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A cross-sectional review: Impacts and sustainability of small-scale renewable energy projects in developing countries

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ABSTRACT

Access to sustainable and affordable energy services is a crucial factor in reducing poverty in developing countries. In particular, small-scale and community-based renewable energy projects are recognized as important forms of development assistance for reaching the energy poor. However, to date only a few empirical evaluations exist which analyze and compare the impact of these projects on local living conditions and their sustainability ex-post implementation.

To better understand the impacts and the conditions that influence sustainability of these projects, the research presented in this paper evaluated 23 local development projects post implementation. By applying an standardized evaluation design to a cross-sectional sample in terms of renewable energy sources (solar, wind, biomass, hydro), user needs (electricity, food preparation, lighting, productive uses), community management models, finance mechanisms and geographical locations, the review results provide valuable insights on the underlying conditions that influence the success or failure of these small-scale local energy interventions. The empirical evidence suggests that the sustainability of small-scale energy implementations ($\leq$ 100 kW) in developing countries is determined by the same factors, independent of the socio-cultural, political and ecological context. These findings allow to better predict the long-term success of small sustainable energy projects in developing countries, this can help to improve project designs and increase the certainty for future investment decisions.

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1. Introduction

Over the last two decades the number of people without access to modern energy services, defining those lacking access to electricity and clean cooking facilities, has decreased significantly. However, 2.6 billion people still lack access to affordable and reliable energy services to meet their basic energy needs [1]. Most of these people live in rural areas in developing countries or belong to the urban poor. Without access to energy the chances of reducing poverty and advancing development are poor. Thus, even though none of the Millennium Development Goals (MDGs), representing the universal development objectives agreed on by the international community, relate directly to energy, it is widely acknowledged that it will not be possible to achieve the MDGs without expanding energy access [2]. But *energy access* is not the only concern; energy supply should also be sustainable, avoiding the drawbacks of conventional energy sources such as harmful emissions, noise, high fuel costs and supply insecurities. This call for sustainable energy access for development is further underlined by the declaration of the decade 2014–2024 as the *Decade of Sustainable Energy for All* by the United Nations General Assembly. The initiative supports renewable energy sources as a key technology to reach the energy poor, offering clean electricity, heating, cooking and lighting solutions to people and communities who currently depend on traditional energy sources and/or expensive fossil fuels. Renewable energy technologies are regarded as particularly suitable because they can provide small-scale solutions and decentralized energy supply that meet the needs of the population most widely affected by energy poverty. Furthermore, innovations and cost reductions over the last decade have made renewable energies more economically competitive in relation to traditional fuels [3], which have also helped to strengthen the case for renewables. Nevertheless, these technologies still face a range of social, economic and structural challenges, requiring not only further technological development but also a deeper understanding of both the success factors and the barriers to accomplish widespread dissemination. This is demonstrated by a recent study by Bhattacharyya [4] on financing energy access and off-grid electrification, which showed that despite recent progress and the support of the international community only limited funding is available for small-scale community projects. According to Bhattacharyya [4] most funds are allocated to larger energy generation projects that barely address the energy needs of the poor. Yet, small-scale projects can play a key role in supporting the transition towards more sustainable energy systems. Therefore, the WISIONS initiative[1] provides support to innovative project approaches and capacity development to respond to energy needs at local level via its Sustainable Energy Project Support (SEPS) scheme. Since 2004, a total of 64 projects worldwide have been selected for SEPS support. These projects focus on different energy-related needs, technologies and implementation concepts. Although most of these projects were completed successfully, small-scale renewable energy projects do not automatically become sustainable in the long term. In the literature there are numerous documented accounts of development efforts that fail because they cannot create conditions that lead to lasting results [5–7]. A study by Bhattacharyya [8] on the relationship between energy access programs and sustainable development suggests that the existing practices of providing energy access are generally unsustainable from a number of perspectives. Therefore it is important to evaluate and accurately assess the impact and sustainability of such projects after the initial project activity is completed, to learn from results and improve the quality of future decisions and projects.

In view of these observations, the main objectives of this paper are: (a) to evaluate the impact; and (b) to determine the mid-term sustainability of 23 small-scale renewable energy projects ex-post implementation as well as (c) advancing the knowledge of the effects of energy access projects at local level by exploring whether influencing factors and barriers are linked to the type of technology, whether they depend on the economic, social or geographical background or whether common patterns independent of these factors can be identified. The results offer stakeholders information about the major influencing factors in the success or failure of achieving sustainability in small-scale renewable energy projects in developing countries.

The article is organized as follows: Section 2 presents the background for evaluating small-scale renewable energy projects, Section 3 describes the methods applied, evaluation design and evaluation sample, Section 4 discusses the results of the impacts and sustainability evaluation, Section 5 summarizes the research outcomes and the recommendations these results imply and the paper conclude with Section 6 that discusses the limitations and future research needs.

2. Overview: the state of evaluating small-scale renewable energy projects in developing countries

Over the last decade the international community has emphasized the importance of evaluating development interventions. This is reflected in the increasing attention the subject receives in publications of donor organizations and research institutions on how to evaluate projects [9–15]. As a result, many evaluations of individual projects or country programs are documented in the literature. However, only very few studies actually evaluate small-scale community projects ($\leq$100 kW) in developing countries with regards to their impact on local living conditions and sustainability post-installation [16–19]. This is in line with the report from the UNDP [20] stating that studies on drivers of success and sustainability of small-scale projects limited to a small number of case studies. Ferrer-Martí et al. [16] who provide an overview of the few studies that have addressed these subjects. Other examples include Hong and Abe's study [17] on the sustainability of off-grid rural electrification on the Pangan-an island in the Philippines, the analysis of lessons learned from small-scale bioenergy projects in rural China by Han et al. [21], the paper by Ilskog and Kjellströmb [22] assessing rural electrification cases by means of indicators as well as Balkema et al. [23] who conduced an impact assessment of several small scale renewable energy projects in developing countries based on the MDGs, could be added to this list.

Nearly all of these studies focus either on one technology or on a specific geographical context. This corresponds to the results on rural electrification projects in general by Schillebeeckx et al. [24] who carried out a content analysis of 232 papers on. This analysis showed a clear dominance of research on technology and institutional contexts while less attention has been given to understanding user needs. With regards to post-implementation studies to the best of the authors' knowledge there have been almost no studies that review the sustainability of small-scale projects that are cross-sectional in terms of technologies, user needs and/or geographical regions. An exception is the meta-analysis

[1] "WISIONS of sustainability" is an initiative by the Wuppertal Institute supported by the Swiss-based foundation ProEvolution. It was launched in 2004 to promote practical and sustainable energy projects. To ensure the sustainable character of the projects supported by the SEPS scheme their selection is based on the following set of criteria: technical viability, economic feasibility, local and global environmental benefits, replicability and marketability, potential for poverty reduction, social equity and gender issues, local involvement and employment potential, sound implementation strategy and dissemination concept. For more detailed information on the program, please visit the website www.wisions.net.

from Brass et al. [19], which reviews case studies of small-scale local energy systems from existing literature with regards to factors that affected the outcomes of these projects. The other cross-sectional evaluations that exist have mostly been undertaken by donor organizations such as the World Bank [25], FAO [26], UNDP [20] or the Japan International Cooperation agency [27]. These evaluations have focused on national programs or projects on larger scales and with higher budget s. However, these studies have served to demonstrate that the evaluation of a number of projects implemented within a common framework, but under diverse contextual factors can provide recommendations, which are relevant across project boundaries. Consequently, the authors of this paper are convinced that despite the methodological challenges, which are discussed in Section 3.2, a cross-sectional evaluation can create synergy effects and provide better insights into factors that influence the success and sustainability of small-scale renewable energy projects in developing countries.

The Millennium Development Goals were chosen as reference frame for the impact assessment as they represent the benchmark for meeting the most pressing challenges of out time climate change and global poverty. Both of these challenges are interrelated and linked to energy. Not to include energy considerations in development projects will severely limit the ability to achieve the MDGs. Therefore, the MDGs are widely used as connectional framework for sustainable energy development interventions.

3. Methods

3.1. Evaluation principles

In the growing field of evaluation practices in development activities it is important to determine the terms and objectives of an evaluation. A set of five key evaluation criteria to examine development assistance was established by the Development Assistance Committee (DAC) and is widely applied by donor countries and multilateral organizations. These five core criteria are [28]: relevance, effectiveness, efficiency, impact and sustainability. While relevance, effectiveness and efficiency should be analyzed in the earlier steps of the project cycle, impact and sustainability can and should be assessed post implementation. These type of ex-post evaluations are particularly helpful in answering the question of what works and why and, consequently, can guide future improvements in project design and practice by identifying success factors and explaining failure [29]. Accordingly this paper focuses on reviewing (a) impact and (b) sustainability.

(a) *Impact* is understood to mean both positive and negative change produced directly or indirectly, intentionally or unintentionally, by a development intervention. This includes the main impacts and effects resulting locally from the activity in terms of social, economic, environmental and other development indicators [28]. The impact evaluation should deliver a balanced assessment of whether the program produced the desired results for individuals, households and institutions and whether those effects can be attributed to the program intervention [9]. These assessments should consider contextual factors such as social, cultural, economic and political aspects as critical conditions that shape the nature of development [5].

To assess the impact the international working group for Monitoring and Evaluation in Energy for Development (M&EED) suggests that the MDGs should be used as reference as they represent the international priorities for sustainable development [30]. Consequently, the findings of this evaluation are assessed on the basis of their contribution to attaining the MDGs.

Although, in a general sense, extending energy services can contribute towards all the development goals, it was not possible to measure all of these impacts through the applied evaluation design. To account for all impacts, detailed on-site studies would have been necessary for each of the 23 projects. Due to time and financial restrictions this was not possible for all projects.[2] Therefore, the impact assessment was concentrated on impacts related to the MDGs presented in Table 1, which could be measured with the applied approach. Table 1 also gives an overview of the impact categories that reflect the contribution made by the projects to achieving the selected MDGs.

(b) *Sustainability* in the present case is concerned with measuring whether the expected benefits of a project, i.e. access to clean energy services, business, employment and training opportunities, food security etc., are likely to persist after donor funding has been withdrawn. Sustainability can be assessed by answering the following two questions (1) to what extent did the benefits of a project continue after donor funding ceased? and (2) what were the major factors which influenced the achievement or non-achievement of sustainability of the project? [26]. The timeframe for this type of post implementation evaluation varies but in most cases project performance is addressed within two or three years after the installation [19]. This paper evaluates projects, with an average duration of 12–24 month, that were started between 2004 and 2008. Clearly this timeframe is insufficient for claiming long-term success, but the fact that the technology is still functioning and being used 2–8 years after its initial introduction can indicate whether long-term sustainability is likely to be accomplished.

3.2. Evaluation design

The study is based on empirical data from the conducted survey and secondary data from literature, national statistics and project progress and final reports. The evaluation process itself was designed as semi-structured in-depth interviews with the organizations that implemented and monitored the initial project activities. This survey approach was chosen as it is time-effective and particularly suitable for addressing questions about why certain decisions are made and why some processes work better than others [9]. This approach inevitably has limitations, namely the problems of generalizing the results along with the possibility that the information provided is biased. The challenge of comparing and generalizing the outcomes was helped by the fact that all projects were supported under the same program and were, therefore, selected based on the same criteria. This means that a number of variables remain constant, providing a sound foundation for identifying common processes and impacts [12]. With regards to the possibility of predisposed interpretations, we tried to limit the risk by validating the information through comparing the reported data with existing project documentation in the form of initial project design, progress and final reports, as well as secondary literature and statistics.

Although the general structure of the questionnaire was identical and key issues were addressed in all interviews, not all questions were relevant to the entire sample, accordingly the questions varied to a certain extent depending on the project design and technology. The main categories addressed were (a) overall project sustainability, (b) technology, (c) social and economic aspects, (d) environment, (e) replication and dissemination and (f) policy development.

[2] While for larger projects the resources necessary for a detailed and effective evaluation amounted to only 0.2–1.25% of the total project cost [9,31], this percentage is much higher for small projects with project budgets up to €100,000.

Table 1
Selected MDG benefits of renewable energy projects.

MDGs	Impact of projects on MDGs
MDG 1: Reducing extreme poverty and hunger	• Access to energy • Productive uses of energy • Reduction in energy expenditure • Employment and training • Improved quality of life
MDG 7: Ensuring environmental sustainability	• Reduced GHG emissions • Unsustainable energy sources replaced
MDG 8: Promoting global partnership for development	• Policy interactions • Development of network connections and partnerships • Development of institutional frameworks • Dissemination

Based on [20] and [24].

Table 2
Overview projects and status.

	Technology	Need/application	Country	Status 2012
1	Micro-hydro power	Electrification	Brazil	Fully operational
2	Solar PV	Electrification and lighting	Namibia	Fully operational
3	Pico-hydro power	Electrification and lighting	Philippines	Fully operational
4	Improved cooking stoves	Food preparation	Laos	Fully operational
5	Biogas	Food preparation	India	Fully operational
6	Improved cooking stoves	Food preparation	China	Fully operational
7	Biogas	Food preparation and heating	Jordan	Fully operational
8	Efficient pumps	Irrigation	India	Fully operational
9	Solar PV and efficiency improvement	Lighting	Mauritius	Fully operational
10	Solar PV	Lighting	Kenya	Fully operational
11	Efficiency improvement	Lighting	Mexico	Fully operational
12	Wind power	Electrification	Peru	Mostly operational
13	Solar cookers and improved cooking stoves	Food preparation	Guatemala	Mostly operational
14	Biogas	Food preparation	Latin America	Mostly operational
15	Solar cookers	Food preparation	Nepal	Mostly operational
16	Solar PV and wind power	Irrigation	Tanzania	Mostly operational
17	Efficient lanterns	Lighting	Sri Lanka	Mostly operational
18	Solar bakery	Food preparation	Cameroon	Mostly operational (2011)
19	Biogas	Electrification	Sri Lanka	Only functioning to a limited extent
20	Solar PV and micro-hydro power	Electrification	Peru	Only functioning to a limited extent
21	Liquid biofuel Jatropha	Irrigation	Nepal	Only functioning to a limited extent
22	Liquid biofuel Jatropha	Irrigation	India	Not functioning
23	Biomass gasification	Industry	India	Not functioning

The data collected consists of quantifiable evidence, such as the number of installations or number of beneficiaries, as well as qualitative aspects, such as user satisfaction, impacts on society, awareness-raising or network development.

With regards to the impact evaluation it was not possible to establish a common baseline for all projects to measure the impacts due to the small number of projects and the lack of detailed socio-economic background data, like household size, income levels, spending habits, education levels, energy consumption etc., for the different user groups in the individual projects. Instead the quasi-experimental design of reflexive comparison was applied, comparing the situations of the participants before and after the intervention [9]. To minimize the risk that this approach implies, the issues of external effects were explicitly addressed in the interviews.

3.3. Evaluation sample

The evaluation cluster consisted of 23 projects, supporting various renewable energy technologies including solar, wind, hydro and biomass power, as well as efficiency measures to meet needs such as food preparation, lighting, electrification or irrigation in over 17 different developing countries (Table 2). About a quarter of the evaluated projects were implemented in Sub-Saharan Africa and a further quarter in Latin America, while the other half were implemented across Asia, with one additional project implemented in the Middle East.

The most common application of the implemented technologies was food preparation, followed by electrification and lighting. Irrigation was the application in 15% of the reviewed projects, while “productive use” as a primary application played only a minor role. In terms of technology, the applications that utilized biomass for energy generation in the broadest sense represented the largest group (37%) (Fig. 1). The second largest group was made up of the technologies that transform solar radiation into energy, such as photovoltaic or solar cookers (30%). Wind and hydro power implementations represented only 7% and 11% respectively of the reviewed projects. Efficiency measures represented 15% of the implemented technologies. In all but one case these focused on efficiency improvements for lighting, such as efficient light bulbs or the improved use of daylight. In the other case the focus was on efficient water pumps for irrigation. Improved cooking stoves are classified as bioenergy technology, but they could also be seen as efficiency improvement technologies; this classification would see the share of efficiency technologies rise to 26%.

4. Results

4.1. Impact

When examining the complex circumstances surrounding local energy access and energy efficiency projects in developing countries, it is useful to consider the following questions: (a) what has happened as a result of the project in terms of measurable impacts? And (b) what real difference has the activity made to the beneficiaries in terms of welfare and empowerment? [28]. In the following section these questions are addressed with regards to the impact the 23 renewable energy projects have had on the MDGs. The review shows that most projects had positive impact on factors such as energy access, energy costs, employment, health, communication and/or access to information, with the result that they improved the quality of life in individual households or communities and contributed to the achievement of the MDGs (Table 3). In addition, the implementation of the renewable energy technologies contributed to the global climate change agenda, although these effects could not be quantified in all cases.

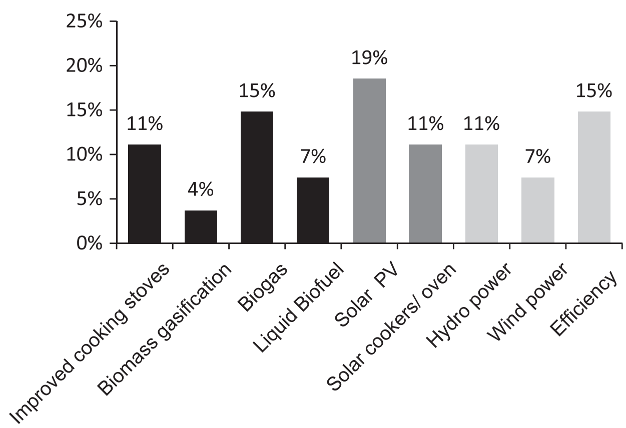

Fig. 1. Distribution of technologies among the evaluation sample of 23 projects.

Impact on economic development was less visible. Most projects were focused on meeting the basic energy needs of the poor, such as lighting, cooking etc., but were missing out on providing real business development opportunities. The review further revealed that small-scale energy projects can have an impact on the development of energy policies if the implementing organizations actively promote the technologies and engage with the government organizations responsible. In the following sections these impacts are described in detail.

4.1.1. Impacts of projects on MDG 1: reducing extreme poverty and hunger

As previously mentioned, access to sustainable and affordable energy services is a crucial factor in reducing poverty in developing countries. This review validates that small-scale projects can improve and increase access to energy for individuals and communities that would not have been supplied by market structures. This is similar to conclusions drawn by other evaluations that focus on either photovoltaic [32] or wind energy [16]. Access to energy was increased through the project activities and was also further extended in several cases. In 57%, depending on the business model, additional devices were either installed, wholesaled or additional households were connected after the initial project was completed. Even though only five interview partners were able quantify the increase, these five projects alone provide 350 additional persons with clean electricity, heating, cooking or lighting solutions. And up to 2500 additional people will furthermore gain access to sustainable energy through ongoing up scaling activities. On the contrary in only two projects the number of beneficiaries decreased, due to reasons including national grid extension, low community participation or unreliable feedstock supply.

However, in terms of productive use the impacts were limited. Consequently, the evaluation findings support the results of other studies on rural electrification [25,20] stating that although electrification may provide opportunities for small business activities, productive use should not necessarily be anticipated from small-scale electrification projects. The same was found to be true for the cooking and lighting projects. This means that even though 12 projects mentioned possible productive uses of energy, the actual number of people that used the energy to start business activities was small. Exceptions were the irrigation projects, where

Table 3
Summary of impacts on selected MDGs.

MDG	Impact of projects on MDG
MDG 1: Reducing extreme poverty and hunger	• Access to energy was increased through the actual projects and could be further extended in nearly 50% of the reviewed cases through the installation/sale of additional devices. In two cases the number of beneficiaries has decreased since the implementation. • 12 projects mentioned productive uses of the provided energy, but the number of people that have used the provided energy services to start business activities has been limited. • Energy expenditure decreased in 65% of the 23 projects. • The renewable energy projects provided additional training and employment opportunities for at least 66 people. • Most projects improved living conditions by reducing health risks, providing access to communication and information services, providing better learning environments, reducing expenditure or/and the daily workload.
MDG 7: Ensuring environmental sustainability	• Quantification was not possible, but the evaluation results support the assumption that additional amounts of GHG emissions were avoided and further unsustainable energy sources were replaced.
MDG 8: Promoting global partnership for development	• On the one hand national grid extension programs had severe negative impacts on four projects. On the other hand at least three projects, in some way or another, stimulated the decision to introduce support schemes for renewable energies at national level. • In 44% of the reviewed projects network connections between stakeholders, institutions and other organizations were developed or strengthened. • Dissemination strategies were generally suitable as in 78% of the cases awareness of, and interest in, renewable energy technologies was raised. • Replication of either the technology or management model was achieved in 40% of the reviewed cases.

higher incomes could be achieved through increased agricultural productivity. In addition, one irrigation project triggered business activity in the form of the establishment of a tree nursery producing seedlings that are sold in the region and beyond to farmer groups, companies and individuals.

With regards to socio-economic benefits the review revealed that all operational projects had positive impacts for the local population. The most mentioned benefit was the decrease in expenditure of households for energy carriers like fuel wood, charcoal, kerosene, which amounted to up to a reduction of 40% in the improved cooking stove projects. Overall, energy expenditure decreased in 65% of the former projects. In 30% of these cases the change in energy expenditure was significant, while in 35% the savings were only marginal.

With reference to capacity building and employment, the question was whether additional employment had been created or further training had been provided since the completion of the projects. The results point out that on the one hand most jobs that had been planned and established during the implementation phase still exist. On the other hand, the generation of additional employment opportunities after the initial projects were completed tended to be limited. In total, eight of the reviewed projects reported that additional people have been trained either in managing, constructing or repairing the renewable energy technologies or in handling and preforming associated tasks like food processing, irrigation or business activities. Five of these projects could provide numbers on how many people were trained and potentially employed, meaning that although the employment potential did not increase significantly after project completion, at least 66 additional people received training and the chance of employment as technicians for the implemented technologies or in the associated business activities. Depending on the projects the people who received training were chosen by the communities or the implementing organizations based on their technical abilities or to improve existing social disadvantages based on their socio-economic or socio-cultural position.

Concerning the overall quality of life, most small-scale renewable energy projects claim that access to energy will improve the quality of life for the local population. But *quality of life* is not easily measured; the positive impacts already noted such as energy access, reduction of energy expenditure and employment opportunities all contribute to improving the living conditions in local households. Most of the projects continue to provide energy services that were previously unavailable and have helped to reduce household expenditure on energy, meaning that the evaluation results allow us to draw the conclusion that the living conditions of most of the target groups improved (at least partially) due to access to basic energy services, clean water and lighting. The replacement of traditional solid fuels, such as wood fuel and fossil fuels e. g. kerosene, helped to reduce indoor air pollution, improving the health situation particularly for women and children. At the same time, in several projects the local population's awareness of health-related issues linked to indoor air pollution was raised. Apart from these factors, other influences that can impact significantly on living standards, such as a reduction in the time spent on gathering fuel wood or increased access to information, communication and entertainment services such as television, radio, mobile phone and internet, could not be explicitly quantified by the evaluation.

4.1.2. Impacts of projects on MDG 7: ensuring environmental sustainability

Environmental objectives related to energy use in developing countries include reducing deforestation by reducing the use of fire wood, preserving biodiversity, preventing unsustainable land-use changes and reducing smoke and GHG emissions by replacing wood and fossil fuels as the energy source. Accordingly, the 23 projects supported by the SEPS scheme should have provided local and/ or global environmental benefits and, at the same time, should not have produced negative environmental side effects. Therefore the technologies introduced in the initial projects aimed to reduce GHG emissions by replacing inefficient technologies and high emission technologies that use fossil fuels or by introducing technologies to reduce the unsustainable supply and use of fuel wood. While these positive environmental effects have been quantified (on an estimated basis) for the initial project phase, it was not possible to provide quantifiable results on a sound scientific basis from the review data. A few interview partners supplied figures relating to the post-project period for the reduction made in tones of GHG emissions and wood or liters of kerosene and diesel – but these were solely based on rough estimates. Nevertheless, as the majority of the technological devices introduced in the projects are still operating, it can be expected that most of the projects have succeeded in reducing CO_2 emissions and fossil fuel and fire wood use on an ongoing basis. With the exception of one project which led to unintended negative effects on the environment as farmers chose to use diesel to fuel their new irrigation pumps, instead of oil from wild Jatropha seeds. Apart from this particular project (and those projects that stopped operating) it can be anticipated that most projects have had some positive impact on ensuring environmental sustainability by replacing unsustainable fuels and reducing GHG emissions.

4.1.3. Impacts of projects on MDG 8: promoting global partnership for development

Introducing innovative renewable energy technologies to local communities is not only about providing those people with energy and reducing the negative impacts of unsustainable fuel use, but is also about spreading knowledge on sustainable energy options, demonstrating how these technologies can be applied in the local context and building networks to promote these technologies. In this context, small-scale energy projects can be seen as a first step in the process of the wider dissemination of sustainable energy technologies. Significant factors include establishing networks and partnerships, promoting interaction at political level and designing strategies for dissemination and replication. Thus following section looks at how far the projects addressed these issues and what contribution they made to building networks and partnerships for development.

One question is concerned with how local actions are affected by national and international systems, strategies and policies and vice versa. The review of the 23 projects emphasized the importance of the following two forms of interaction: the direct negative effect national infrastructure developments can have on local projects and the positive effects small-scale energy projects can have on local, regional and national energy regulations. Four of the projects in the sample were negatively affected by national grid extension programs; the result in most of these cases was the abandonment of the project, as households newly connected to the national grid dropped their commitment to the decentralized energy systems. This was particularly the case for technologies that are not cost competitive with the electricity prices and the service quality of 24-h power supply from the grid. On the other hand, it was discovered that when successful projects are communicated well to the political level they can have influence on renewable energy regulations. To influence regulations, the technologies introduced must be cost-effective in relation to alternative energy regimes (e.g. kerosene, diesel generator, grid extension to remote areas) and the potential for the country must be proven. Although direct causal relationships are hard to prove, there is evidence to suggest that at least three projects stimulated to some extent government decisions to introduce support schemes – such as feed-in-tariffs or cheap loans – to foster the dissemination of the respective technologies. One example was the Latin America and Caribbean biogas network "Redbiolac", which facilitated the exchange between practitioners and decision makers. The exchange in the network and at the workshops provided decision makers with evidence on the feasibility of the biogas technology in the region. This gave decision makers in Nicaragua the confidence to push the technology, therewith supporting the introduction of a national biogas program in Nicaragua.

In order for an individual project to make an impact outside the local context, it is vital that the project succeeds in developing, extending and strengthening partnerships and links at local, national and international level. Of the 23 reviewed projects, 44% stated that network connections between parties involved were developed or strengthened. Equally, 44% reported that other organizations within the region had become involved with the technology. The importance of working with other organizations and exchanging knowledge and information, as well as the presence of institutions accompanying the introduction of new technologies, was stressed by several interview partners. Two of the projects declared that network development between communities, academic institutions, NGOs, rural and national government organizations etc. was one of the most important impacts of the project. On the other hand, the lack of these network connections or institutional frameworks led to difficulties or failure for at least three projects. The results correspond with experience from photovoltaic implementations [32,33], which found that interventions with a clear view beyond the donor commitment period had higher sustainability rates. Implementing organization that had strong ties to the region and were not only involved for the implementation period often proved to be more successful in achieving these long-term goals [34]. A study on the scaling up of development projects in Tadzhikistan [35] came to the same conclusion, describing it as *stick-with-it mentality*.

With regards to dissemination, it is necessary to provide information on the project itself and the applied technology in order to convince local stakeholders, such as authorities, funding institutions or project developers of the benefits. This can help to increase not only the acceptance, which is vital for renewable energy projects [36], but also the replication of the project. In the evaluation sample all 23 projects had strategies in place to inform stakeholders and spread information and stated at the outset that the replication potential was high. The findings of the evaluation show that these dissemination strategies were generally suitable as in 78% of the cases the awareness of, and interest in, renewable energy technologies was increased. But an information system is of little relevance if it does not form part of a wider action system. The review data revealed that the potential for replication was strongly influenced by the continuing involvement of the implementing organization. Overall it was possible to replicate either the technology or the management model in 40% of the cases. Another factor that was mentioned as a central barrier to replication was the high up-front investment costs required for renewable energy systems. These costs meant that donor funding or other forms of subsidies were needed for replication in all but one case. This shows that although a system may be successful and accepted by the users, replication rarely happens on its own but that several conditions need to be in place before replication is possible. These conditions include long-term commitment by the implementing organization, strategies with an explicit focus on replication and the availability of additional medium to long-term funding.

4.2. Sustainability

The first question this evaluation aimed to answer with regards to *sustainability* was whether or not the energy services and structures could be sustained over an extended period of time after the initial project was completed. As described in Section 3.1 the indicator applied to evaluate *sustainability* was whether the technology was still functioning and in use at the time of the review. The findings show that the majority of the 23 projects (78%) were still operating and in use by the beneficiaries. Of these projects, 48% were fully functioning and 30% were largely operational, with only some installations or structures no longer functioning. A further 13% of the former projects were only functioning to limited extent, while 9% of the projects failed completely (Fig. 2). Of the cases that failed or are only operational to limited extent, technologies using biomass as renewable fuel source represented the largest cluster (80%). All projects that aimed to meet the need of food preparation using technologies that need less energy inputs such as improved cooking stoves and solar cookers are still fully or mostly operational.

The second question the evaluation attempted to answer with regards to the sustainability of the projects was what the critical factors were that influenced the achievement or non-achievement of sustainability. In answering this question it was discovered that the extent to which the energy services were sustained depended on a number of factors including system inherent elements such as the effective functioning of the technical system, the financial viability of the service and the effective management of the project, as well as external factors and events such as institutional and policy developments or environmental conditions. This demonstrates that there are a wide range of potential factors that influenced the success or failure of small-scale energy projects in developing countries. Despite this, it was possible to identify several common factors that supported the sustainability of projects while two factors were recognized as being instrumental in leading to failure of the reviewed technology interventions. Those factors that positively or negatively influenced the sustainability of the 23 projects are described in detail in the following section and are summarized in Table 4.

In over 70% of the successful cases, significant changes were made to the initially proposed project design. These adaptations included technical changes, modifications in finance mechanisms or adjustments to the business model or management system. The modifications were possible because the implementing organizations were flexible enough to adapt to practical needs which arose during the implementation and afterwards. In detail, adjustments

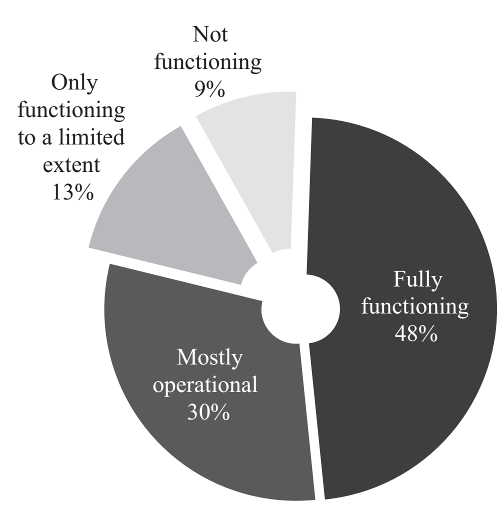

Fig. 2. Sustainability measured in terms of the status of the 23 projects in 2012.

Table 4
Summary of factors that influence the sustainability of small-scale renewable energy projects.

Positive influences	Negative influences
• Local availability of maintenance and repair service • Trust and reliability between implementing organization and other stakeholders • Sense of ownership among beneficiaries was critical, particularly in community projects • User satisfaction with technology	• Unsuitability of technology in geographic context • External influences such as political, institutional and environmental settings • Low motivation of potential users/producers, lacking sense of ownership • Problematic logistics, lack of capacity to manufacture and install technology properly

to the applied technology, major repairs or selection of new components were reported in 47% of the projects that are still mostly or fully operational. In order to sustain the systems, the availability of maintenance and repair service for the implemented technology was vital. In nearly 80% of the successful cases, maintenance and repair services were at least partly offered locally, indicating that small repairs can be done locally without outside support or time-consuming ordering of replacement parts. The findings further indicate that availability of knowledge, expertise and skills required to sustain the technical systems was central to the technical viability of the projects. This observation is in line with the findings from other studies [24,25,32], which acknowledged problems resulting from lack of technical capacity in rural areas and the logistical difficulties of servicing equipment as one of the major issues. That the availability of local maintenance service is not only an important factor for the sustainability of small-scale projects but also one of the concerns that the users have with regards to renewable technologies was shown by Pode [37] who studied the financing of LED solar home systems in developing countries.

The integration and interconnection of the implementing organization within the region was also identified as an essential factor to support sustainability. While the integration and participation of the beneficiaries is already an important selection criterion for SEPS support, the evaluation provides indications that links between the implementing organization itself and local, regional and national institutions, governmental organizations and other local stakeholders are equally important. This factor is described by one interview partner as *being in it for the long run;* he further pointed out the importance of trust and reliability on both sides: the implementing organization as well as the local partners. Consequently, poor communication and cooperation between the project team, the users and the institutions was identified as a major factor that put the sustainability of a project at risk. It was also demonstrated that this ongoing involvement was not only important for the projects' sustainability, but also a vital factor for the replication potential of the renewable energy systems. In all replicated cases the organizations continued to actively support the technology and were connected to, or present in, the region.

In addition to the characteristics already mentioned, it was recognized that two other factors affected the sustainability of the projects: the sense of ownership, referring to the commitment of the beneficiaries to the project and/or the technology, and how satisfied the users were with the technology in terms of energy supply, reliability and the daily operation of the systems. These results are in line with the existing literature on sustainable energy interventions, identifying *ownership* as one of the factors that contribute to the sustainability of rural electrification projects [38]. The 23 projects provided evidence that ownership was less of a problem if individual households were the owners and took responsibility for the technology, as in the case of improved cooking stove or solar cookers. In the case of efficient and improved lighting projects in institutions like universities or hospitals ownership was also not the most pressing issue because the actual beneficiaries (e.g. students and staff) did not have to take care of the systems. But for community projects ownership proved to be a critical factor for the sustainability of the development intervention. In certain projects the absence of ownership was a major factor contributing to an unsustainable outcome. These factors proved to be especially critical with in bioenergy projects. An example is the case of a biogas project where due to the lacking sense of ownership nobody felt responsible for the supply of the substrates, resulting in underuse of the technology and conflict between the community members.

In terms of user satisfaction with the implemented technology, in 82% of the projects the users were at least partly satisfied. Of these, 65% were content and the remaining 17% were partly content. In light of this high level of user satisfaction, the findings support the assumption that in small small-scale energy projects it is rarely the technology on its own that defines the sustainability of a project.

With regards to funding opportunities, the question addressed was to which extent the projects could encourage financial institutions, government or community organizations to provide adequate finance options for the supported energy technologies [20]. As already described, such finance options are vital for replication and dissemination because most potential users cannot afford the technology without some kind of support. The evaluation findings show that in 35% of the reviewed cases some kind of financing is now available. These finance options vary widely, from feed-in tariffs to loans from governmental or community organizations. In some cases financing is in theory available but in reality the poor find it difficult to actually obtain these loans or the people are not willing to make high upfront investment in a technology that is new to them. An alternative finance option was further donor funding. With the successful demonstration of the technology in the project supported by WISIONS, some organizations were then able to secure larger grants from other sources. Due to the high upfront investment required for some renewable energy systems this is often the only realistic way to promote these technologies in an early stage.

One organization mentioned a different aspect with regards to financial sustainability. Their experience was that most people in their project areas were not used to credit periods longer than one year, meaning that they hesitated to make the type of long-term investment required for some energy systems. Therefore, for certain technologies, finance models where people do not have to make large upfront investments but pay small amounts for renting the equipment may be an option. In this way users do not take the risk of paying the whole system without knowing if it will deliver the promised services.

When examining the factors that lead to unsustainable developments the evaluation results show that four of the five projects that ceased operating or are only functioning to a limited extent, were using biomass as energy source, while one project implemented photovoltaic and micro-hydro power technology for electrification. Analyzing the details that of what caused these projects to be unsustainable it becomes obvious that one factor all biomass projects struggled with was to supply the needed substrates. Although the causes for the insufficient supply of biomass substrate differed, the conclusion can be drawn that the technology was not appropriate in the social and geographic context. These undesirable experiences with bioenergy projects correspond to findings from Han et al. [20] on small-scale bioenergy in China.

The second factor identified as critical for the unsustainable developments was the influence of policy developments, environmental surroundings, technology advances and institutional settings. Because projects are not implemented in perfect isolation, these external elements are highly influential for success or failure. As already described in Section 4.1.3, the evaluation results provide evidence of the direct effects that national infrastructure developments can have on local projects. In addition to these two factors other barriers that were mentioned to influence sustainability include the low level of motivation of potential producers/users, problematic logistics in remote areas and a lack of local capacity to manufacture and install the technology properly.

5. Research outcomes and recommendations

Our research indicates that although the 23 projects implemented different renewable energy technologies in different socio-economical, environmental and geographical contexts with different management models and finance schemes, parallels can be drawn with regards to impacts and factors that influence mid-term sustainability. When the impacts of these small-scale renewable energy projects are measured against the MDGs, most projects show similar developments in terms of energy access, energy expenditure, productive uses and awareness-raising. With regards to sustainability, the results support the assumption that sustainability does not only depend on the reliability of the technology itself but also on a sense of ownership, user satisfaction, availability of adequate knowledge and skills as well as network connections and the commitment of the implementing organization. Therefore, the remaining question to be answered is what lessons can be learned to improve future development interventions in terms of impacts, sustainability and the opportunities for dissemination and replication.

There is no doubt that projects must be context sensitive and adapted to local needs, yet the following universally valid recommendation can be made to improve the selection process, project design, implementation phase and follow-up of future projects based on the lessons learned from the comparison of the 23 projects presented in this paper:

- First of all it is important to ensure that the implementing organization is committed to the region and/or the technology beyond the length of the project. Ideally the organization should be embedded in the local context.
- Even more emphasis should be put on the motivation and involvement of the potential users. It has to be assured that they develop a sense of ownership, even when the equipment does not belong to an individual but to a community.
- Especially for technologies that use biomass as energy source, detailed analysis of the availability and supply of substrate should be conducted. Estimates have proved to be insufficient for ensuring a continuous substrate supply for an actual project.
- The expectations regarding productive uses and business development initiated by renewable energy projects at local level should not be too high, as the potential for development in this area has been overestimated. The project design must explicitly incorporate activities that go beyond energy access in order for these to be an outcome of the project.
- Instead of addressing only energy related needs, other needs such as local environmental protection, sustainable agriculture and/or capacity building should be addressed jointly.
- To improve the need and impact assessment, a baseline study on the status quo of regional conditions should be developed for each project prior to implementation. This would allow for better quantification of project outcomes.
- As well as project monitoring during the implementation phase, post-evaluations should become an integrated part of project concepts. At least one ex-post evaluation should become mandatory.
- Regional networks, partnerships and South–South cooperation should be intensified because projects run by organizations with established extensive network connections and good links to the region and beneficiaries proved to have higher success rates.

In conclusion, the majority of the 23 projects had positive effects on sustainable development that were measurable against the MDGs, although there is no single solution for ensuring that projects produce positive impacts. However, this evaluation has demonstrated that energy projects, even if only small-scale cannot be one-time development assistance but require continuously involvement and further support (as opposed to one-off support).

6. Discussion and conclusion

We conclude by discussing the limitations and implications of the presented study results. One of the main constrains is the limited scope of the study. On the on hand the projects were all supported under the same scheme, meaning that they were already selected based on criteria that are sensitive to the problems occurring in small-scale energy projects. Therefore the high sustainability rate might not be representative for these types of development interventions. On the other hand the number of projects was limited. Although many impact evaluations and sustainability assessments focus on an even smaller number of projects, due to the cross-sectional nature of the study a larger number of projects analyzed under the same framework could improve the robustness and validity of the result. A third potential constraint to the study stems from the fact that the environmental dimension of sustainability could not be fully assessed. Environmental indicators such as the reduction of CO_2 emissions, avoided conventional fuel use, reduction of deforestation or preservation of biodiversity are more difficult to measure and to quantify than e. g. numbers of installations or people trained. As the projects supported by WISIONS are small-scale with limited budgets it is not possible to provide quality data on these types of indicators, it is therefore difficult to determine the full environmental impact.

Despite these limitations, the results give a first indication on how the sustainability of energy interventions at the local level can be improved. However, further research is required especially if replication and dissemination are to be achieved. The limited availability of data is still hindering the research progress. Therefore, sustainable energy projects in general, including those on a small-scale, addressing households or communities, should be systematically evaluated in regular intervals. Hereby sound empirical evidence on differentiated welfare and empowerment gains and the conditions under which these interventions have the greatest impact can be gathered. Moreover, the results imply that research needs to be carried out not only to identify the technical potentials in rural areas, but to show how local stakeholders can be better motivated to use the energy for economic activities and how the replication potential of projects can be enhanced. In connection with the replication and dissemination potential another area calling for closer assessments is the financing of local energy access. It is necessary to further investigate how to provide adequate finance mechanisms to the poor of the poor and to communities as a whole to prevent problems associated with the limited length and amount of funding. Finally the research should not only focus on impacts in isolation, but on the transition processes occurring within the socio-technical systems that lead to these impacts. In the end impacts and sustainability of energy interventions do not stand alone, but are a result of the changes in the socio-economic configurations.

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