. The information on which this figure is based is coming from the SE4ALL Global Tracking Framework report 2015 and comes with a warning that different sources of information have been used to compile the overview. As a general rule it does indicate that the energy intensity has decreased during the reporting time span. This is mainly attributed to technological improvements across all sectors of the economy.

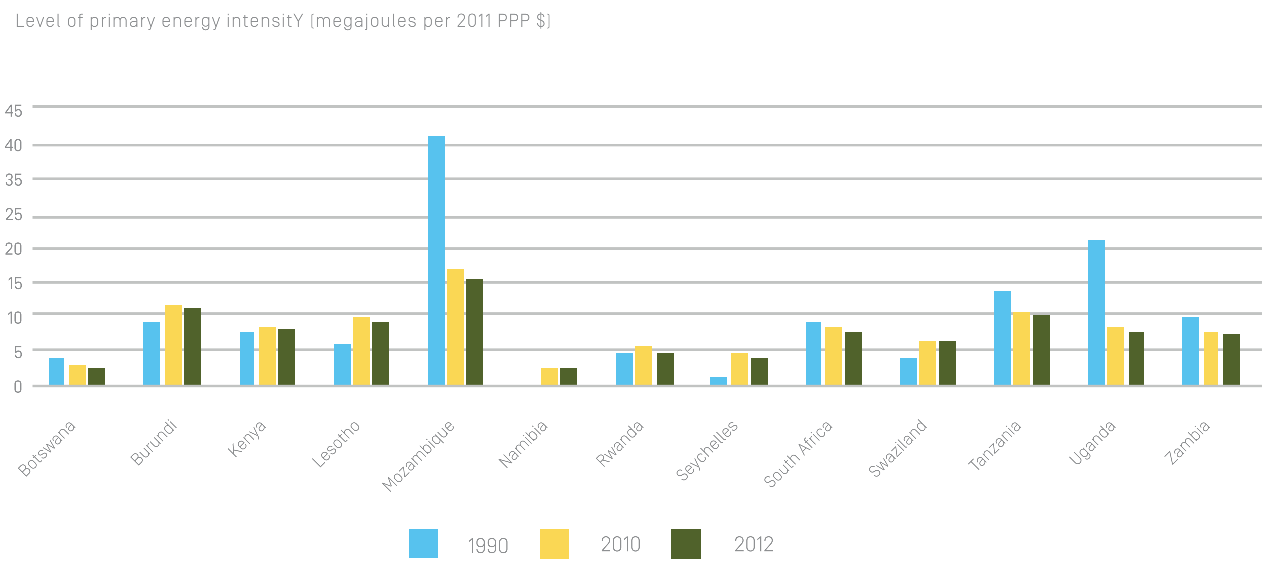


Figure 1 Energy intensity in the EEP countries

DEMAND SIDE MANAGEMENT MEASURES

The following paragraphs provide an overview of the Demand Side Management (DSM) activities implemented or under implementation in the EEP countries. Governments and utilities in the region have implemented these measures in order to reduce the use of existing energy facilities, defer the addition of new generation capacity and reduce peak loads, as well as to reduce the risk of load shedding in a constrained electricity system.

Most of the DSM measures relate the electricity sector, while some refer to other sectors such as cooking energy. Sometimes DSM is also referred to using the term Integrated Demand Management (IDM).

AWARENESS RAISING

Awareness raising is targeted all energy users to make them aware on how to use energy wisely and sparingly. Such programmes typically target behavioural change and raising awareness of available energy efficient appliances. For the latter energy labelling can play an important role in making energy users aware of the efficiency of appliances used.

<note: we can consider to include a picture of an energy label here>

Targeting industrial energy use, programmes offering energy audits and action plan development can come a long way in creating awareness on energy usage and efficiencies in industries.

MORE EFFICIENT TECHNOLOGIES

Technologies that reduce energy use are available for almost all end-use applications in the residential, commercial and industrial sectors. These can be, for example, replacing incandescent light bulbs with CFL and LED bulbs or replacing air conditioners and refrigerators with higher-efficiency models. In an effort to reduce peak consumption, utilities in nearly all [i] EEP countries have been implementing exchange programmes where incandescent bulbs are replaced with CFL or LED bulbs.

In the cooking subsector, improved cooking stoves can convert more than 20% of the energy in wood fuel into heat as opposed to the 10% by conventional stoves. These stoves can, therefore achieve savings of at least 50% in the quantity of fuel used for cooking. This is particularly important in urban and peri-urban areas where prices of charcoal are increasing. EEP has been instrumental in supporting a substantial number of projects for the introduction of such improved cook stoves.

Energy efficiency in the cooking sector has seen a more varied response by the different countries. Although improved cookstoves can reduce fuel consumption, the lack of clear international performance and quality standards has prevented widespread adoption of these stoves. At present, improved cookstoves programmes are present in every EEP country, but with few exceptions, these programmes are primarily funded and led by outside entities with limited national government input.

Kenya, the leader in clean cookstove distribution in Africa, has drafted the Improved Biomass Cook Stoves Regulation, which makes it mandatory for institutions and large consumers of biomass energy to use energy-efficient cookstoves. The regulation also stipulates standardisation and performance requirements for those stoves.

The development of the recently approved SADC Centre for Renewable Energy and Energy Efficiency (SACREEE) will help raise the profile of energy efficiency for both policy and programming in the region. The implementation plan for SACREEE calls for the organisation to support a variety of efficiency measures, including the sustainable supply and demand for clean cooking fuels. Similar priorities are expected to be defined for the East Africa Centre for Renewable Energy and Energy Efficiency.

FUEL SWITCHING

The use of wood fuel for cooking can cause deforestation and indoor pollution. By switching to a different source of energy, the demand for wood fuel can be reduced and therefore the pressure on forest land be decreased.

Most commonly used fuel for this is LPG. However, as LPG is a fossil based fuel, EEP does not have supported projects in this sector.

LOAD MANAGEMENT

Load management is the practice in which the demand on the national grid will be managed using different technologies to reduce peak demand by shifting power from periods with high electricity demand to those with lower demand. Typical examples are water heater controllers that turn off appliances during peak times and solar water heaters that can replace electric water heaters.Programmes with industry on voluntary shifting of loads have been applied in the region as well.

EEP supported one project in this category that included energy management in municipal owned buildings.

GRID LOSSES

Losses in the energy grid infrastructure in southern and East Africa is considered high and several programmes are currently being implemented to address this issue. This application of energy efficiency is outside the mandate of the EEP programme.

BUILDINGS

Buildings are responsible for more than a quarter of the final energy consumed worldwide. This is expected to be also the case in the EEP countries; however, there is a generalised lack of understanding by the majority of the countries concerning their building stock and their energy consumption. This fact is further exacerbated by a general lack of building codes or a lack of reference to energy usage in the existing codes in the different countries.

In some countries initiatives have been initiated to address the issue of energy efficiency in buildings, of which the processes in Namibia and South Africa have received support from EEP.

ENERGY EFFICIENCY WITHIN THE EEP PORTFOLIO

The targeted impact from the EEP programme is poverty reduction through inclusive and job-creating green economy and improved energy security while mitigating global climate change. EEP will contribute towards this through increasing inclusive access to sustainable energy services by promoting wider uptake and use of renewable energy and improvements in energy efficiency.

Energy efficiency is one of the world's greatest future 'sources' of energy. With the rapid increase in global energy demand and political pressures to curb humanity's carbon emissions, there is a global trend to exploit available energy more efficiently.
In essence, the world is learning to produce and use power more efficiently.[ii]

Energy efficiency is a concept that affects all systems that produce, transmit, store or consume energy. Although EE is not necessarily reported within all projects in the EEP portfolio, its extensive impact has to be acknowledged and understood. For this reason, the portfolio has been reviewed to elucidate EE-specific considerations within the following four areas:

- clean cookstoves,
- energy efficient lighting,
- energy efficiency in the building sector
- solar photovoltaic systems.

In addition to this closer look at the EEP portfolio, four technical briefs accompany this report that focus on the concepts of energy efficiency, clean cookstoves, energy efficiency in the built environment and energy efficiency considerations for solar PV.

Nearly one tenth of the available EEP S&EA support to projects has been allocated to clean cookstove projects. By definition, clean cookstoves are designed to burn fuel efficiently and to improve the energy transfer from fuel to cooking pot. These efficiency improvements can be achieved through inexpensive design and manufacturing methods, which make mass production and roll-out of clean cookstoves a cost-effective options for realising fuel savings and emission reductions in low-income communities.

Since energy efficiency is a core reason for using clean cookstoves, this detailed study and the accompanying technical brief provide an overview of the principles of operation, basic technology types and efficiency standards for these stoves. This knowledge base is created to draw attention to different factors that affect cookstove efficiency, and the standards that are required for validating true efficiency.

The energy efficiency for the respective technologies in the EEP S&EA portfolio has been reviewed. A clear distinction has been made between claimed efficiencies and verified efficiencies for the respective technologies. The purpose of this distinction is to elucidate the importance of verified efficiency claims for accurate project evaluation and M&E. The detailed study is concluded with evaluation criteria which can be used by project developers and evaluators for assessing efficiency-related matters for future clean cookstove projects.

The purpose of EEP S&EA is to increase access to sustainable energy by means of supporting the fast-tracked development of renewable energy (RE) and energy efficiency (EE) projects in Southern and East Africa. The majority of projects that are currently in the EEP S&EA portfolio have focused on development or implementation of RE infrastructure or technologies. Even though many projects have a latent EE component, only a scant 1% have been reported directly under the energy efficiency category. One reason for this is the latent feature of energy efficiency in most (if not all) projects, as will be examined in this study. A typical example is the use of energy efficient lighting technologies in most rural electrification projects, which would not have been possible from a technical and financial perspective without the use of CFLs and LEDs. Figure 1 provides a breakdown of the contracted projects within the EEP S&EA portfolio up to March 2016.

The purpose of this report is to provide a brief overview of EE concepts, and to elaborate on four areas within the EEP S&EA portfolio which are significantly impacted by EE

These areas are a sample of energy efficiency projects from a portfolio of over two hundred contracted projects in thirteen African countries.

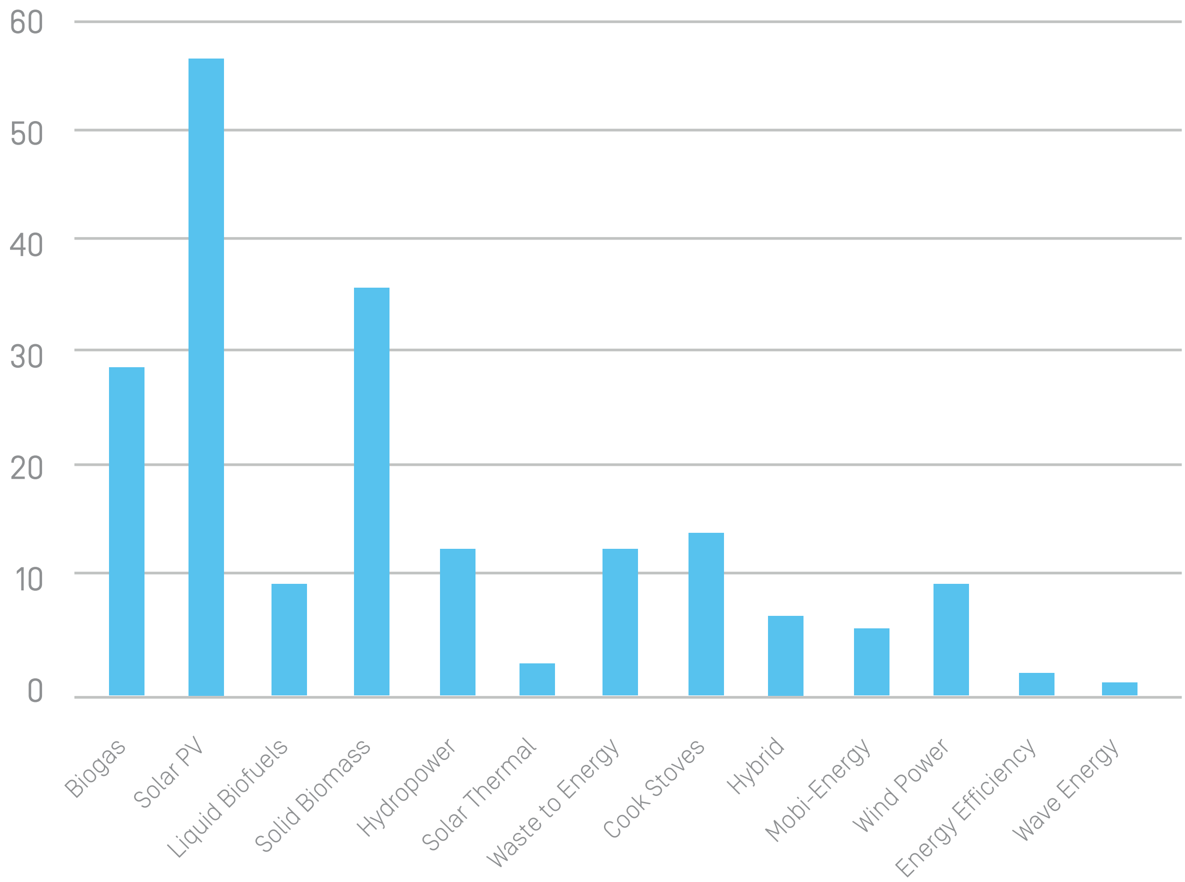


Figure 1: Project types within the EEP S&EA portfolio[iii]

CLEAN COOKSTOVE PROJECTS FUNDED BY EEP IN S&EA

The EEP S&EA portfolio contains several improved cookstove projects. Out of a portfolio of approximately €53 million, almost €4 million was allocated to clean cookstove projects.

The clean cookstove projects that have been reviewed in this study are listed in Table 1 – they comprise 8% of the total EEP budget, as shown in Figure 12.

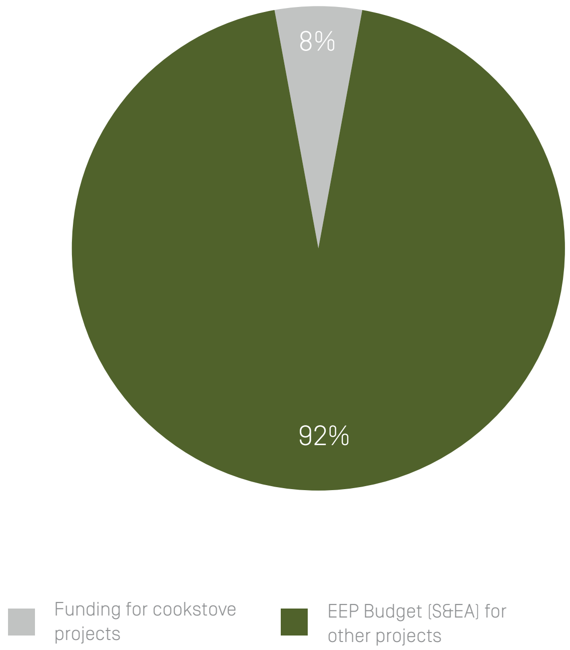


Figure 12: Budget allocation for cookstove projects reviewed in this case study

Project Code	EEP Funding	Lead Partner Organization	Location	Stove used
BUR8073	491 290,00 €	Ecosur Afrique	Bujumbura, Burundi	Jiko Mamu, Jiko Kitoko
KEN9021	106 673,00 €	iSmart Kenya	Nairobi, Kenya	Burn Jikokoa
MOZ5002	208 275,00 €	Mozambique Carbon Intiatives LDA (MozCarbon)	Matola, Maputo - Mozambique.	Different stoves, most used: Envirofit Econochar
REG10039	500 000,00 €	BioLite, Inc.	Kenya and Uganda	Biolite HomeStove
REG610	500 000,00 €	Burn Manufacturing Co.	Ruiru, Kenya	Burn Jikokoa
SA5013	201 500,00 €	Renewable Energy Solutions	Berlin- Mdantsane	Five star clean stove
UGA11013	201 500,00 €	Uganda Stove Manufacturers Ltd	Kampala, Uganda	Ugastove
UGA11086	201 500,00 €	Green Bio Energy Ltd. (GBE)	Uganda	Briketi stove
SA9031	201 500,00 €	Nova Institute NPC	Limpopo, South Africa	Brickstar rocket stove
NAM6	201 500,00 €	Consulting Services Africa	Namibia	Institutional brick rocket stove

Table 1: Projects under review in this study

EEP is closely monitoring and evaluating the results achieved by the projects it is supporting. Programme level results are reported on based on completed projects only. Projects included in this study that have successfully completed their activities have contributed significantly to the programme level results of EEP.

In addition, we expect the ongoing projects to reach a further 300,000 households. There are of course differences in stove efficiencies and employment impact per project, but to make a rough estimate, we can assume the impact on other indicators to be +50% to +70% of the results reported in Table 2

The current study did have a close look at the improved stove technologies being applied in the EEP supported projects. A detailed analysis of the nine different designs can be found in the overview table on the next pages.

Indicator full description	Total completed cookstove projects	Total EEP by June 2016	% of total
OPI 1.2a: Annual cumulative t CO2e emission reductions achieved	84,100	199,235	42 %
OPI 1.3a: Number of rural and urban households with improved access to off grid clean energy	144,977	144,977	33 %
OPI 1.3c: Number of direct jobs created for women, men and youth	462	4,077	11 %
Total jobs men	15	529	3 %
Total jobs women	195	1,748	11 %
Total jobs youth	167	1,305	13 %
OPI 1.4c: Absolute amount of energy saved through installation of energy efficient technologies / projects. (MWh)	219,437	501,326	44 %

Table 2 Contribution by reviewed stove projects to the overall programme level results

Project Code	Stove Used	Stove Image	Short description	Fuel	Energy Efficiency Claims (Internet/ media/brochures)	Official Energy Efficiency Measurements	Special Features
BUR8073	Jiko Mamu, Jiko Kitoko		Most similar to the Kenyan Jiko. Fuel is fed and lit from top. Only primary airflow can be controlled.	Charcoal	Up to 60% charcoal savings [iv]	None found	n/a
KEN9021 & REG610	Burn Jikokoa		Metal shell with ceramic wool insulation between inner and outer layers. Charcoal is loaded and lit at the top. Only primary airflow is controlled through bottom.	Charcoal	* Uses 50% less charcoal than nearest competitor stove. [v] * In a tests conducted in Kenya by The Paradigm Project, the Tank was shown to boil water 48% faster while requiring only 38% as much charcoal as the standard Kenyan charcoal stove. [vi]	Listed and rated on GACC portal: Emissions: Level 1 Efficiency: Level 3 Indoor emissions: Level 1 Safety: Level 3 Tested IWA Thermal Efficiency: 43.0% [vii]	The stove is designed to be robust and user-friendly. Lab tests and field tests yield similar results due to the ease of use for the product.
MOZ5002	Different stoves used in project. Most used: Envirofit Econochar		Double-walled charcoal stove. Charcoal is fed from top. Newspaper is lit from the bottom. Ash drawer is sed for regulating primary airflow.	Charcoal	34.3% thermal efficiency; fuel use reduction of 57% [viii]	Listed and rated on GACC portal: Emissions: 0 Efficiency: 2 Indoor emissions: 1 Safety: unrated Tested IWA Thermal Efficiency: 31% [ix]	Easy control of primary air flow through bottom ashtray.
REG10039	Biolite Home Stove		Micro-gasifier stove; wood fed from bottom. Secondary air flow is driven by a fan which is powered by by a TEG.	Wood, bmass	Requires 50% less fuel than a conventional open fire [x]	Listed on GACC portal with no rating. Efficiency test documentation is listed but not available in online file.	The stove produces electricity (1,5 W at 5V) which is sufficient to charge mobile phones or power LED lights. Since the ower source is a thermoelectric generator, it requires a fire to create electricity: It is important to note risk of fuel abuse for charging phones.
SA304 & SA5013	Five star clean stove		Micro-gasifier stove; loaded with wood pellets from the top	Wood pellets	The cost to cook for 2 hours per day is only R4 [xi]	Listed in the GACC partner directory. [xii] Tier 3 thermal energy, high combustion efficiency; * Max Efficiency: 32% * Min efficiency: 24% [xiii]	Fan-powered forced updraft gasifier stove; the fan is powered by a solar-charged battery. Power pack is sold with stove. Environmental advantage: Biomass pellets are used, which takes pressure off deforestation.
UGA11013	Ugastove		Metal shell with ceramic burn chamber; fuel loaded from top and lit from bottom of the stove Manufactured by artisans using simple tools; Plans for automation with the help of Design Without Borders.	Biomass; Charcoal	*Reduces HH fuel consumption by 35% [xiv] * Save 50% compared to a traditional cookstove [xv]	Listed on GACC portal but not rated. Average 36% reduction cited from Gold Standard case study [xvi]	
UGA11086	Briketi stove		Metal shell with thermal lining between inner and outer layers. Fuelled from the top, lit from the bottom. Only primary airflow is controlled through bottom.	Charcoal briquettes	Thermal efficiency of 25% (the highest on the market) thanks to great insulation materials and improved air flow. [xvii]	Listed on GACC website but not rated. [xviii]	Briketi is an organic charcoal briquette using only waste material to make it an eco-friendly product. It is made out of charcoal dust, various organic waste and agricultural residue; char is made from organic wastes.
SA9031	Briketi stove		Dual rocket stove. Constructed from bricks. Fuelled and ignited from bottom chamber	Firewood, biomass	The project saves approximately 40-50% of the wood that would previously be required to cook the same meal.	Gold Standard certification requires at least 30% savings. Although an official thermal efficiency rating is not provided, there is a confirmed saving. [xx and xxi]	Simple and inexpensive construction using readily available building bricks.
NAM6	Institutional energy efficiency stove		Dual rocket stove. Constructed from bricks. Sizing is specifically for large pots, which are placed inside the chimney stack.	Firewood, biomass	The project saves approximately 50% of the wood that would have been previously required to cook the same meal. [xxii]	None found	Simple and inexpensive construction using readily available building bricks.

Table 3: A comparison of performance between seven stove models in the EEP S&EA portfolio

CONCLUSIONS ON COOKSTOVES

ACCURACY OF EFFICIENCY CLAIMS

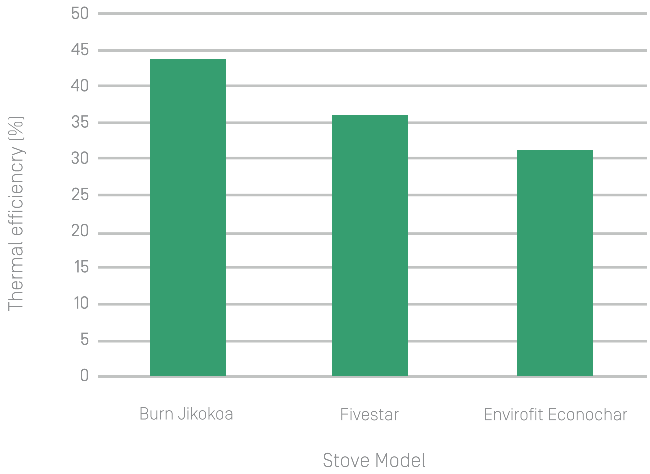
The graph below provides an overview of the ratified efficiency claims in Table 3. Several cookstoves within the portfolio have unverified efficiency claims that are similar or better (in terms of household fuel savings) that that of Burn's Jikokoa, which is one of the best performing (validated) stoves in the portfolio.

The following examples from the portfolio demonstrate different types of problematic efficiency claims:

1. COMPARATIVE BASELINE TECHNOLOGY NOT CLEAR:

- Comparative EE statements do not include a reference to a clear or acceptable baseline.
- Some manufacturers refer the efficiency of their stives to other stives in the market, for example: "Uses 50% less charcoal (than nearest competitor stove)".
- Since the "nearest competitor stove" is a regionally subjective technology, it would be more appropriate to indicate the stove model and the thermal efficiency or fuel consumption of this model.

2. COMPARATIVE BASELINE CONSUMPTION NOT CLEAR:



If fuel savings are used as an indication of efficiency, it is important to indicate what products or technologies are being replaced.

A typical efficiency claim in this respect is: "The project saves approximately 40-50% of the wood that would previously be required to cook the same meal.

Since this statement does not indicate how the same meal was previously cooked, the relative comparison cannot be authoritively used.

3. UNVERIFIED EFFICIENCY CLAIMS:

- If thermal efficiency is cited, it should be referenced against a test standard and ideally also be referenced against proofs of the test, as is done in many cookstoves that are listed on the Global Alliance for Clean Cookstoves portal.
- An example of such unverified efficiency claim is: "Thermal efficiency of 25% (the highest on the market) thanks to great insulation materials and improved air flow."
- Even though this statement might be correct, it is essential that equipment manufacturers back up their efficiency claims with reference to the industry-standard verification.

EFFECTS OF USER BEHAVIOUR

Clean cookstoves are low-cost energy efficient appliances, which means that they are operated by end users. The operation is not automated or regulated by control systems, as would be the case with more complex systems. The end user's behaviour has a significant impact on the overall performance of the stove including efficiency.

Where human operation impacts on system efficiency, EE claims that are verified in lab conditions have to be verified in the field. Proper training is essential to mitigate compromised efficiency due to negligent or unskilled use. If human operation impacts on system efficiency, M&E has to be performed on a sufficiently large sample group to consider the impacts of operators.

Human operation is especially significant for the following cases:

1. Where the rate of forced air flow is controlled, such as the Biolite Homestove and Five Star micro-gasifier stove. Given that lab tests are conducted by trained professionals that understand the complex processes involved in controlling a fire, stoves with more complex control mechanisms may underperform in the field.
2. Where the efficiency of the device differs according to the power level. For example, the Five Star stove's official verification indicates that efficiency is significantly reduced (from 36% to 24%) for low power use. The effects of drastically altered efficiencies for different power intensities could lead to fuel waste, since the calculation for fuel mass becomes more complex.

MISUSE OF TECHNOLOGY

Further consideration should be lent to the ramifications of integrating an electricity supply with fan-powered micro-gasifier stoves. Since the adoption rate of mobile phones is significantly higher than the electrification rate in sub-Saharan Africa, this added feature provides a definite benefit for the end user. However, for stoves that employ a thermo-electric generation device to power the fan, the electricity supply will only be available whilst the stove is burning. A study is recommended to explore whether this feature leads to unnecessary fuel burning in order to create electricity, even when the device is not being used for cooking.

INTEGRATED RENEWABLE SUPPLY CHAINS

Clean cookstove projects such as Five Star and Briketi have created novel value chains between renewable fuel sources and efficient cookstoves. These projects relieve the pressure on deforestation through a two-fold process. Whilst the Briketi stove can be used with various forms of charcoal and briquettes, the Five Star Stove is integrated into the business structure in such a way that the fuel and product relationship is more securely established, which minimizes the chances of the stoves being used with other fuel sources such as charcoal or wood.

Energy savings and emission reductions are directly reported in the EEP's M&E. These figures are affected by efficiency. As indicated Table 4 above, validation of efficiency claims and discrepancies in efficiency values should be considered during the M&E.

IN-DEPTH M&E CONSIDERATIONS

ASSUMPTIONS

1. EEP has several reasonable assumptions for M&E on clean cookstoves:
2. A clean cookstove replaces a three stone fire.
3. A clean cookstove's lifetime is assumed to be 2 years (most stoves have a longer lifespan).
4. The thermal efficiency of a three stone fire is assumed to be 13%.
5. The thermal efficiency of an improved cookstove is greater than 26%.
6. The fuel reduction is assumed to be 50% when a clean cookstove replaces a three-stone fire.

M&E ON UNVERIFIED EE DEVICES

Ideally, the efficiency claims for cookstoves or any other EE devices should be ratified through industry-specific tests, prior to subjecting the project to Monitoring & Evaluation. However, if an M&E is performed on a project that does not have verified thermal efficiency claims, the following recourse is suggested:

1. The device should be compared to the closest verified technology match(es) in the category-specific efficiency lookup table.
2. In order to ensure that conservative savings are calculated, the minimum efficiency should be selected from these technology matches.

OVER-REPORTING ON SAVINGS

Consider the seventh item in Table 1, namely the Briketi stove. This appliance has a claimed thermal efficiency rating of 25%, which is 1% below the assumed M&E efficiency. Consequently, fuel savings and emission reductions will be slightly over-estimated due to the difference between the assumed efficiency and the appliance's claimed efficiency.

UNDER-REPORTING ON SAVINGS

More than 120,000 Jikokoa stoves from Burn Manufacturing have been distributed by EEP S&EA. These stoves possess a verified thermal efficiency of 43%, which means that it saves significantly more fuel than the assumed efficiency in the M&E calculations. Consequently, fuel savings and emissions reductions are significantly under-reported for this model stove. It is recommended that the lookup table for verified device-specific efficiencies should be consulted for accurate M&E calculations.

APPLIANCE LIFETIME

The assumption on appliance lifetime has several effects on the accuracy of EEP's M&E process. Some clean cookstoves are manufactured specifically for durability, which means that they have a significantly longer effective lifespan. Other cookstoves have to be replaced every two years in order to maintain their performance.

Given that the EEP S&EA has been funding clean cookstove distribution for more than five years, and that these appliances have been mass produced over by several other organisations during this time period, the assumption that clean cookstoves only replace three stone fires should be revisited to determine whether the market is still sufficiently unsaturated to maintain the assumption in M&E calculations.

When considering Burn Manufacturing Jikokoa, which is rated with an official lifespan of two years, the following scenarios could be considered:

1. If a Jikokoa replaces a three-stone fire: The thermal efficiency ratio of 43%:13% should be used in the M&E calculation. Note that this is significantly more than 50% fuel savings as compared to a three stone fire.
2. If a Jikokoa replaces another model stove: The thermal efficiency ratio between the stoves should be used in the M&E calculation.
3. If a Jikokoa replaces another Jikokoa: There is no net benefit, but the regression to less efficient technologies is prevented.

The above scenarios indicate the need for effective recordkeeping due to the fact that more EE technologies are constantly distributed. It is advised that product serial numbers are recorded for all M&E activities, in order to validate manufacturing and possibly retail dates for stoves.

EEP SUPPORT THE ENERGY EFFICIENT LIGHTENING TECHNOLOGIES

EEP has supported a considerable number of rural electrification projects in which the combination of declining costs of solar panels and advancements in lighting techniques through the introduction of energy efficient lighting, made it possible to reach large numbers of customers at affordable costs.

Providing rural communities with efficient lighting technologies, such as compact fluorescent lamps, (CFLs) or light-emitting diodes (LEDs), reduces the amount of electricity required by households and increases the number of households that can receive power from solar, wind or hybrid systems, while also reducing the cost of delivering this service.

Most of the EEP supported projects that include the provision of lighting have an embedded element of energy efficiency. Providing lighting services, in particular to off grid communities, is only possible if energy efficient technologies are used. Using ordinary incandescent light bulbs would require large amounts of electricity that cannot be provided at affordable cost. Using energy efficient lighting solutions like CFLs and LEDs have enabled service providers to deliver lighting services at prices affordable to poor rural communities.

A separate in-depth study analyses EEP supported solar PV projects in east Africa . It relates the energy service level provided by solar projects to the tier of energy access as developed by World Bank. For the lowest tiers of energy access, the application of energy efficient lighting technologies is essential in order to offer affordable energy supply to base of the pyramid customers. Up to tier 2 the use of energy efficient appliances needs to be an integral part of the technical solution offered. Or more explicitly: with the use of energy efficient lighting solutions these projects would not have been possible.

The use of these energy efficient lighting technologies has enables EEP to reach substantially more households through our project support than was envisaged at the development stage of the programme.

At the same time, the advancements in available energy efficient technologies, has limited the anticipated installed capacity of electricity generation as result of the EEP programme. With current energy efficient technologies far less generation capacity is required to deliver the same amount of effective energy services (see for more details the Energy Efficiency technical brief).

The energy efficient lighting solutions provided through EEP supported projects range from task lighting, full solar home systems to localised mini grids.

Typically the projects that apply energy efficient lighting technologies do provide a replacement for traditional lighting using kerosene / paraffin.

The EEP monitoring and evaluation methodology does look into the amount of energy saved by replacing this traditional lighting with the electrical light as provided by the solar PV system. By end 2016, completed EEP supported projects that provided lighting solutions have resulted in cumulative energy savings of 120 326.80 MWh compared to the energy previously used in kerosene / paraffin lights. Savings that would not have been possible without the application of the energy efficient lighting solutions as discussed.

EEP SUPPORT TO THE ENERGY EFFICIENCY IN THE BUILDING SECTOR

Two projects in the EEP S&EA portfolio have been classified directly under the Energy Efficiency category; both these projects focus on improved energy consumption in buildings. One of these projects implemented passive design principles to regulate indoor temperatures in a low-cost residential structure. The second project aimed to improve building energy consumption through a behavioural change intervention.

The building energy efficiency technical brief (which has been published by EEP separately) indicates that energy consumption in buildings is a function of design as well as end use. The respective projects explore efficiency strategies on both these fronts.

The building energy efficiency technical brief (which has been published by EEP separately) indicates that energy consumption in buildings is a function of design as well as end use. The respective projects explore efficiency strategies on both these fronts.

The respective case studies highlight that energy efficiency improvements can be cost effective and attainable within the sub-Saharan context. The case studies also reveal the importance of measureable baselines for validating new building efficiency claims, and long-term data logging for efficiency comparisons in refurbishments or behavioural change projects.

ENERGY EFFICIENT STRUCTURE IN WINDHOEK, NAMIBIA[XXIII]

The aim of the project was to investigate and demonstrate improved efficiencies for small residential buildings in sub-Saharan climates. The case study evaluated an energy efficient building at the Windhoek Polytechnic of Namibia. In Windhoek, summer temperatures exceed 40°C and winter night-time temperatures are often below freezing. The building aims to demonstrate that the inside temperature can be controlled naturally in all seasons without the use of electricity from the national grid. The concept is depicted in Figure 3.

During the two-year demonstration period, the structure was inhabited, thus ensuring a real-life demonstration of thermal functionality rather than merely relying on a theoretical evaluation.

A weather station outside the site provided data on ambient conditions. Airflow and temperatures throughout the structure were monitored with an array of sensors to evaluate the thermal performance of the building.

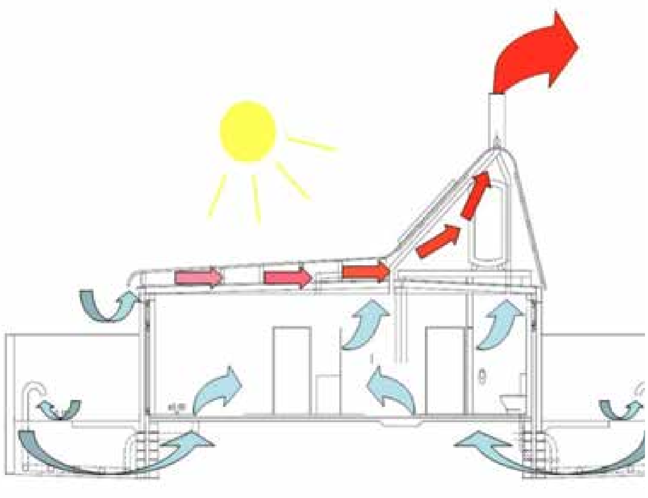


Figure 3: Thermal flow model for the structure designed for Namibian project

PROJECT EE FEATURES

This project implemented several EE standards which are closely related to the Passivhaus standard. The most notable of these measures are the following:

GROUND-COUPLED HEAT EXCHANGE

The year-round sub-surface temperature was recorded as 19.5°C at 1m below ground. The sub-surface temperature was used to cool ambient air from the outside by way of sub-soil air-heat exchangers. For the purpose of the project, the cold sides of heat exchangers were immersed in water and sand and the performance was measured.

SHADING WITH SOLAR CHIMNEY

The structure had a double-roof system which allowed for constant shading and thermal venting between the irradiated surface. The airflow from the solar chimney created a cooling draft between the hot roof and the cooler inner superstructure during the daytime.

The solar chimneys in the structure enabled a passive ventilation system. There was no mechanical control for the system, which means that it was cost effective and followed ambient conditions. The system saves energy that would have otherwise been required to power ventilation fans.

THERMAL INSULATION

The structure was thermally insulated with an outer cement brick shell which was isolated from the load-bearing inner structure with 100mm insulation material. Thermal bridging was minimized by connecting the outer shell to the inner load bearing structure using wire anchors. Double-glazed windows and doorframes aligned with the structure to create a uniform thermal insulation.

AIR-TIGHT STRUCTURE

The only air flow into and out of the building was designed to be an upward flow of fresh air through the ground heat exchange system and warm (dirty) air being expelled through ducting in the ceiling of the structure. The rest of the superstructure was sealed to avoid warm air leaking into the building.

MONITORING

The structure was equipped with multiple temperature sensors to monitor the performance of the sub-soil heat exchangers and to monitor the temperatures in every room. As discussed above, effective monitoring may lead to potential behavioural adjustments which can result in improved energy use.

STRUCTURE COLOUR

The exterior of the structure was painted with a light-coloured paint to reflect sunlight and reduce absorption of solar radiation.

EE IMPROVEMENT SUGGESTIONS FOR THE PROJECT

The building's numerous EE features regulate the indoor temperature so that comfortable living conditions are passively maintained without the need for energy-consuming temperature control. However, the absence of an experimental control means that EE claims cannot be made without a measureable baseline. It would have been useful to compare the EE of the test structure against an equivalent superstructure which lacks all the test structure's EE improvements. The relative efficiency of the structure can only be gauged in relation to meteorological data as supplied by the on-site weather station.

Although the building's EE features have an effect on stabilising the indoor temperature, further basic measures are available improving the building's efficiency. The current passive design is geared towards maintaining comfortable indoor temperatures on the hottest of summer days, but the

A rectangular structure would have an improved ratio and associated thermal exchange rates over the current eight-faceted design.

BUILDING MONITORING IN CAPE TOWN, SOUTH AFRICA [XXIV]

This EEP EE project employed behavioural adjustments for improved building efficiency. The project implemented real-time data logging on mains power of council buildings in Cape Town. Building occupants and operators were sensitized to EE issues, and building consumption was monitored to derive annual consumption trends.

The objective was to demonstrate that significant improvements in energy consumption can be achieved without refurbishments or upgrades to existing infrastructure.

These improvements in efficiency were solely contingent on behavioural adjustments of the building operators and occupants.

Energy consumption was logged since June 2012 and compared over a two-year period. The final report evaluated 14 buildings of which three demonstrated significant energy improvements, possibly due to behavioural changes by the occupants. The figures show these energy savings for the three buildings.

PROJECT EE FEATURES

This project implemented several EE standards which are closely related to the Passivhaus standard. The most notable of these measures are the following:

GROUND-COUPLED HEAT EXCHANGE

The year-round sub-surface temperature was recorded as 19.5°C at 1m below ground. The sub-surface temperature was used to cool ambient air from the outside by way of sub-soil air-heat exchangers. For the purpose of the project, the cold sides of heat exchangers were immersed in water and sand and the performance was measured.

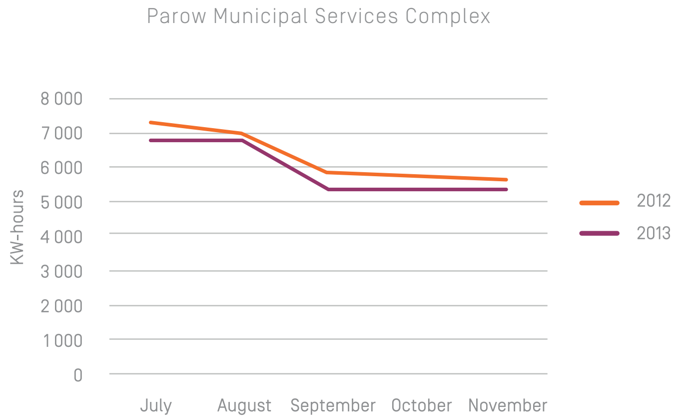


Figure 4: Energy savings in the Parow Municipal Complex due to behavioural adjustments

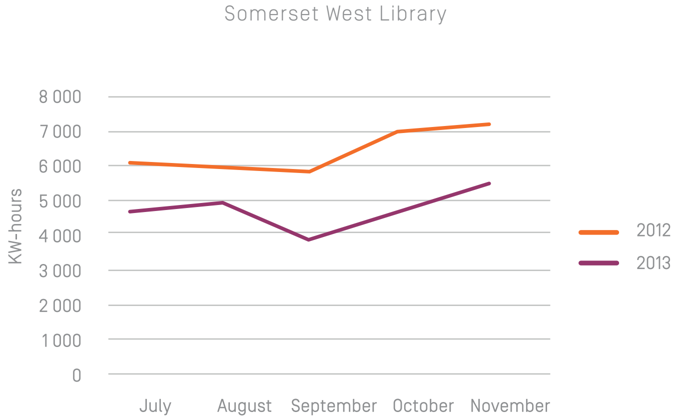


Figure 5: Energy savings in the Somerset West Library due to behavioural adjustments

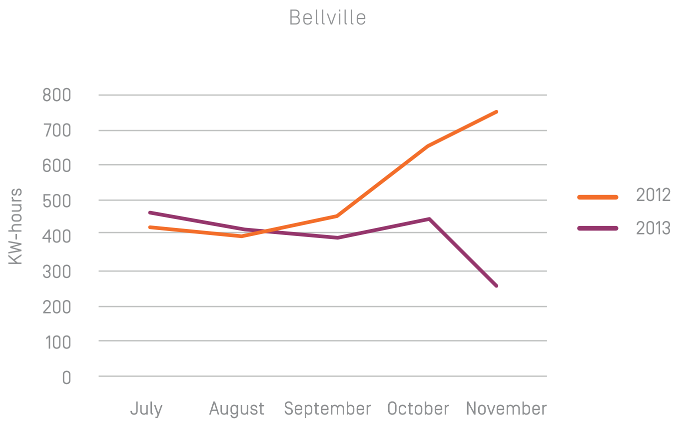


Figure 6: Energy savings in the Bellville Municipal Building due to behavioural adjustments

SHADING WITH SOLAR CHIMNEY

The structure had a double-roof system which allowed for constant shading and thermal venting between the irradiated surface. The airflow from the solar chimney created a cooling draft between the hot roof and the cooler inner superstructure during the daytime.

The solar chimneys in the structure enabled a passive ventilation system. There was no mechanical control for the system, which means that it was cost effective and followed ambient conditions. The system saves energy that would have otherwise been required to power ventilation fans.

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The structure was thermally insulated with an outer cement brick shell which was isolated from the load-bearing inner structure with 100mm insulation material. Thermal bridging was minimized by connecting the outer shell to the inner load bearing structure using wire anchors. Double-glazed windows and doorframes aligned with the structure to create a uniform thermal insulation.

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The only air flow into and out of the building was designed to be an upward flow of fresh air through the ground heat exchange system and warm (dirty) air being expelled through ducting in the ceiling of the structure. The rest of the superstructure was sealed to avoid warm air leaking into the building.

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The structure was equipped with multiple temperature sensors to monitor the performance of the sub-soil heat exchangers and to monitor the temperatures in every room. As discussed above, effective monitoring may lead to potential behavioural adjustments which can result in improved energy use.

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The exterior of the structure was painted with a light-coloured paint to reflect sunlight and reduce absorption of solar radiation.

EE IMPROVEMENT SUGGESTIONS FOR THE PROJECT

The building's numerous EE features regulate the indoor temperature so that comfortable living conditions are passively maintained without the need for energy-consuming temperature control. However, the absence of an experimental control means that EE claims cannot be made without a measureable baseline. It would have been useful to compare the EE of the test structure against an equivalent superstructure which lacks all the test structure's EE improvements. The relative efficiency of the structure can only be gauged in relation to meteorological data as supplied by the on-site weather station.

Although the building's EE features have an effect on stabilising the indoor temperature, further basic measures are available improving the building's efficiency. The current passive design is geared towards maintaining comfortable indoor temperatures on the hottest of summer days, but the air circulation system should be restricted during winters to maintain a comfortable indoor temperature in the structure.

Furthermore, the surface area to volume ratio of the structure could be improved by removing the structural protrusion on the front façade.

PROJECT EE FEATURES

TRAINING FOR BEHAVIOURAL ADJUSTMENTS

The project aimed to influence behavioural adjustments which would reduce the collective energy consumption of the occupants in the buildings.

The following steps were taken to engage the occupants of the buildings:

- A week-long email campaign communicated EE concepts to council staff.
- An EE exhibition was hosted in each building to engage staff.
- A “green team” was established in each building, to muster the collective efforts of interested building occupants.
- A competition was run for council staff to encourage further engagement and to provide feedback on engagement.

The following behavioural changes were encouraged: [xxv]

1. Switching off equipment instead of using standby mode.
2. Unplugging all chargers and adaptors when not in use (or switching off at the wall).
3. Switching off non-essential lights.
4. Properly closing fridge doors
5. Dressing according to the weather and avoiding excessive use of air conditioners.
6. Adjusting thermostats: 1 degree less in winter and 1 degree more in summer; thereby reducing electricity consumption.

MONITORING AND DATA CAPTURING

A total of 55 automatic meter readers were installed in the main distribution boxes of 55 council buildings. The readers were installed between June 2012 and July 2013. The project’s final report evaluated only 14 buildings which had complete year-on-year sets of consumption data.

It is important to note that the behaviour change programme was intensively implemented between in November 2013, which was towards the conclusion of the EEP funding period.

The efficacy of the behavioural changes should be confirmed with long-term trends in consumption data. Given that the same awareness and behavioural change campaign was implemented on all the buildings, but energy consumption only decreased in some of the buildings by the conclusion of the project, long-term data analysis (well beyond the scope of the EEP funding period) is necessary to map energy consumption trends. Long-term trends should be analysed to identify changes in consumption trends which could correlate to specific behavioural adjustments.

EE SUGGESTIONS

A further step in gaining useful data inputs would be to discriminate between loads, so that the consumption trends of main energy culprits such as ventilation, geysers and building lights can be monitored.

For concrete claims of improvement to be made, a longer-term data analysis is necessary to correlate specific behavioural trends with improvements in energy consumption. A long-term analysis will also demonstrate the time-dependent characteristics of any behaviour-related improvements, such as a time lag in the energy improvements due to adoption tempo or a return to the normative consumption state due to a desensitisation to the information over time.

Any long-term data analysis should be combined with site visits to establish which long-term behavioural changes have become entrenched due to the awareness campaigns.

CONCLUSION ON ENERGY EFFICIENT BUILDINGS

The two energy efficient building projects that have been funded within the EEP S&EA portfolio demonstrate the following cost-effective efficiency measures:

1. Behavioural changes can result in efficient energy consumption. These adjustments can be catalysed through training and awareness campaigns. The criteria in Table 1 provide guidelines for evaluating management policies, processes and information systems that could lead to improving the behaviour of building occupants.
2. Recognised passive design standards such as Passivhaus can be successfully modified for the sub-Saharan context:
   - Passive cooling and ventilation can be achieved by exploiting cool soil temperatures in combination with solar chimneys to drive convective air circulation through a building.
   - Effective thermal insulation and air-tight structures can be exploited to manage a building's interior temperatures.

Internationally recognised standards such as Energy Star and Passivhaus have been specifically developed to evaluate energy efficiency in buildings. Even if a structure is not rated according to a specific green building standard, effective M&E can be performed if the following information is available:

1. For refurbished buildings: One year's energy consumption data on either side of the refurbishment.
2. For new buildings: Control structures can be monitored so that the energy performance of the EE structure can be compared to that of the equivalent control structure.

ENERGY EFFICIENCY ASPECTS OF EEP FUNDED SOLAR PV PROJECTS

Solar PV technology makes a significant contribution to the EEP Challenge Fund Portfolio in Southern and East Africa.

Figure 12 illustrates the funding that has been allocated solar projects across the 13 different EEP S&EA countries.

The types of technologies that have been funded in the EEP S&EA portfolio include the following technologies:

- Grid connected Solar PV plants
- Offgrid solar minigrids
- Solar/Diesel hybrids
- Solar Home Systems
- Solar lights and lanterns

Energy efficiency and yield considerations have a significant impact on the feasibility of a solar PV plant.

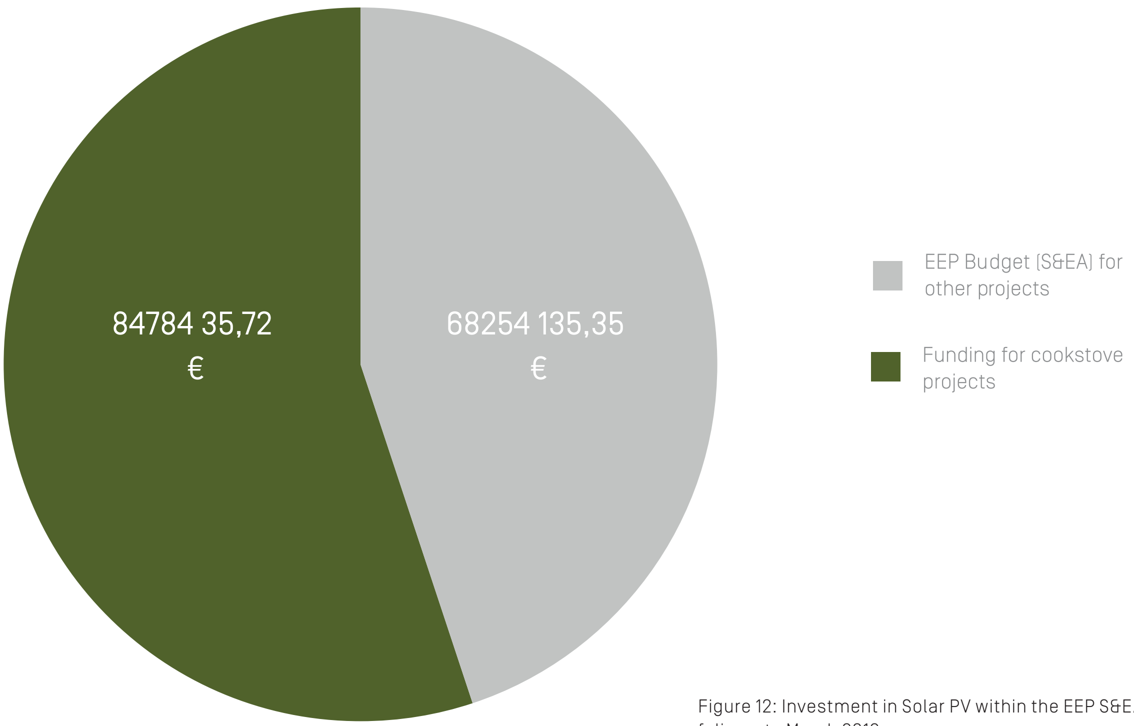


Figure 12: Investment in Solar PV within the EEP S&EA portfolio up to March 2016.

CASE STUDY: AN 8,5MW SOLAR PV PLANT IN RWANDA

Gigawatt Global received EEP funding to complete a feasibility study in Rwanda on an 8.5 MW Solar PV plant with tracking technology. The project's bankability was confirmed shortly after the feasibility study. Financing and implementation followed shortly thereafter. This project connected to the Rwandan grid with a generation capacity equivalent to 6% of the entire national grid producing power. The power output from this project is sufficient to power approximately 100 000 homes.

By employing latitudinal tracking from east to west, energy yield is increased so that the plant produces around 8.5 GWh per year.

Infrastructure breakdown and sub-system efficiencies:

- 28,360 panels with a rated efficiency of 17.5%.
- 8 inverters (Model 300WK SMA Sunny Central 900CP) with name plate efficiency of 98.6%.
- 4 wet oil filled transformers increase the voltage to a medium voltage of 1800V that matches that of the grid for distribution to the local community. Wet oil transformers are approximately 99% efficient (see technical brief)

SPECIAL EE FEATURES

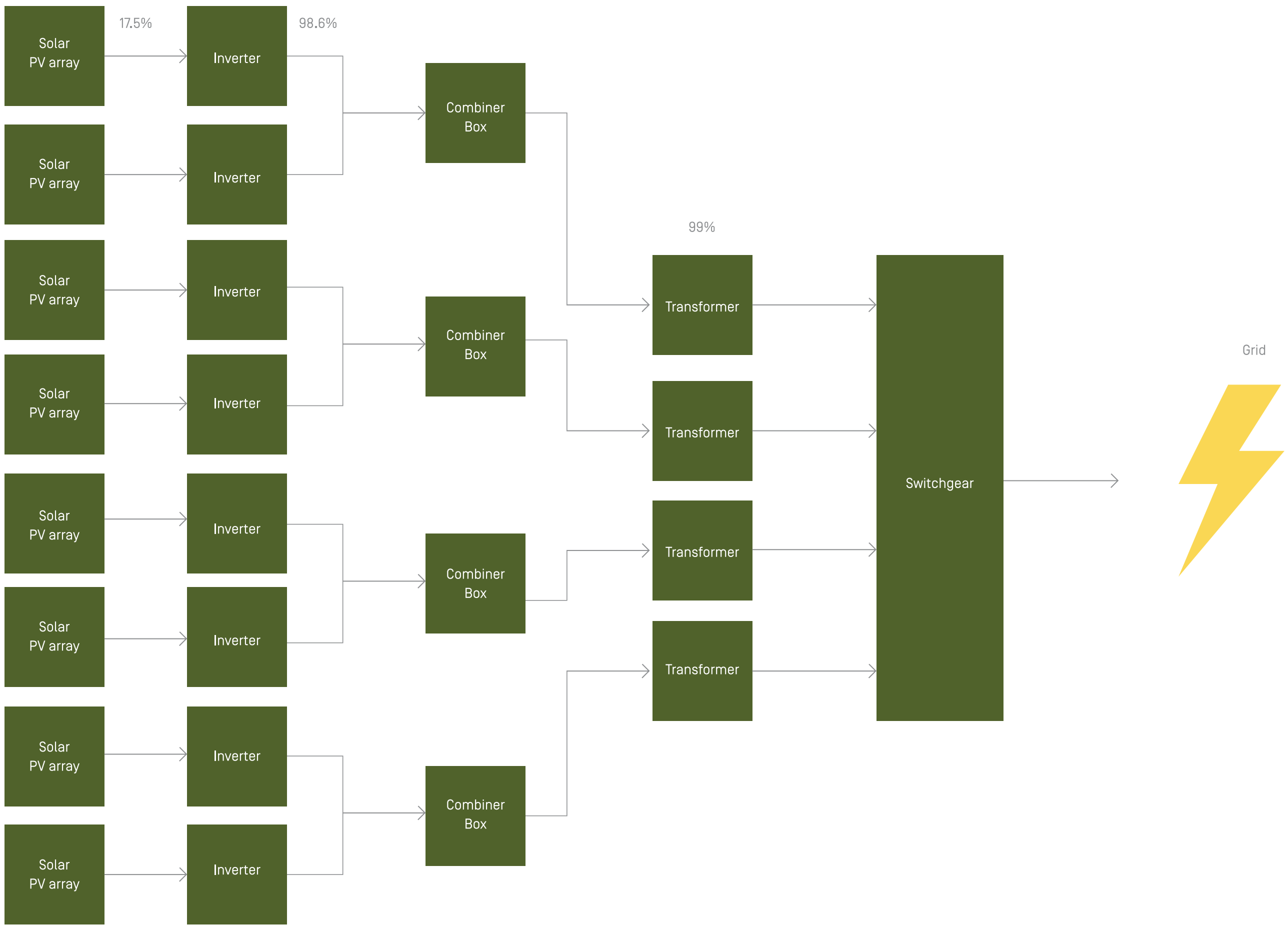
The tracking system allows a 15-20% increase in yield over a system where panels are stationary at fixed tilt angles.

Dust management is ensured through contractual obligations for cleaning in the maintenance agreement. The effect of dusting is monitored by maintaining specific control panels which are not cleaned. Losses due to soiling are reported to be between 2-3%. The developer is attempting to reduce this loss by increasing the frequency of the washing schedule from the planned biannual rate.

Figure 14: Washing of panels to improve efficiency [Courtesy Mr Chaim Motzen]

OVERALL SYSTEM EFFICIENCY

A high level system diagram of this plant is shown in Figure 15 below:



Total plant efficiency =
Epanel x Einverter x Etransformer
= 17,5 x 98,6 x 99
= 17,1%

Assuming 3% dusting loss, the output efficiency can be reduced to 16,6% when the panels are not cleaned regularly.

Figure 15: The combined efficiency at peak output is 17.1%, ignoring dusting losses and assuming perfect efficiency in combiner boxes and switchgear

CONCLUSION

TECHNOLOGY

Due to the diversity of solar PV technologies and topologies that are implemented in the EEP S&EA portfolio, the following information is required for effective project assessments:

1. A system diagram must indicate the topology of all functional elements.
2. Product specifications must be supplied for all functional elements of the system.
3. Peripheral systems for improving system efficiency (such as panel or battery cooling or tracking systems) must be listed.

Technology checklists are provided in Table 1 and Table 2 below.

POWER OUTPUT

The power produced depends on the following:

1. Wattage rating of the solar PV panel or solar PV array.
2. Sub-system capacity and efficiencies as explained in Section 2.1.
3. Design and yield considerations as explained in Section 2.2.

Solar home systems are strongly supported by the EEP and are becoming widely adopted in sub-Saharan Africa. Since the power from solar home systems is used mostly at night, the M&E should consider the both rated power output of the solar panel as well as the energy transfer to the system's battery. If the solar panel is oversized, the storage capacity of the battery and the efficiency of the battery will determine the power output of the system. If the battery is oversized, the output power from the solar panel and the yield considerations due to installation will determine the amount of useable power.

INSTALLATION

System installation directly affects the energy yield of a solar PV system. The impact of installation standards becomes more pronounced for distributed systems (such as solar home systems), where multiple contractors of varying technical ability are often used to deploy the systems. M&E on distributed systems must be performed on a statistically significant sample to verify consistent installation standards. Furthermore, the evaluation should include installations from all installation contractors on a roll-out, in order to ensure consistency.

OPERATION AND MAINTENANCE

The annual power output of a solar PV installation is significantly affected by maintenance. Without proper maintenance (such as cleaning), efficiency rapidly declines. Similarly, effective usage and consistent operational conditions affect the annual energy output of a solar system. From the case study of RWA5015 it was evident that the standard of washing panels twice a year may not be adequate in some dusty areas as efficiency reduces quickly and more frequent washing is foreseen to increase efficiency of the solar system.

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