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Impact pathways of small-scale energy projects in the global south – Findings from a systematic evaluation

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ABSTRACT

Access to clean and affordable modern energy services has been widely recognised as a significant factor for enabling social and economic development. Stand-alone systems and mini-grids are presumed to play an important role in the provision of sustainable energy to those people who currently lack access. Accordingly, an increasing number of small-scale energy projects are being implemented in developing countries and emerging economies. However, despite the large number of energy development projects, only limited evidence exists about the actual contribution they make to sustainable development. This paper addresses this research gap by providing a systematic assessment of three selected impact pathways based on the evaluation of over 30 small-scale sustainable energy projects. Applying a theory-based evaluation approach in the form of a contribution analysis, the aim of this research is to better understand if and how these types of technical interventions can create development outcomes and impacts. The results show that technological issues are often not the most decisive factor in achieving development effects, but that embedding the technology in a set of actions that address social, cultural, economic and environmental aspects is essential.

1. Introduction

Access to energy has been acknowledged as a key component in reducing poverty and supporting social and economic development [1]. Accordingly, providing affordable and reliable energy services to the energy poor is given high priority by many developing and newly industrialised countries [2,3]. However, access to energy is not the only concern; the energy supply should also be sustainable and avoid the drawbacks of conventional energy sources. Ensuring sustainable energy access is therefore featured high on the international development agenda, with the declaration of the decade 2014-2024 as the “Decade of Sustainable Energy for All” by the United Nations General Assembly [4] and the formal adoption of “affordable and clean energy” as one of the 17 sustainable development goals (SDGs). Technologies using renewable energy sources are regarded as an essential element for supplying sustainable energy, as they offer clean electricity, heating, cooking and lighting solutions to people and communities. These technologies are also considered to be particularly suitable in the development context because they can provide small-scale solutions and a decentralised energy supply to the energy poor [5].

However, despite this potential and the numerous implementations of small-scale renewable energy solutions over the last few decades, many energy development interventions fail or fall short of successfully translating into development impacts [6–8]. This is particularly true for projects addressing energy issues in developing countries [9,10]. The reasons for the lack of impact and sustainability are seldom solely technical issues; but can often be attributed to socio-cultural, institutional and/or economic aspects [11,12]. In order to enhance not only the technical aspects of development, but also the social and economic aspects, it is necessary to understand the factors that support or hinder the effectiveness of local initiatives promoting decentralised renewable energy solutions.

Albeit that monitoring and evaluation have received increased attention within the international development community over the last decade, to date few systematic efforts have been made in either the academic or practitioner literature to evaluate small-scale energy projects (≤ 100 kW) in developing countries with regards to their impact on local living conditions and post-installation sustainability [9]. Although many evaluations of individual projects or national programmes are documented in the literature, there is a need to systematically evaluate and analyse the energy delivery models of small-scale projects with regards to their development impacts across technologies, energy needs and regions. According to Schäfer et al. [13], such systematic evaluations and comparison of lessons learned across countries and continents could help to develop better strategies to meet the challenge of decentralised energy supply in developing countries.

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To address this research gap, the authors conducted systematic evaluations of the outcomes, impacts and mid-term sustainability of small-scale energy projects in developing countries. The evaluated projects were all supported by the "WISIONS of sustainability" initiative,[1] which has supported over 100 projects and capacity development activities since 2004 to respond to energy needs at local level[2] via its Sustainable Energy Project Support (SEPS) scheme. The projects apply different technologies, use diverse energy sources and address different energy needs (e.g. electrification, lighting, heat supply, food processing and conservation) in distinct geographical locations.

Accordingly, the main objective of this paper is to review whether and how small-scale energy projects contribute to sustainable development and, ultimately, to achieving the SDGs. To this end, three selected impact pathways are analysed based on the evaluation results of the outcomes and mid-term impacts of 30 energy development interventions, thereby advancing the knowledge of the effects of energy projects at local level and beyond. The results can help decision-makers and stakeholders to understand the most important links that determine the success or failure of achieving impact and sustainability in small-scale renewable energy projects in developing countries.

2. Methodology

2.1. Evaluation: from aid-effectiveness to development effectiveness

The importance of evaluating the effectiveness of development interventions has been the subject of intense debate in recent decades. However, despite the increasing focus on the topic of aid-effectiveness (e.g. in the form of the Paris Declaration on Aid Effectiveness in 2005), the evidence base remains weak in comparison to the large sums spent on development aid. This fact was identified and highlighted as an evaluation gap by the Center for Global Development in 2006 [14]. Since then, the number of evaluations addressing the question "what works?" in order to provide evidence of the effectiveness have significantly increased [15]. Many donor organisations now also actively promote monitoring and evaluation, requiring evaluations of their own projects and providing guidelines and information on how to evaluate development projects in general e.g. [16–18]

Despite this, many projects still fail to conduct post-project appraisals or focus mainly on quantitative macro-level outputs [19–21]. Nowadays, however, development interventions are expected to provide not only economic growth but also improvements in living standards, empowerment, social welfare and capacity-building; all while protecting the environment. These increasingly complex and, to an extent, elusive goals are often not directly measurable, making the evaluation of development projects a challenging task [22]. Furthermore, development projects are usually temporary endeavours (lasting an average of one to three years), but human development objectives are often not achievable in the short term [19,23,24]. Therefore, ex-post impact evaluations are essential for assessing whether or not a development intervention contributes to the overall goal of human development.

Such impact evaluations should also address the questions "how" and "why" projects achieve development outcomes and impacts, instead of only asking "what works". Answering why and how interventions have impacts opens the so-called "black box" between the input activities and the observed outcomes and impacts, thereby increasing the confidence level that the intervention really is the cause of the effect [25,26]. In this way, instead of solely focusing on the aid-effectiveness, the development effectiveness is also evaluated.

In addition to the questions why and how development projects work, there is an increasing need to go beyond the evaluation of individual projects and systematically conduct multiple evaluations [27]. The results of multiple evaluations under a common framework can be aggregated and synthesised to increase the knowledge base on development effectiveness and support the development of better strategies to meet future development challenges. For small-scale energy interventions in particular, few systematic efforts have been undertaken to date that analyse whether results are context-specific or can be transferred to other regions or different technologies [12,13]. Correspondingly, a report from the UNDP [28] states that studies on the drivers of success and the sustainability of small-scale projects are limited to a small number of case studies.

The authors have attempted to address this research gap by repeating an impact evaluation of small-scale energy projects. The findings from the first evaluation cycle suggested that certain factors contributed to the creation of positive outcomes and impacts [11]; however, the first study did not analyse the links within the impact pathways and the underlining assumptions in detail, resulting in only a weak contribution claim. The analysis presented in this paper places a stronger focus on establishing the causality and contribution of impacts from a multi-site and multi-level perspective.

'Impact' in this study is understood according to the DAC definition as positive and negative change produced directly or indirectly, intentionally or unintentionally, by a development intervention. The impact of development projects should be measured against the international priorities for sustainable development [29]. This is also in line with the recommendations from the international working group for Monitoring and Evaluation in Energy for Development (M&EED) [10,30].

The timeframe for this type of post-implementation evaluation varies, but in most cases project performance is assessed within two to three years of the installation [13]. This paper evaluates projects with an average duration of twelve to twenty-four months that were initiated between 2004 and 2010. Clearly, this timeframe is not sufficient for claiming long-term success, but the fact that the technology is still functioning and being used two to ten years after its initial introduction may indicate whether long-term sustainability is likely to be achieved.

2.2. Evaluation approach: how to evaluate?

The evaluation presented aims to assess *what* happened and *if*, *how* and *why* the development projects analysed contributed to achieving development outcomes and impacts. To establish contribution claims, it is necessary to draw causal links between observed changes and the intervention. The more complex the system, the more difficult it is to determine whether an outcome was actually caused by the project itself or by other circumstances [31].

In order to establish causality, many approaches call for counterfactual analysis [32], an approach that attempts to ascertain what would have happened if the intervention had not taken place by comparing an observable world with a theoretical one [25,33]. Counterfactual analysis usually use quantitative experimental or quasi-experimental approaches. However, while these approaches are prevailing for impact evaluations in the development sector [34,35], they can usually only answer the question "what works", but cannot address why an intervention led – or did not lead to – the intended outcomes and impacts [36,37]. Hence, these approaches have been criticised as being too limited. Befani et al. [22] summarise these limitations as follows:

[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 programme, please visit the website www.wisions.net.

[2] Local in this context can be understood as having a limited scope, focusing usually either on community level or individual household level.

inability to contribute to programme improvement and transferability of lessons learned; limited number of programmes where experimental methods are applicable; and failure to capture the increasingly complex and multi-faceted dimensions of development goals. Accordingly, several authors have demanded that the range of designs and methods for impact evaluations should be broadened e.g. [22,25,36,37]. Correspondingly, development organisations such as the Department for International Development (DFID) and the German Development Cooperation (GIZ) have promoted alternative impact evaluation approaches.

These proposed alternative approaches can be categorised using the term 'theory-based impact evaluations'. These theory-based approaches focus on the question "how" an intervention caused the intended effects by examining the causal chain from inputs to outcomes and impacts [32,36]. Theory-based approaches consist of two main components: (1) a conceptual part in the form of a theory of change representing a logical model for an intervention showing how outputs are expected to lead to a series of outcomes and impacts and (2) an empirical segment presenting evidence of observed effects caused by an intervention [26,38].

One frequently discussed theory-based approach to impact evaluation is the contribution analysis developed by Mayne in 2001 [39]. Compared to other theory-based approaches, the contribution analysis offers a more systematic and structured approach for analysing and reporting on the impacts of development interventions [38,40]. The analysis tests the established theory against the observed results, while taking different sources of evidence and other influencing factors into account. The aim is not to measure impacts but to increase the confidence that the intervention actually caused the impact [32]. To conduct a contribution analysis, Mayne [38] proposes six iterative steps[3]: (1) set out the cause-effect issue to be addressed; (2) develop a theory of change and risks to it; (3) gather evidence on the theory of change; (4) assemble and assess the contribution story and challenges to it; (5) gather additional evidence; (6) revise and strengthen the contribution story. However, as Mayne [38] points out, these steps can be modified in practical applications of the contribution analysis to fit the specific circumstances.

To date, few studies are documented in the academic literature that apply the approach in practice [36,38,40]. However, the analysis approach appears appropriate based on the recommendations made by the international working group on M&EED, which suggest a similar model to establish links between the energy projects and national development goals [10]. The contribution analysis, which offers the possibility of testing the assumptions underlying the chain of reasoning and adapt the impacts pathways to the changing circumstances [36], seems therefore to be a fitting approach. Accordingly, the research presented applies an adapted contribution analysis approach (see Fig. 1) to evaluate the impact of small-scale energy projects in developing countries.

2.3. Evaluation design and sample

The research presented in this paper is based on (a) the empirical findings from impact evaluations repeated at regular intervals and (b) on secondary data including project documentation, field visits conducted to a small number of projects and in-depth analysis of relevant scientific and grey literature.

The empirical results presented are based on the findings from the second evaluation cycle of the WISIONS programme (conducted in 2015) in comparison to the findings from the first evaluation (in 2012). In 2015, the cross-sectional evaluation sample consisted of 30 projects (detailed list in Table1), of which 10 had been part of the first evaluation cycle in 2012 (comprising 23 projects).

The empirical data was acquired through semi-structured in-depth interviews with the organisations that implemented and monitored the initial project activities. The interview partners where in a first step contacted and asked to participate in the evaluation. After a positive response they were provided with the survey questions as preparation for the following one to two hours oral phone interview. The response rate for the second evaluation cycle was 63%, which is similar to the response rate in the first evaluation cycle with 65%. The survey itself included 37 question points from the following seven categories (a) overall project sustainability, (b) technology, (c) social and economic

[3] For a more detailed description of the contribution analysis, please refer to Mayne [37,38,41].

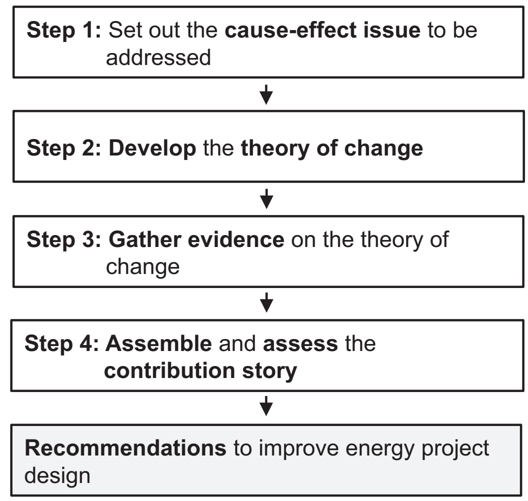

Fig. 1. Overview of the steps of the applied contribution analysis. (Source: own figure based on [41].

Table 1
Overview evaluated projects 2015. (Source: own figure).

	Technology	Need/ Application	Country/ Region
1	Efficiency improvement	Lighting	Mexico
2	Biogas	Food processing & preparation	India
3	Solar cookers	Food preparation	Argentina
4	Solar PV	Lighting	Kenya
5	Micro Hydro Power	Lighting	Philippines
6	Efficient pumps	Irrigation	India
7	Solar PV	Electrification	Togo
8	Pico Hydro	Lighting	Sri Lanka
9	Solar PV	Lighting	East Timor
10	Solar PV	Electrification	Thailand
11	Biogas	Electrification	India
12	Biogas	Food processing	India
13	Biogas	Food preparation	China
14	Biogas	Food preparation	Guatemala
15	Biogas	Cooling	Pakistan
16	Solar cookers	Food processing	Morocco
17	Solar cookers	Food preparation	Argentina
18	Solar PV and Wind Power	Irrigation	Tanzania
19	Efficient lanterns	Lighting	Sri Lanka
20	Biogas	Food processing or preparation	Latin America
21	Solar oven	Food preparation	Gambia
22	Micro Hydro Power	Electrification	Brazil
23	Efficient stoves	Food preparation	Sierra Leone
24	Solar dryer	Food conservation	Mozambique
25	Solar PV and Micro Hydro Power	Electrification	Peru
26	Solar cookers	Food preparation	Burkina Faso
27	Biomass gasification	Industry	India
28	Biomass combustion	Food processing	Burkina Faso
29	Solar cookers	Food preparation	Paraguay
30	Solar dryer	Food conservation	Afghanistan

aspects, (d) environment, (e) replication and dissemination, (f) policy development and (g) gender concerns. The questionnaire was designed in the way that all 37 question points started with a closed question, followed by a open enquiry to explore the circumstances behind the response.

The closed questions were designed with either yes or no answer options (depending on the question possible answer options included yes/no/partially/not applicable), asking for numeric information or in some cases with multiply choice answer options. A multiple choice question was for example used for the classification of causes (external/internal/both) and type of changes (technical components, practical use, business model, management system, finance mechanism, socio-political environment, environmental elements) made to the original project set-up. These closed questions allowed on the one hand to gather quantifiable evidence, to answer what happened compared to status of the project at the time of its completion. This included the collection of numerical data for example in form of number of devices installed, number of people trained or amount of conventional fuel sources replaced. In cases were no exact numbers could be given the interviewees were asked to indicate the direction of developments (increase, decrease or stable). On the other hand the closed-end questions also served the purpose of collecting statistical information, which acts as basis for the relative numbers given in the result section. The percentages represents the number of projects for which a particular answer was given as a proportion of the number of project for which the question was answered.

The open questions fulfilled the objective to explore how and why things developed in a certain way. While, the survey design and the central questions were identical in all interviews, not all questions were applicable to each case, therefore some questions were not answered for all projects and the open questions varied to a certain degree depending on the project set-up and the technology applied. To organize and systemize the empirical data, the information was manually coded, grouped and thematically analysed. The design of the evaluation as a survey offered the advantage of being time-effective and particularly suitable for addressing questions about why certain decisions are made and why some processes work better than others [42]. Although, on-site evaluation visits might have provided even deeper insights, this was not feasible for the evaluation of the type of small-scale projects analysed in this paper. The reasons are mainly of financial nature, while for large-scale projects the resources necessary for a detailed and effective evaluation amounted to about 0.2–1.25% of the total project cost [42,43], this percentage would be unreasonably high for small-scale projects with budgets up to €100,000.

The projects evaluated in the second evaluation cycle 2015 implemented 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 20 countries (Fig. 2). About a third of the evaluated projects were implemented in Sub-Saharan Africa, another third was located in Latin America and the largest number were implemented across Asia. The most common energy needs addressed by the implemented technologies were agricultural needs, followed by food issues (Fig. 2). While only a small number of the projects applied renewable technologies in an industrial setting, 75% of the small-scale energy projects overall included the establishment or improvement of productive use activities as part of their project activities. In terms of technology, the applications that used solar power for energy generation represented the largest group, followed by technologies that transform biomass into energy, such biogas, biomass combustion or gasification. No wind power applications featured in the second evaluation cycle.

Next to the empirical information, secondary data was used to supplement and validate the findings from the impact evaluation. The secondary data included a) project related information, in form of progress and final reports for each of the analysed projects as well as quantitative information from surveys conducted at the end of the project implementation phase and follow-up reports on the status of the projects a year after completion, and b) scientific and grey literature. The project information was used twofold, firstly as baseline information to validate the developments since the completion of the respective project and secondly as background information in regard to aspects such as type of finance services provided, capacity building activities conducted or extent of information and knowledge transfer delivered during the original project implementation. Like the empirical information the secondary data on the projects was systemized, grouped and thematically analysed. The scientific and grey literature on the other hand was mainly used in the third step of the contribution analysis, the gathering of evidence on the theory of change. Next to empirical information from the impact evaluation existing findings from the literature are considered and synthesised to validate or challenge the theory of change.

3. Analysis and results

3.1. Contribution challenge: access to sustainable energy services improves livelihoods and supports sustainable development

The first step of the contribution analysis is to define the contribution challenge. As described in the introduction, it is important to analyse how small-scale local efforts translate into livelihood impacts and contribute to sustainable development. Accordingly, the contribution challenge that the following analysis aims to address is *how access to sustainable energy services can improve livelihoods and support sustainable development.*

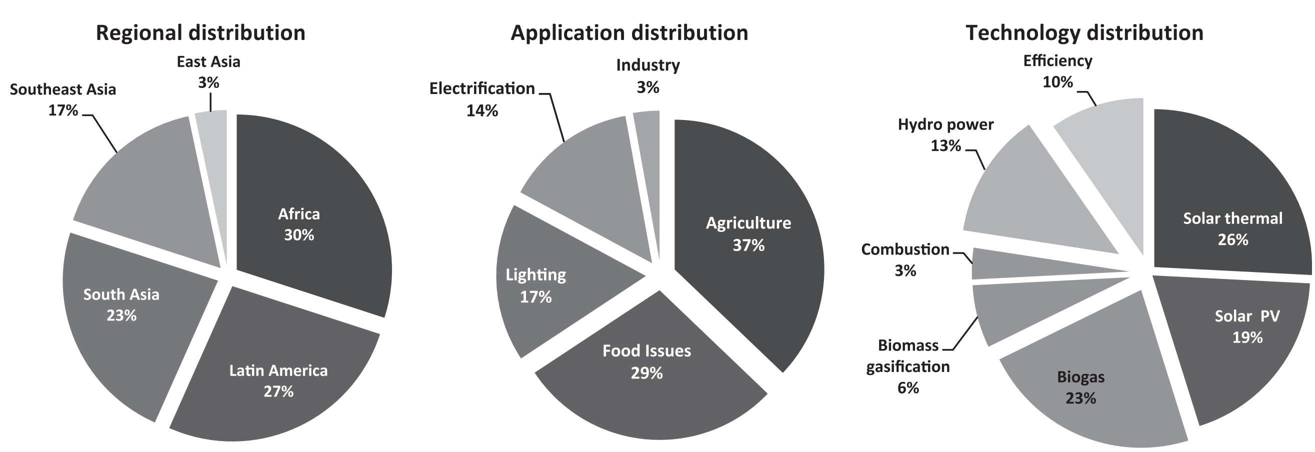

Fig. 2. Regional, application and technology distribution in the evaluation sample of 30 projects. (Source: own figure).

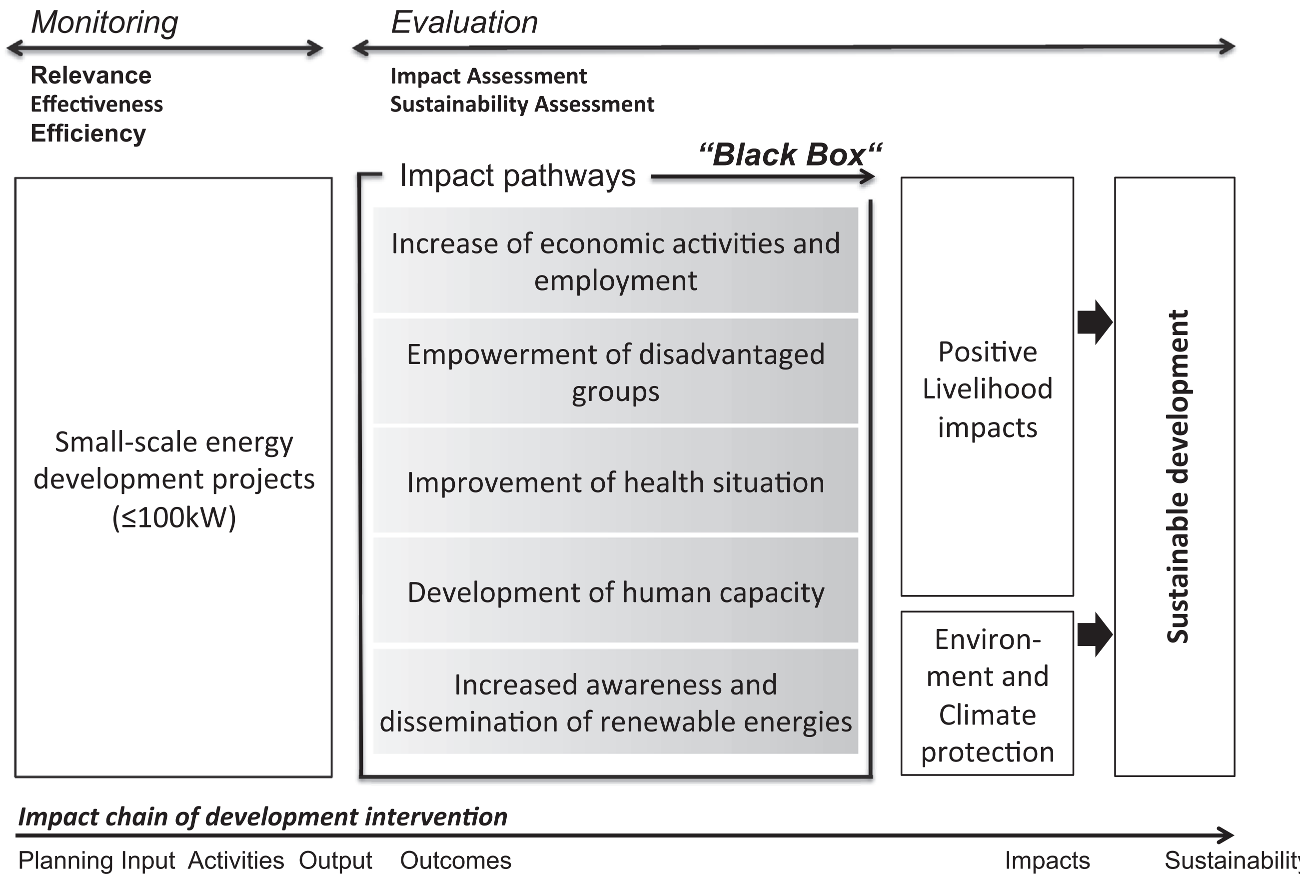

Fig. 3. Overview of the theories of change (ToC) of small-scale energy development projects. (Source: own figure).

3.2. Theory of change for small-scale energy projects

Following the definition of the contribution challenge, the next step is to develop a theory of change (ToC) for the small-scale energy development projects analysed, which is a logical model showing how outputs are expected to lead to a series of outcomes and impacts. In this paper, the authors based the theory of change on elements described in the literature and on their own knowledge and experience from over 100 projects supported by the WISIONS initiative. Despite the fact that very limited information is available on the causality chain as a whole, a variety of documentation exists providing details on specific links within the casual chain.

As shown in the overview in Fig. 3, small-scale energy projects are associated with not one but a number of impact pathways. Access to clean, affordable and reliable energy services provided by renewable energy technologies is expected not only to result in improvements in welfare (such as better health or reduced workload), but also to contribute to economic development, to increase local capacities and, in some cases, to empower marginalised groups such as women, the young or poor farmers [44]. Moreover, it is assumed that these projects raise awareness of renewable energy technologies, which supports the wider dissemination of clean energy solutions. This, in turn, will help to protect the climate and environment (Fig. 3).

Although these effects are, in theory, all possible and reasonable, empirical evidence of the extent to which these projects contribute to these developments is sparse. It is, therefore, necessary to analyse the individual impact pathways in more detail. For this paper, three[4] potential impact pathways as subsets of the general pathway presented in Fig. 3 were selected for detailed analysis. The selection was based on the data availability from the impact evaluation, which was in turn influenced by the focus of the supported projects. The three impact pathway are (a) increased dissemination of renewable energy through and beyond the implemented projects, which is a specification of the general pathway "Increased awareness and dissemination of renewable energy solutions" in Fig. 3; (b) the productive use of energy as one specific way to increase economic activities and employment; and (c) the contribution made by energy projects to the empowerment of women in order to advance gender equality, whereas women being selected as one specific disadvantaged group due to the distinct data and information available for this group (Fig. 3). Fig. 4 shows a schematic overview of the most important links for these three selected impact pathways. In the following section, these three pathways and their links are analysed against the background of the empirical results from the impact evaluations.

3.3. Evidence from the impact evaluation

In this section, the results of the analysis for the three selected impact pathways are presented, addressing the following questions: *what* happened as result of the projects and *how* and *why* did the small-scale projects contribute to achieving the desired development outcomes?

3.3.1. Contribution to the diffusion of sustainable energy solutions

Small-scale energy projects do not only supply a group of beneficiaries with sustainable energy; they can also contribute to advancing

[4] Although very important, we did not consider health, environmental and educational outcomes because making valid statements on these impact pathways would require a more detailed empirical analysis, which was not part of this evaluation.

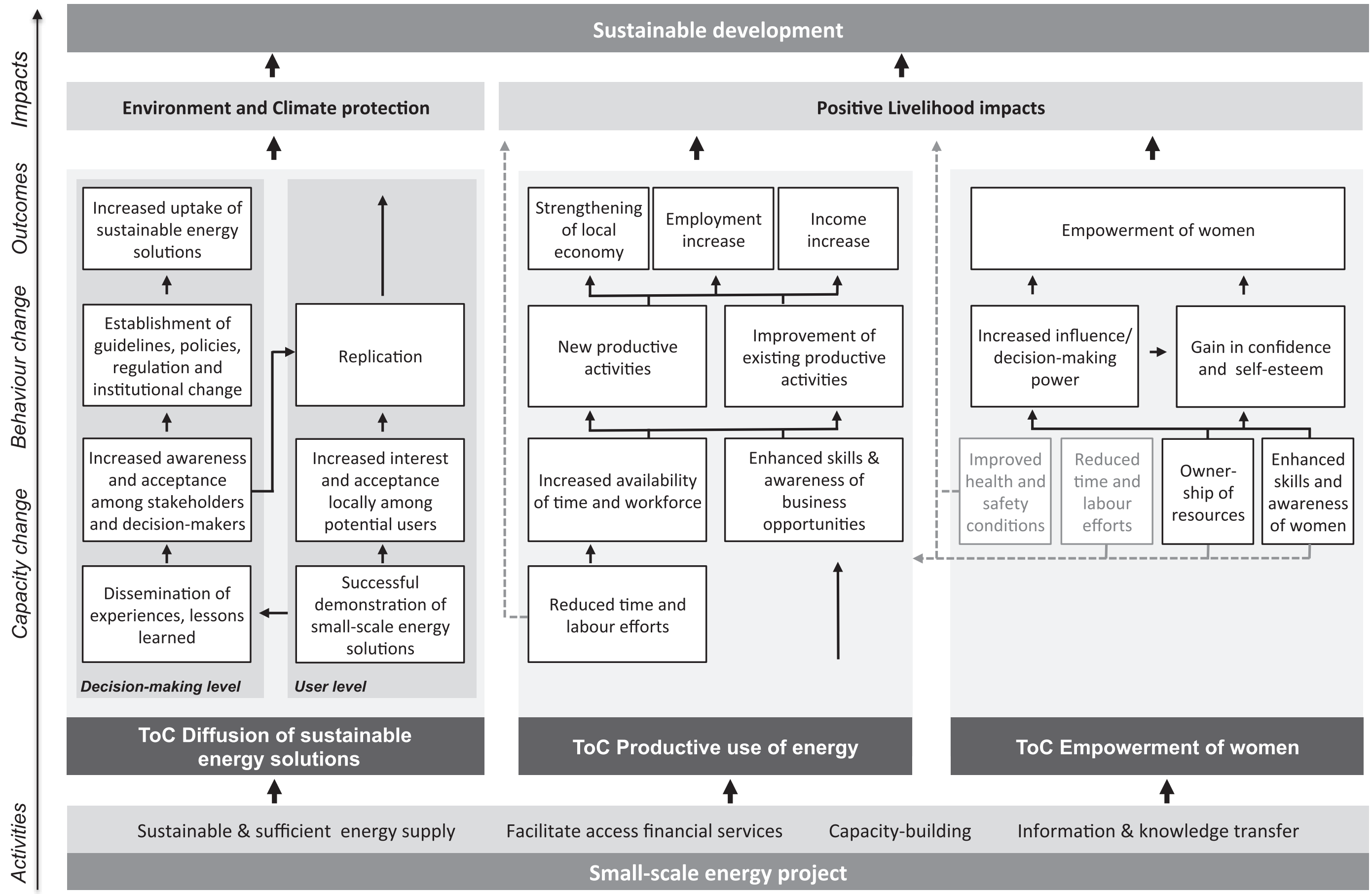

Fig. 4. Basic theories of change (ToC) for three selected impact pathways of small-scale energy development projects. (Source: own figure).

the dissemination of sustainable energy solutions by demonstrating how these technologies work in the local context. Sharing and spreading knowledge on experiences and lessons learned from these projects can contribute to a) increased awareness and acceptance at the decision-making level; and b) the creation of local interest, encouraging the replication of these solutions at user level (Fig. 4). Specifically, disseminating lessons learned to the decision-making level can contribute to an increased awareness and acceptance of small-scale local solutions, which in turn can lead to increased support from decision-makers for these solutions, for example by including specific technology options in policies and support programmes or by directly supporting replications, which can both contribute to a wider uptake of renewable energy technologies. On the user level successful demonstration projects can serve as lessons-learned for the decision-maker level but also to increase the confidence in renewable energy technologies at the local level. If a sustainable energy technology is for example successfully implemented in one village the surrounding communities might also become interested in the technology. In this sense, small-scale energy projects can be understood as a first step in the process of the wider dissemination of sustainable energy solutions.

In order to lay the foundation for the wider uptake of the energy solutions implemented, the projects should successfully demonstrate that the technology can meet the energy needs of the beneficiaries. In terms of the viability and sustainability of these energy solutions, the majority of the 30 projects analysed in the second evaluation were still fully functioning and in use (70%) or at least partly functioning (17%), while only a minority (13%) had stopped operating. No clear trend could be identified to explain why projects had stopped operating and the reasons can be equally attributed to internal and external factors. Likewise, no clear picture emerged in terms of the specific types of factors that contributed to the failures as a range of factors, including technical issues, practical application, business model, management system, finance mechanisms and socio-political and environmental elements, were all mentioned once or twice. However, of the 87% of the analysed projects that continued to provide energy to the beneficiaries, the majority (81%) made changes to the project design after the implementation phase. The changes were predominantly required due to internal factors (78%) and mainly included technical adaptation (26%), changes to the business model (20%), changes to the management system (13%) and adaptations to the finance model (13%). The high number of changes required shows that flexibility and continuous engagement also after the project is completed, is necessary to ensure continuous energy supply. In addition to the question of whether the projects continued to provide energy, it was important to analyse whether the energy generated was sufficient to meet the energy needs of the beneficiaries, as many projects fail in this respect [45]. The evaluation shows that 58% of the projects fully met the energy needs addressed and 35% met the energy needs at least partly, while the remaining 8% did not sufficiently fulfil the energy needs. Based on these results, it can be reasoned that energy in sufficient quantity and quality was provided and energy needs were met by most projects.

In view of these findings, it was relevant to examine whether these successful demonstrations led to increased interest and replication at the user level. The evaluation results show that the projects triggered replications both within and outside the community/project area. In about 77% of cases, additional members within the community or project area decided to use the technology or adopt the practice and in 65% of cases the technology or implementation model was replicated outside the project area. An important factor identified to support replication is the continuing involvement of the implementing organisation in the local and/or technological context. The evaluation results show that all implementing organisations continue to have regular (77%) or at least partial (23%) exchange with the local project partners. This continuing involvement contributes in two ways: on the one hand, continuous exchange supports the sustainability of the projects, which then serve as a positive example for replication and, on the other hand, the know-how of the organisation continues to be available and can be applied to design replication projects. Furthermore, organisations who are focused on specific technologies within a region seem to have greater levels of commitment beyond the project implementation and a direct interest in replication. Accordingly, 73% of the organisations developed further projects applying the same or similar concepts, technologies or managerial components as the original project.

In addition to replications at user level, successful demonstrations of sustainable energy solutions can also support the wider uptake of sustainable energy options by raising awareness and acceptance at the decision-making level. In order to contribute to the broader diffusion of sustainable energy solutions, knowledge and lessons learned need to be disseminated to a wider audience of stakeholders. Accordingly, all reviewed projects had strategies in place to inform different groups of stakeholders. These dissemination strategies were generally shown to be effective in the majority of cases; as it was reported that the number of stakeholders that are aware of the programme increased in 77% of the cases. However, the dissemination activities not only increased awareness of the specific project, but 73% of the projects analysed also managed to create further interest in renewable energy technologies among stakeholders. In terms of factors that enable the dissemination of lessons learned, it is important that the implementing organisations do not simply execute the project but that networks and partnerships exist – or are developed – in which results can be shared and knowledge can be spread. The evaluation results show that 73% of the projects reported that network connections or partnerships have been either developed, strengthened or extended; in the first evaluation, only 44% reported this outcome.

Building on these dissemination activities, the next question to ask is whether the projects were able to trigger or support energy strategies, policies or regulations related to their respective sustainable energy solutions. Of the projects that were still in operation, 38% stated that they supported the development of policy and institutional frameworks at local, regional or national level. Examples include a local authority taking responsibility for the payment of repair and maintenance costs for small renewable generation plants (Project 25) and a project being frequently referred to in the wider political debate on its respective technology (Project 5). However, despite these positive examples, in only 19% of cases have the technologies implemented become an integrated part of regional or national policies. This shows that an individual small-scale project generally only has a limited possibility to influence or support the development of renewable energy strategies and policies. This is where the network connections and partnerships can play an important role by facilitating the dissemination of information to authorities, funding institutions or project developers that are difficult to reach and influence on an individual level.

3.3.2. Contribution to economic development by enhancing productive activities, employment and income generation

One of the assumed positive outcomes of small-scale energy projects is the productive use of energy, which is expected to contribute to employment creation, increased income and reduced hardship by a) freeing time and reducing labour efforts previously needed for the provision of energy, which can now be used for productive activities; b) improving existing productive activities by replacing unsustainable fuel sources or increasing the availability of energy; and c) establishing new productive activities that require energy input (Fig. 4). In addition to increased availability of time and workforce skills developed based on capacity building activities during the project implementation phase as well as the creation of awareness of economic opportunities are important components that can support the improvement of existing and the uptake of new activities. These in turn ideally result in a strengthened local economy and an increase in employment and income thereby contributing to an improvement of the local livelihoods.

Regarding these three possibilities, how energy can contribute to employment creation, increased income and reduced hardship, the impact evaluation shows that 50% of the projects focused on establishing new productive activities. A further 27% focused on the improvement of existing productive use activities, such as the provision of better lighting for night fishing, supporting a fuel switch from diesel to biogas electricity for milk chilling (Project 15) or the introduction of more efficient stoves for fish smoking (Project 23). The remaining 23% of the projects mainly provided wellbeing improvements in the form of access to electricity, energy for lighting or the provision of clean cooking fuels – all of which potentially reduce the time, effort or money spent on fulfilling these energy needs. Overall, the percentage of projects incorporating productive use activities is high (77%), compared to the results of the first evaluation (52%). This is also indicate by other studies, which state that although electrification can theoretically provide opportunities for small business activities, in practice these outcomes should not necessarily be expected from small-scale electrification projects [28,46–49]. Addressing the question why the share of productive use activities in the presented evaluation is high, the analysis shows that this success is strongly linked to the original project activities and the associated capacity changes. Most of the projects addressed the productive use of energy explicitly, by improving energy supply to existing productive activities, establishing new productive uses and/or providing special capacity-building for the development of local businesses. This shows that the foundation for the positive outcomes in terms of productive use activities was already established in the design and selection phase of the projects. Productive use was not simply triggered just by the availability of energy, which is still the expectation in many energy development projects. The importance of the link between project design and outcome in terms of economic development through the productive-use of energy is also supported by other studies [49,50], which point out that positive effects mainly occurred where projects had been accompanied by a specific programmes to promote the productive uses of energy.

Concerning socio-economic development, the question is whether these productive use activities translated into employment and income generation. In terms of employment creation, the analysis sought to discover whether additional employment had been created, or further training had been provided, since the completion of the project. The results show that, on the one hand, most jobs that had been planned and established during the implementation phase still exist and, on the other hand, that additional employment opportunities were generated in 38% of the projects after the end of the funding period. This result is similar to the result of the first evaluation, in which 35% of the projects reported additional employment. This indicates that despite the higher number of projects which established productive use activities in the second evaluation sample, productive use activities do not increase the likelihood of employment creation in addition to the planned jobs. However, in terms of the actual number of people that benefitted from training during the project activity, over 600 people were trained (and partly also employed) in the projects reviewed, which is high compared to the first evaluation where 66 additional people were trained. Therefore, although the likelihood of additional employment creation after the implementation of small-scale energy projects did not increase, the number of beneficiaries increased significantly with the integration of productive use activities in the energy project.

In terms of the contribution made by small-scale energy projects to income generation, the evaluation shows that about one third of the projects reported an increase in income. Unfortunately, it was not possible to gather data on the level of increase, except in one case where an increase of 25% was reported (Project 10). In two cases, the increase was stated to be 'high' (Projects 6 and 13), while in two further cases only a 'small' increase in income was reported (Projects 9 and 23). However, these small increases were perceived to be substantial by the beneficiaries. The findings that the majority of the projects did not report an increase of income are in line with findings reported by other studies [46,48,51–54]. One factor that has been identified as essential for enabling income generation is access to markets. In order to enable beneficiaries to market their goods and services and to prevent overproduction or false expectations regarding revenue and income potential, it is important to consider the subsequent value chains from the outset (at the project design stage) and throughout the project.

3.3.3. Contribution to empowerment of women

It is now widely recognised that access to sustainable energy technologies can affect the lives of women and girls differently to the lives of men [13,47,55]. The negative implications associated with the unavailability or unaffordability of reliable energy sources disproportionally affect women and girls due to their traditional sociocultural roles. Accordingly, energy interventions imply significant gender-related benefits for women, such as reduced time spent gathering fuel wood for household energy needs like cooking, lighting, and heating; decrease in respiratory infections from indoor air pollution; reduced danger of burns and household fires caused by unsafe traditional stoves; improved nutrition and health due to the increased availability of cooked food, boiled water and space heating; and the improved safety of women and girls due to street lighting at night, which enables them to attend night schools and participate in community activities [28,56–58]. These benefits are mainly welfare improvements – they are obviously important for improving wellbeing and quality of life – but do not necessarily contribute to the empowerment of women (and thereby gender equality) in terms of decision-making, participation or access to resources [59,60]. In order to contribute to female empowerment, income generating and educational opportunities need to be provided and participation in decision-making processes (within and outside the household) need to be ensured. To this end, access to resources, training and skill-building activities have been emphasised as important requirements for ensuring women's participation in energy projects [56]. If these requirements are met during the implementation phase of energy projects, this can increase the ownership of women in energy projects and technologies as well as enhance their skill sets and increase awareness of women in regard to technology and economic opportunities. This in turn can reinforce the confidence levels of women and potentially also strengthen their influence and decision-making power. This in turn can contribute to empower women and thereby reduce the level of gender inequality in households and/or communities.

Analysing these aspects in the evaluation sample, 73% of the projects did at least partly contribute to gender equality or address gender-related issues, while 23% did not. For the remaining 4%, it was reported that the question was not applicable to the project. Addressing the question of whether and how these projects supported the empowerment of women, and thereby contributed to gender equality, the analysis showed that the majority of projects (68%) supported welfare improvements resulting from the provision of sustainable energy (such as reduced workload, a clean cooking environment or increased safety due to better lighting) without integrating specific gender-related activities into the project design. The other projects (32%) aimed at empowerment and were generally designed to explicitly target women with their activities, for example by providing capacity building specifically for women or implementing business and management models that enable women to generate income. The findings underline the fact that in energy projects addressing gender related issues is still widely conceived as being related to wellbeing effects. However, to contribute to the empowerment of women, and thereby gender equality, it is not sufficient simply to refer to the benefits that access to sustainable energy can bring to women. Instead the participation of women in the project activities must be actively promoted. Taking an active role in the project activities, for example by receiving training or taking on certain responsibilities, can support capacity changes for the women involved, which can than potentially contribute to increased confidence, influence and decision-making powers, laying the foundation for the empowerment of women.

3.4. Assembling the contribution story

Following the gathering of empirical evidence on the three selected impact pathways, the next step in the contribution analysis is to review the causal chains in the theory of change (ToC) and assemble the contribution story based on these analyses in a qualitative manner. As this paper aims to review the potential contribution that access to sustainable energy services can make to improving livelihoods and supporting sustainable development, the individual contribution stories for the three impact pathways are not described in detail, but instead the results and their implications are discussed jointly. Table 1 summarises the results in relation to the findings on whether, why and how certain outcomes were or were not achieved for the three selected impact pathways.

The review shows that the majority of projects resulted in positive outcomes, such as increased access to sustainable energy and the productive use of the energy provided. In addition, some of the projects contributed to employment creation, income generation and/or the empowerment of women. Moreover, most of the projects were successful in fostering replications and disseminating the knowledge gained from the projects (Table 2)

Achieving these outcomes depended on a variety of factors. These were mostly system inherent elements, starting with the effective functioning of the technical systems for the provision of energy in sufficient quantity and quality to meet the energy needs addressed, followed by activities such as the provision of sufficient training and information and awareness-raising among the beneficiaries. External factors and events, such as institutional and policy developments or environmental conditions, did affect the outcomes of individual projects but did not prove to be of systematic relevance for the overall evaluation sample. Generally, it is clear that a wide range of potential factors exist that can influence the impact pathways of small-scale energy projects and their contribution to development. However, despite the potential number of factors relevant to the development of the impact pathways in the individual projects, it is possible to identify common factors that supported or hindered achieving the desired development outcomes.

Firstly, it is apparent for all three impact pathways that in order to achieve development outcomes and impacts simply providing access to sustainable energy is not sufficient. In most cases, access to sustainable energy will not by itself result in economic development, empowerment of women or the wider uptake of renewable energy technologies. In order to create income and employment opportunities, to enable women to own resources and make decisions and to scale-up sustainable energy solutions, it is essential to explicitly integrate and address these objectives in the project design. This means that in parallel to the activities targeting the core objective of access to sustainable energy (e.g. technology implementation and training), detailed steps and activities need to be planned and implemented to achieve the desired socio-economic and environmental development objectives. For example, in order to use the energy provided to generate employment or additional income, it is necessary to explore and understand feasible business opportunities and provide corresponding technical capacity and training, thereby establishing links to the market and addressing questions such as is there a demand for product or services, where can the products be sold and how can the products be transported to the market. Furthermore, the activities need to fit the local skill levels and interests of the potential beneficiaries. The same holds true for women empowerment. Access to energy does not automatically lead to

Table 2
Summary of findings on the contribution claims for three selected impact pathways of small-scale energy development projects. (Source: own figure).

Contribution claims	What happened	Why and how did it happen?
Contribution to the diffusion of sustainable energy solutions	• 87% of the projects analysed continued to provide energy to the beneficiaries • Of the functioning projects, 58% fully met the energy needs addressed and 35% at least partly met the energy needs of the beneficiaries • 73% of the analysed projects created further interest in renewable energy technologies among decision-makers and stakeholders • In 73% of the reviewed projects, network connections or partnerships were developed, strengthened or extended • 38% of the cases supported the development of policy and institutional frameworks at local, regional or national level, but in only 19% did the implemented technology become an integrated part of regional or national policies • Replications in the project area took place in 77% of the cases, while outside the project area the technology or implementation model was replicated in 65% of the cases analysed	• A key factor supporting the sustainability of the projects was the flexibility to adapt to different external and internal challenges • Continuous engagement of the implementing organisation and working within existing community structures supported the sustainability of the energy infrastructure and supply • Dissemination strategies and analysis of the replication potentials should be an integrated part of the project planning process • Knowledge management and conservation are essential for fostering replication and dissemination • Continuing involvement of the implementing organisation supports replication and facilitates contact with decision-makers and stakeholders • Practitioner knowledge networks can help to disseminate knowledge across regions
Contribution to economic development by enhancing productive activities, employment and income generation	• 50% of the projects analysed established new productive use activities, 27% focused on the improvement of existing productive use activities and 23% mainly provided energy for consumptive uses • One third of the projects reported an increase in incomes • Additional employment opportunities were generated in 38% of the projects after the end of the funding period, resulting in over 600 additional people trained	• Access to energy does not automatically trigger productive use activities; these activities need to be an integrated part of the project • Beneficiaries need training and knowledge, not only about technical infrastructure but also on management aspects and business opportunities • Market value chain analysis are necessary at the beginning of the project • Financing options must be both available and accessible for small-scale entrepreneurs
Contribution to the empowerment of women	• 73% of the projects at least partly contributed to gender equality or addressed gender-related issues	• Contributions to gender equality were widely perceived as meaning improvements in women's wellbeing • Projects that aimed at empowerment were mostly designed to explicitly target women with their activities • Projects that mainly addressed gender-related issues by providing welfare improvements often did not integrate specific gender-related activities into their project design

empowerment - not for women, nor for other marginalised groups. These groups need to be integrated in the training and decision-making processes and be given the opportunity to take on responsibilities and become owners of resources. This requires, on the one hand, assurances that access to and integration in all the activities associated with the energy system will be guaranteed, but also requires the planning of additional activities, technology solutions and management approaches specifically designed to target these groups. All these aspects should, ideally, be integrated in the design of the energy delivery model. This highlights the fact that small-scale energy projects in developing countries are not only about implementing a technology, but that skills beyond technical expertise are needed to address the social, cultural and economic features of a project. These findings emphasize the circumstance that project design and planning that looks beyond the technological implementation is essential to achieve the desired development outcomes.

The analysis results further indicate that, in addition to the detailed planning of all the objectives at the outset, it is equally important to provide continuous support after the implementation phase in order to foster development outcomes because such outcomes are not typically realised in the short-term. On-going involvement, however, requires the implementing organisation to remain in contact with the beneficiaries. This is most likely to be the case if the implementing organisation continues to actively support the energy solutions implemented and is connected to, or present in, the region. On-going involvement also supports dissemination and replication; ideally this should not be a one-off event but a continuous process. This can be facilitated if the organisation is linked with local, regional and national institutions, governmental organisations and other local stakeholders.

These findings suggest that contrary to the common allocation of activities, efforts and funds in the (technology) implementation phase, the phases before and after the project implementation (i.e. planning phase before and the support phase after) are at least equally important for establishing the basis and continuing to support the achievement of development outcomes and impacts. Based on this analysis of the common factors in the contribution chains, it can be summarised that the small-scale energy projects analysed have the potential to contribute to achieving development objectives. However, in order to take full advantage of this potential, development aims must be given serious consideration from the outset and not left to chance.

4. Discussion and conclusion

Despite the large number of small-scale energy projects that have been implemented in developing countries, surprisingly little evidence exists of their achievement or non-achievement of livelihood impacts and sustainability after the completion of the initial project activity [13]. This paper addresses these shortcomings by providing a systematic evaluation of three selected impact pathways for small-scale renewable energy projects. Applying a theory-based evaluation approach in the form of a contribution analysis, the aim was to address not only the questions of *what* the outcomes were, but also *why* and *how* these outcomes came about. While the chosen evaluation approach provides valuable insights on the potential positive contributions of small-scale energy projects and how these can be achieved it inevitably also has its limitations. For once the analysis could only focus on three selected impact pathways and these impact pathways needed to be simplified focusing only on the most relevant factors in order to reduce the complexity to a manageable level. A further constraint was that it was not possible to gather empirical information on all aspects and links established in the theories of change for the three selected impact pathways as the analysis was based on an existing data set. Future impact evaluations should therefore be designed to specifically address each link in the theory of change. Another challenge was to generalize the outcomes, this task was however helped by the fact that all projects were supported under the same program so that a number of variables remains constant, providing a sound foundation for identifying common processes and impacts.

Despite these limitations the results show that technological issues are not the only important component for achieving development effects – embedding the technology in a set of actions addressing social, cultural, economic and environmental aspects is essential. Therefore, while this research validates the assertion that small-scale projects can improve and increase access to energy for individuals and communities who would otherwise not have been supplied by market structures, it also shows that complementary activities and capacity building are required to increase the potential further benefits of these projects. Essentially, the project design must not only focus on delivering energy, but also consider how to unlock the potential that access to sustainable energy can have for socio-economic development. This requires a perspective that goes beyond the technical and engineering aspects of energy towards a more people-centred approach, which takes the needs, skills and interests of the potential beneficiaries into account. Accordingly, this analysis supports the assumption that although access to sustainable energy does not automatically trigger development effects, with the right approach these interventions have the potential to contribute to sustainable development.

These results are in line with a number of other reviews that did not conduct actual impact assessments, but assessed existing case studies from the literature for evidence of the contribution that access to sustainable energy can make to achieving development effects. These reviews show that in many cases the expected development impacts were not achieved, underlining the fact that social and economic development is not triggered by access to sustainable energy alone but that other factors play an equally or even more important role. The review from Brass et al. [13] showed, for example, that small-scale localised energy systems only seem to support social or economic outcomes if these projects are not solely viewed as technical tools. Rao et al. [46] analysed the impacts of small-scale electricity systems but could not verify a relationship between sustainable energy and income generation or female empowerment, leading them to the conclusion that energy itself was not the primary determinant for achieving development outcomes. Similar findings were noted by Pueyo and Hanna [45] and Pueyo et al. [61], who conducted extensive literature reviews and concluded that the relationship between access to electricity and poverty reduction could not be proven.

Furthermore, the results from the theory-based evaluation approach applied in this study are, in part, comparable to Aklin et al. [62] who applied an experimental design to understand the socio-economic effects that access to off-grid solar electricity can have in India. Their research showed that although the access to modern energy was improved, no significant social or economic development effects could be observed and the effects on indicators for female empowerment were even described as negligible. Similarly, the quasi-experimental study by Burlig and Preonas [63] concluded that rural electrification may not be as beneficial as previously considered without additional supporting activities.

Comparing the results of this analysis with the results of existing studies leads to the conclusion that, on the one hand, access to sustainable and affordable energy services is recognised as a crucial factor for reducing poverty, with several case studies supporting the expected effects of energy access on socio-economic development. On the other hand, systematic reviews show that, despite these positive case study results, the majority of energy access projects fall short of achieving social or economic development outcomes and impacts. This demonstrates that a gap exists between the expectations of the transformative potential and the research findings of the contribution that small-scale energy projects can make to SDG 7 and the related SDGs, such as poverty reduction (SDG 1), gender equality (SDG 5) or climate change mitigation (SDG 13).

In view of these findings, it is clear that further research is needed to better understand what the critical factors in the energy delivery model are and what external geographic, climatic or economic factors determine the achievement of development outcomes and impacts. Only by improving our detailed understanding of how development can be achieved, rather than simply anticipating these types of outcomes and impacts, can we improve the success rate of small-scale decentralised energy systems. In order to identify these decisive elements, further systematic and comparative analyses of larger evaluation samples are required. These should focus on systematically analysing the different elements along the entire impact pathways. Furthermore, it should be explored in more detail 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.

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