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Reviewing the outcomes and impacts of small energy projects in the global south

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Productive use of energy – pathway to development? Reviewing the impact of small-scale energy projects in developing countries

Abstract: It is widely recognised that access to sustainable and affordable energy services is a crucial factor in reducing poverty and enhancing development. Accordingly, various positive effects beyond simple access to energy are associated with the implementation of sustainable energy projects. One of these assumed positive outcomes is the productive use of energy, which is expected to create value – for example in the form of increased local availability of goods or higher incomes – thereby having a positive impact on local livelihoods. Many projects and programmes are based on such expectations regarding the productive use of energy but systematic evidence of these outcomes and impacts is still limited. This study analyses the results of an impact evaluation of 30 small-scale energy development projects to better understand whether and how the supply of sustainable energy services supports productive use activities and whether these activities have the expected positive impacts on local livelihoods. A contribution analysis is applied to systematically evaluate the impact pathways for the productive use of energy. The results show that access to sustainable energy does not automatically result in productive activities and that energy is only one of the input factors required to foster socio-economic development. Furthermore, the results demonstrate that activities, materials and information to support the productive use of energy – such as training, equipment or market research – need to be an integrated part of the energy project itself to allow for productive activities to develop on a wider scale.

Keywords: impact evaluation, productive use, contribution analysis, small-scale energy projects, sustainability, developing countries

1. Introduction

Energy development projects are associated with various outcomes and impacts expected to improve the living conditions of the beneficiaries and ultimately lead to sustainable development. One of the assumed positive outcomes is the productive use of energy, which is expected to create value [1], for example in the form of increased income or reduced hardship [2,3], resulting in positive impacts on local livelihoods [1,2,3]. There are high expectations concerning the positive impacts of productive use activities triggered by access to energy or improved supply, but actual evidence of these impacts is scarce [2]. Rao (2013) [4] highlights that the understanding of the causal chains linking electricity supply and income benefits and the conditions that enable these causal links is still limited. Likewise, Kooijman-van Dijk (2012) [5] states that insights into the causality chain between energy supply and impacts on income generation are lacking in many macro-economic or micro-economic studies. An analysis by UNDP [6] asserts that although potential productive use is frequently reported, only a small number of people benefit from these activities. This is also supported by Brüderle et al. [7], who maintain that many energy access programmes in developing countries mention the productive use of energy as an intended outcome, but the level and pace of uptake of productive activities often falls short of these expectations.

Despite the sparse evidence, many government programmes and development projects are based on this assumed positive relationship between energy and productive activities which are expected to contribute to social and economic development [8,5]. Therefore, to improve future strategies and project designs, it is crucial to analyse more closely how and why energy development projects support productive use activities and whether these activities translate into positive development effects. Although it is important to provide evidence for both large and small-scale projects, larger projects are more regularly evaluated than small-scale energy projects (≤100kW). Small-scale, local efforts often address under-served populations at the base of the pyramid [9], making it imperative to analyse how these types of projects can translate into positive livelihood impacts and support sustainable development at local level.

The research presented aims to address these questions and, by doing so, to contribute to strengthening the evidence base of the role of productive use activities in small-scale energy projects in developing countries. The analysis is based on the results of a systematic impact evaluation conducted in 2015 of 30 local development projects. This post-evaluation represents the second evaluation cycle of projects supported by the "WISIONS of sustainability" initiative[1]. Since 2004, WISIONS has supported 110 projects and capacity development activities responding to energy needs at local level via its Sustainable Energy Project Support (SEPS) scheme. The projects apply different technologies, use diverse energy sources and address different energy needs in distinctive geographical locations. By evaluating projects implemented within a common framework but in diverse contexts, this study aims to provide better insights into how the productive use of energy can be fostered and how it can contribute to achieving development impacts across project boundaries.

Consequently, the research questions this paper attempts to answer are: whether and how energy development projects lead to productive use activities; and whether these activities contribute to achieving development. To answer these questions the detailed research objectives are (a) to establish impact pathways for the productive use of energy and (b) to evaluate the links, assumptions and risks associated with these impact pathways, thereby (c) strengthening the evidence base and confidence level with regards to the anticipated positive effects of small-scale energy projects beyond simply providing access to sustainable energy.

2. Background: productive use of energy

The term "productive use of energy" was traditionally associated with impacts at macro-level measuring the economic impact of energy on gross domestic product (GDP) [10]. Focusing on the micro-level and

[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, they are selected based on the following 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.

reflecting the shift to measuring development against the MDGs and now the SDGs, the definition of "productive use of energy" has been adapted. In this paper, we generally follow Kapadia [11] who defines the term as "*utilization of energy – both electric, and non-electric energy in the forms of heat, or mechanical energy – for activities that enhance income and welfare.*"

This definition includes both electrical and mechanical power. This is important because although research into productive use activities often focuses on "electricity" [1], thermal and mechanical energy play an equally important role for productive uses, especially for the activities of people at the base of the economic pyramid (Table 1). Furthermore, this definition not only focuses on economic gain, such as income, but includes improvements to welfare. While the creation of economic value is an important impact, improvements to welfare in the form of freeing up time and reducing effort and labour are equally important – especially for the small-scale projects analysed in this study. However, it should be recognised that this definition implies that the productive use of energy automatically leads to income generation and/or improvements to welfare. While this should be the objective, these are exactly the type of assumed causal relationships for which there is still a lack of evidence and which need to be analysed in more detail.

Linked to the assumed economic benefits, it is also often assumed that the productive use of energy increases both the demand for energy and the ability to pay for it, which in turn contributes to the financial viability of the energy infrastructure implemented [5]. Productive activities are also assumed to increase the overall load factor as they often require energy during the day, while consumptive uses are concentrated in the evenings [12]. Although this makes sense in theory, little empirical evidence exists to underpin these assumptions and practical experiences have demonstrated that the ability of beneficiaries to repay or pay up front for technology costs is often overestimated. The IEA (2017) [13] special report on energy access states that the upfront technology costs have traditionally been a significant barrier to uptake in poor communities. Williams et al. [14] highlight the fact that the ability to pay varies between countries, regions and even within communities, and that poor farming households might not have a regular cash flow to pay for energy services.

Table 1: Overview - productive use of renewable energy

Energy need		Type of productive use		Type of business	Renewable energy technology
		Improvement to existing activity	New productive use activity		
Electrification	Information & communication		Provision of services such as mobile charging, internet	Shops	Solar PV, micro-hydro power, small wind
	Services		Provision of services using electric appliances e.g. sewing, battery charging	Shops	Solar PV, micro-hydro power
Food Issues	Drying	Improved quality of existing product (e.g. compared to sun drying)	Preservation, storage, selling products off-season or in higher value markets		Solar dryer, biogas powered dryer
	Smoking	More efficient smoking e.g. fish	Creation of value-added products that can be sold locally		Improved biomass stove
	Cooking & baking	Increased efficiency of food businesses	Creation of value-added products that can be sold locally	Food vendors, bakery, restaurants, home-based businesses	Biogas powered oven, solar oven, biomass oven
Agriculture	Irrigation	Increase in yields, higher sales/ availability	Cultivation of new crops with higher value/previously unavailable	Farmers	Micro-hydro power, biofuel powered pumps, wind pumps, solar pumps
	Post-harvest processing (e.g. milling, grinding)	Higher productivity, higher quality production	Creation of value-added agricultural products Provision of processing service	Farmers, millers, New processing businesses	Watermills, biofuel powered motors, small wind turbines, biogas to electricity, solar PV, micro-hydro
Cooling		Preservation of products (e.g. food products, medicine) Reduction of cooling costs (e.g. mill chilling)	Preservation, storage, selling products at higher value markets (e.g. fish) Provision of cooled products (e.g. cooled beverages)	Farmers, fishermen, shops	Biogas to electricity, solar PV
Lighting		Extended operating hours	New home-based productive activities	Shops, home-based businesses,	Solar PV, solar lamps, small wind turbines
		Improved practices e.g. night-time fishing		Fishermen	Solar PV, solar lamps

Source: own compilation based on [7, 45, 46]

Although this paper focuses on productive use, it is important to mention that the distinction between productive and consumptive use is not always straightforward, especially for small-scale projects addressing household energy needs [11]. A good example is a household which uses energy originally provided for consumption for productive use. Furthermore, it is important to bear in mind that although productive use activities are important, the benefits of energy consumption are often equally or more important to the beneficiaries [2]. In addition, investing in productive use activities may entail financial risks, such as debt for the beneficiaries, which need to be taken into consideration when planning these activities.

3. Materials and method

This study applies a theory-based evaluation approach to shed light on the causal links between access to sustainable energy solutions and the establishment and resulting benefits of productive activities.

3.1 Evaluation approach: contribution analysis

To answer the questions whether and how the analysed development projects lead to productive use activities and contribute to achieving development outcomes and impacts, it is necessary to draw causal links between observed changes and the intervention. To establish causality, this study applies a theory-based impact evaluation approach focusing on the question "how" an intervention caused intended effects by examining the causal chain from inputs to outcomes and impacts [15,16].

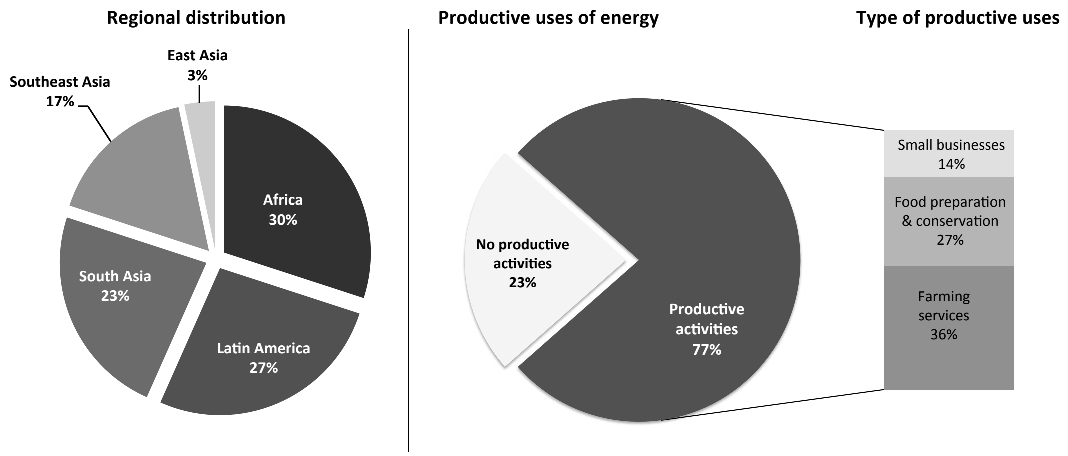
The applied contribution analysis approach, developed by Mayne [17,18], represents a systematic and structured evaluation approach for analysing and reporting data on impacts. The aim is not to measure the impacts, but to increase confidence in the likelihood that the intervention contributed to an outcome or impact [15]. To conduct a contribution analysis, Mayne [18] proposes six iterative steps[2]: (1) set out the cause-effect issue to be addressed; (2) develop a theory of change and identify risks; (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 [18] points out, these steps can be modified in practical applications of the contribution analysis to fit the specific circumstances. In this study, we applied a four-step contribution analysis approach as presented in Figure 1.

The first steps represent the conceptual part, which describes the contribution challenge and develops the theory of change (ToC). The ToC represents a logical model for an intervention, showing how outputs are expected to lead to a series of outcomes and impacts. The established ToC is then tested in the ensuing empirical section against the observed results, taking different sources of evidence and other influencing factors into account [18, 20].

The existing literature provides some guidance and recommendations on how to build a ToC, but there is no commonly accepted method or process. Depending on the purpose of the ToC, the development can be based on deductive, inductive, mental or collaborative models [21]. Furthermore, it is recommended to drawn on a combination of information and processes (e.g. expert opinions, previous evaluations, research-based theories and findings, stakeholder perspectives) to establish the impact pathways [22]. However, independently of the applied approach, the impact pathways can never fully represent reality – they need to be simplified by concentrating on the major causal links [23].

[2] For a more detailed description of the contribution analysis, please refer to Mayne [17,18, 23,24].

Figure. 1: Overview of the steps of the applied contribution analysis



(Source: own figure based on [24])

In addition to developing the ToC, the contribution analysis requires to make the assumptions and risks associated with the different links explicit and to identify external influencing factors [24]. Assumptions can be understood as conditions that must occur for the causal links to materialise, while risks are factors that can hinder the expected development [25]. External factors, on the other hand, are circumstances beyond the influence of the energy project that can either positively or negatively influence the impact pathways or provide alternative explanations for observed outcomes and impacts [18].

In this paper, the authors based the ToC (including its underlying assumptions and risks) on a review of elements described in academic and practitioner literature, findings from a previous evaluation in 2012, and knowledge and experience from the implementation of projects supported by the WISIONS initiative. A small group of internal experts then discussed and modified the draft ToC.

Following these conceptual steps, the authors conducted an empirical analysis and systematically related the findings to existing evidence from similar energy development interventions presented in studies, scientific analysis or project reports. Although very limited information is available on the causality chain as a whole, several studies provide details on specific links in the impact chain. Some studies, for example, focus on if and what type of productive use is established with newly gained access to modern energy services. Fishbein [26], for instance, summarises experiences of promoting productive uses of electricity from different projects and programmes. Other authors focus on the back end of the impact chain by analysing, for example, the effects of rural electrification on employment [27, 28] or income

[29]. The following section 3.2 presents the data and information sources for the empirical evaluation (see also Figure 1).

3.2 Evaluation data and sample

The research presented in this paper is based on (a) the empirical findings from an impact evaluation; (b) secondary data including project documentation, field visits and in-depth analysis of selected projects; and (c) a comprehensive literature review. The empirical data analysed in relation to the research question originates from the impact evaluation of 30 local energy projects (see Table 2) undertaken in 2015 in the 2nd evaluation cycle of the WISIONS initiative. Ten of these projects were also part of the first evaluation cycle in 2012. The impact evaluation was carried out via semi-structured in-depth interviews with the organisations that implemented and monitored the initial project activities.

Table 2: Overview projects impact evaluation 2015

	Technology	Need/ Application	Country/ Region	Ownership	Payment method energy services/ energy system	Status 2015
1	Efficiency improvement	Lighting	Mexico	Institution	n/a	Fully operational
2	Biogas	Food processing & preparation	India	Implementing organisation	Tariff	Fully operational
3	Solar cookers	Food preparation	Argentina	Individual	Technology purchase	Fully operational
4	Solar PV	Lighting	Kenya	Cooperative	Rental	Fully operational
5	Micro Hydro Power	Lighting	Philippines	Implementing organization	Tariff	Fully operational
6	Efficient pumps	Irrigation	India	Community	Tariff	Fully operational
7	Solar PV	Electrification	Togo	Individual	Technology purchase	Fully operational
8	Pico Hydro	Lighting	Sri Lanka	Community	Usage fee	Fully operational
9	Solar PV	Lighting	East Timor	Community	Usage fee	Fully operational
10	Solar PV	Electrification	Thailand	Individual	other	Fully operational
11	Biogas	Electrification	India	Community	Tariff	Fully operational
12	Biogas	Food processing	India	Community	Tariff	Fully operational
13	Biogas	Food preparation	China	Community	Other	Fully operational
14	Biogas	Food preparation	Guatemala	Individual	Technology purchase	Fully operational
15	Biogas	Cooling	Pakistan	Individual	Technology purchase	Fully operational
16	Solar cookers	Food processing	Morocco	Institution	Pilot no payment	Fully operational
17	Solar cookers	Food preparation	Argentina	Individual	Technology purchase or rental	Fully operational
18	Solar PV and Wind Power	Irrigation	Tanzania	Institution	Tariff	Fully operational
19	Efficient lanterns	Lighting	Sri Lanka	Individual	Technology purchase	Fully operational
20	Biogas	Food processing or preparation	Latin America	Individual/ Communities	Tariff	Fully operational
21	Solar oven	Food preparation	Gambia	Implementing organisation	Pilot no payment	Fully operational
22	Micro Hydro Power	Electrification	Brazil	Cooperative	Tariff	Partly functioning
23	Efficient stoves	Food preparation	Sierra Leone	Individual	Technology purchase	Partly functioning
24	Solar dryer	Food conservation	Mozambique	Cooperative	in kind	Partly functioning
25	Solar PV & Micro Hydro Power	Electrification	Peru	Community	Tariff	Partly functioning
26	Solar cookers	Food preparation	Burkina Faso	Cooperative	Pilot no payment	Partly functioning
27	Biomass gasification	Industry	India	Individual	Technology purchase	Not functioning
28	Biomass combustion	Food processing	Burkina Faso	Implementing organisation	Pilot no payment	Not functioning
29	Solar cookers	Food preparation	Paraguay	Individual	Pilot no payment	Not functioning
30	Solar dryer	Food conservation	Afghanistan	Implementing organisation	Pilot no payment	Not functioning

Source: own compilation

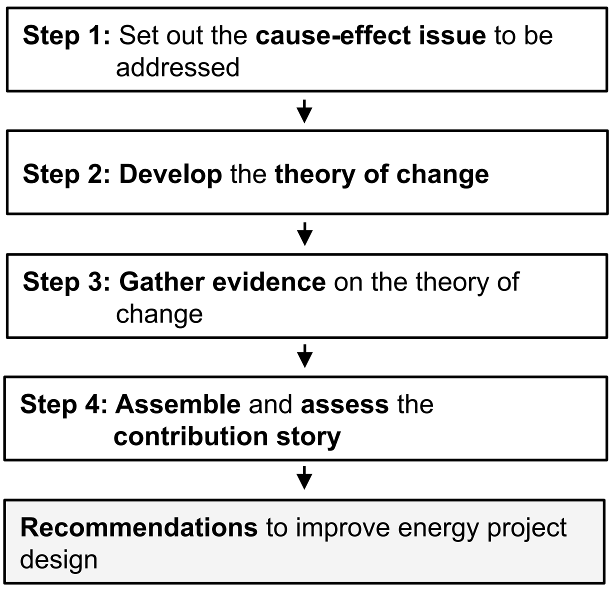
The projects evaluated applied various renewable energy technologies using different renewable energy sources such as solar, wind, hydro and biomass power, as well as incorporating efficiency measures to meet energy needs such as food preparation, lighting, electrification or irrigation in over 20 different developing countries. About a third of the evaluated projects were implemented in Sub-Saharan Africa

(30%), 27% in Latin America and the largest proportion (43%) in Asia. In terms of technology, the applications using solar power for energy generation represented the largest group (45%). The second largest group comprised technologies that transform biomass into energy, such as biogas, biomass combustion or gasification (32%). Of the implemented technologies, hydropower accounted for 13% and efficiency measures represented 10%. No wind power applications featured in this evaluation cycle.

Looking at the overall evaluation sample of 30 small-scale energy projects, 77% included the establishment of productive use activities as part of their project activities. Most of these projects focused on the productive use of energy in the agricultural sector (48%), for example by providing energy for irrigation or milling. 35% of the projects supported the productive use of energy for food preparation or conservation, for example for drying food crops or preparing products such as jam or bread. The remainder (18%) focused on the productive use of energy for small-scale businesses, for example solar kiosks. Of the 23% that did not incorporate activities to establish productive use, all but one provided energy services to the beneficiaries that enabled productive activities, such as lighting or access to electricity. Of these 23%, over half (57%) still triggered new productive uses.

Compared to the first evaluation cycle, this second evaluation cycle comprised a higher number of projects that established productive use activities. While the first evaluation indicated that productive use cannot be expected to occur naturally [30], the data from the second evaluation allows for greater focus on the question of how productive use activities can be realised in small-scale energy projects.

Fig. 2 Regional distribution and productive use in the evaluation sample of 30 projects



(Source: own figure)

4. Contribution analysis: results and discussion

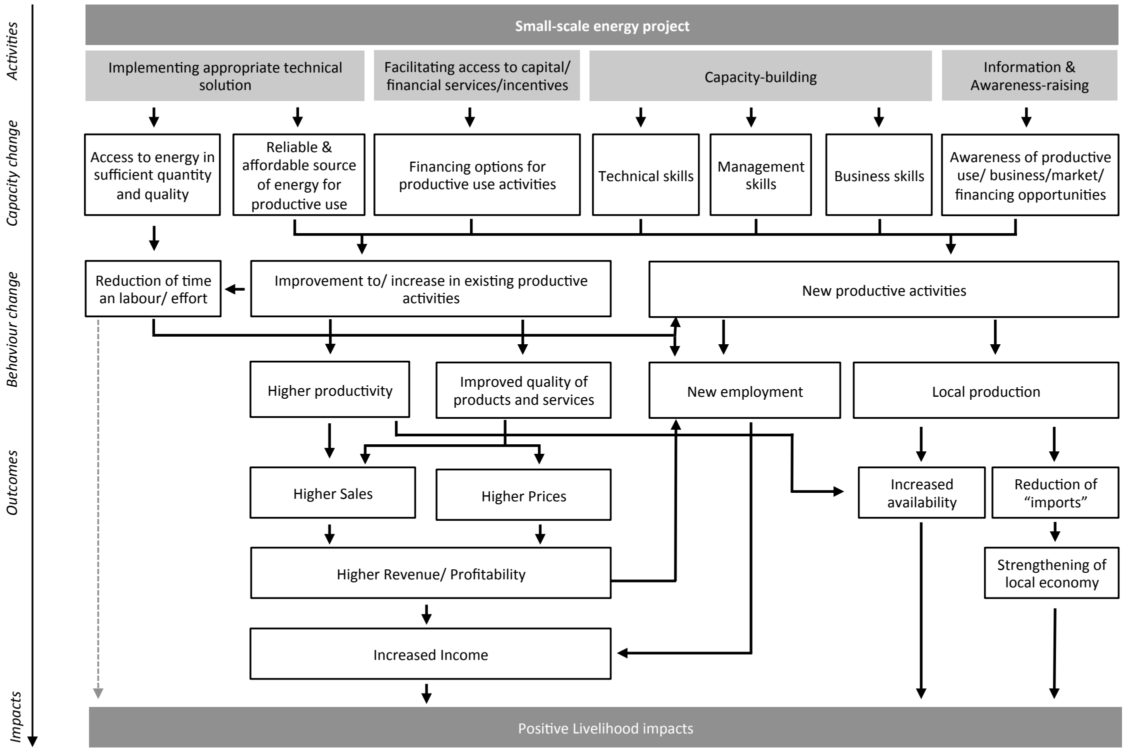
The following sections present the different analysis steps and the resulting findings of the contribution analysis (illustrated in Figure 1).

4.1 Conceptualisation: establishing the contribution challenge and theory of change for productive use activities in small-scale energy projects

The contribution claim postulates that access to clean, affordable and reliable energy services provided by renewable energy technologies will contribute to social and economic development. This development may take the form of employment, income and/or the strengthening of the local economy, as well as improving welfare – for example by reducing reduced hardship and increasing time availability. To verify this contribution claim, the first step is to develop the theory of change (ToC), presenting the cause-effect relationships between activities, outputs, outcomes and impacts (Figure 2).

As presented in Figure 2, one of the preconditions (i.e. conditions that must exist for the subsequent effect in the pathway to take place) for the uptake of productive use activities is the provision of energy in the required quantity and of the required quality [31]. This is because the amount and quality of energy provided can affect the levels to which positive livelihood impacts can be achieved [8]. In addition to a sufficient energy supply, the uptake of productive use activities usually requires technical skills, management competencies, entrepreneurship and the ability to invest in equipment, as well as information on and access to markets. These complementary services are widely recognised by rural energy experts and development practitioners as means of supporting the uptake and productive use of energy [32]. Mayer-Trasch et al. (2013) [2] note, for example, that business development services or access to finance can potentially enhance the impact of access to energy by enabling income generation and poverty alleviation. Kooijman-van Dijk [5] underlines the importance of complementary services to provide beneficiaries with knowledge on and access to markets, as well as training activities to increase their financial literacy and enable them to identify product niches and market products. Similarly, Lecoque and Wiemann (2015) [33] state that to start and run a business, locally-based capacity-building and training are important. Hence, as shown in the ToC, complementary services such as capacity-building, provision of financing options, awareness-raising and access to information are important elements for fostering productive use [32]. These activities must be twofold: they need to address the energy system itself, which must be accepted, financed and operated by the beneficiaries, and support the new or improved productive activities [30].

Figure 3: ToC productive use activities of small-scale energy development projects



(Source: own figure)

If these preconditions are met, access to sustainable energy can (a) free up time that was previously spent on the provision of energy – this time can be used for productive activities; (b) improve existing productive activities by replacing unsustainable fuel sources or increasing the availability of energy; and (c) be used to establish new productive activities that require energy input. In terms of using energy to improve existing productive activities, the expected outcomes include improved productivity, better quality and/or increased quantity, which can lead to increased local availability and/or higher revenues. This can increase the income of the entrepreneurs and possibly the employees. It may also lead to additional employment. In terms of new productive activities, initiated either due to additional time available or based on the availability of energy, it is anticipated that employment opportunities and income will be created, with local production increasing the local availability of goods and services and strengthening the local economy.

These impact chains (Figure 2) are based on certain assumptions that need to hold true to result in productive use activities. The assumptions and risks associated with selected links in the ToC are presented in Table 2. To reduce the complexity of the analysis, assumptions and risks are not provided for every link. Instead, the focus is on those links most critical for the impact pathway.

Table 3: Assumptions and risks associated with the links in the ToC for productive use activities

Link Impact Pathway	Assumptions	Risks
Appropriate technical solution is implemented	Sufficient resources – funds, people, time, infrastructure – are available for implementation Technology is appropriate and sensitive to social and cultural conditions	Technology option is not suitable for the local conditions (e.g. insufficient resources, unsuitable for the social and cultural conditions), leading to insufficient energy supply or failure
Reliable and affordable source of energy for productive use is available	Energy technology is functioning well and sufficient energy is generated to meet the demand for productive use activities Costs/ tariffs are appropriate for productive uses	Imbalance between the supply and demand for energy for productive uses (quantity or quality) Using energy for productive use activities is not financially feasible
Reduced time and labour efforts allow for the uptake of productive use activities	Provision of new energy source is less time-intensive Beneficiaries are able and willing to start new productive activities or find other employment	Freed time is taken up by household tasks Lack of skills for productive activities or employment Household lacks the means to initiate productive uses Additional time is not used for productive activities
Access to capital supports investment in productive use activities	Financing options are suitable for the beneficiaries Willingness to invest in productive use activities Investment support by financial/governmental/ public/private institutions	Financing options are not suitable for beneficiaries (e.g. access, payback time) Investment risk for beneficiaries is too high Institutions do not see the benefits of the project
Capacity-building supports productive use activities	Capacity-building reaches the right people Target group is interested and motivated Capacity-building activities are appropriate Implementing partners have the necessary qualifications	Intended target group is not reached Training is not sufficient to initiate productive use Capacity-building does not meet needs of target group Lack of entrepreneurial spirit
Awareness of productive use/ business/market/financing opportunities is created	Information reaches the right people Target group is interested and motivated Information is appropriate for the target audience Increased awareness among local authorities	Information is not convincing enough to start productive use activities Information does not reach the right target group Awareness-raising activities do not address different stakeholder groups
Existing productive activities are improved	Beneficiaries are motivated and able to apply skills and knowledge systematically and make use of opportunities provided Improved production is less time-intensive and results in better products/services Extended working hours or opening times	Improvements to productive uses are not achieved due to the risks listed above Improved process is not less time-intensive Improved process does not result in higher outputs Improved process does not provide higher quality products
Productive use leads to higher revenues/incomes	Demand for the additional products/services Access to markets Higher quality results in higher prices Improvements in household income materialise and benefit all household/community members	Demand/willingness to pay for better products is low Beneficiaries have no access to markets Higher productivity leads to overproduction Revenue is not sufficient to recover investment Not all groups benefit from the increased income Improvements in household income are undermined by shocks
New employment opportunities are created	New productive activities require additional labour Revenues are invested in the expansion of the productive use activity resulting in new jobs	Improved production requires less labour Higher revenues are not invested No demand or access to markets
Local economy is strengthened by increased availability and reduced imports	Shift of value-added activities to the area Decrease of prices/costs due to reduced transport costs Money stays within the community (multiplier effect)	No added value activities in the region because processing is carried out in another location

(Source: own compilation)

In addition to the assumptions made about the links in the ToC, external factors that can positively or negatively influence the impact pathways or can provide alternative explanations for observed outcomes and impacts must also be determined. These external factors may, for example, include other infrastructure developments, such as grid extensions or road developments. The effects of policy and regulatory frameworks may also be relevant, for example in the form of feed-in tariffs or other subsidies. Further external factors may include social and cultural influences, like the level of organisation within the community or openness towards new developments, as well as environmental factors such as resource availability or other one-off events such as floods or droughts. In section 4.2.6, the empirical part of the contribution analysis the type and influence of external factors. will analyse more closely.

4.2 Empirical analysis: evidence from the impact evaluation of small-scale energy interventions and the literature analysis

The following section presents the empirical findings relating to whether, why and how small-scale energy development interventions contribute to productive use for selected links in the ToC. These findings are systematically related to existing evidence from literature on similar energy development interventions.

4.2.1 Improvement of existing or establishment of new productive uses of energy

The fact that energy services and structures were sustained (still in operation and use at the time of the evaluation) was used as an indicator of the sufficiency of the energy supply in terms of quantity and quality. This implies that the amount of energy provided was sufficient for meeting the energy needs. However, this is not always the case in energy projects – in fact many projects fail in this aspect [9]. Of the 30 projects analysed, 92% reported that the energy needs were addressed either fully or to a large extent, providing a sound basis for this indicator. The results show that in most cases (87%) the projects were still in operation and were providing energy for potential productive uses. Of these projects, 70% were fully functioning and 17% were largely operational, with only some installations or structures no longer functioning, which may have reduced the scope of their productive use potential. In the remaining cases (13%) energy was not provided in sufficient quantity and quality. These projects were unsuccessful in sustaining the energy services. For the subgroup of projects that included productive use of energy in their project design, the numbers are comparable, with 83% still in at least partial operation and 17% no longer functioning.

In terms of the establishment of new productive use activities or the improvement of existing productive use activities, the evaluation shows that of the 23 projects that included productive use activities in their project design, 65% focused on initiating new productive activities. The other 35% focused on the improvement of existing productive use activities. Examples include improving night-time fishing by providing better lighting, supporting a fuel switch from diesel to biogas electricity for milk chilling and implementing more efficient stoves for fish smoking. These projects had all planned their productive use activities. Therefore, the split between new/improved productive activities in these cases does not allow for conclusions to be drawn regarding the likelihood of a certain type of productive use to occur if only access to sustainable energy services is provided. However, the projects that did not include productive use activities in their project plan can provide further insights into this question. The evaluation shows that new productive activities were initiated in most of these projects (75%). These new productive activities comprised either the establishment of a small business (such as a restaurant or a carpentry shop) or focused on the production of services for renewable energy systems. These findings differ from other studies, which report that the main productive use of energy is for lighting and cooling. Several authors claim that sustainable energy access mainly benefits small existing retail businesses but seldom drives the initiation of new productive activities. Rao et al. [31], who analysed productive use in India and Nepal, observed for instance that less than half the interviewed entrepreneurs expressed an interest in starting new businesses more reliant on electricity, even if they were guaranteed a reliable and affordable energy supply. Similarly, Ilskog [34] reports that experiences in Tanzania, Zambia and Kenya showed that energy was mainly used for lighting to extend the working hours of existing businesses such as bars or grocery shops. Likewise, in Kooijman-van Dijk's study (2008) [6], lighting was the most common use (78%) among the 246 surveyed enterprises in India. According to Neelsen and Peters (2011) [35], the businesses they interviewed hoped that lighting improvements would enable longer business hours and increased accuracy of work, but no expansion of business activities was mentioned.

In terms of the type of productive uses, the development is obviously strongly related to the type of energy system and capacity level installed. Solar cookers, for example, primarily allow for productive activities such as food preparation and conservation. Biogas systems on the other hand, can provide cooking fuel or electricity services. Likewise, the ownership model and the type of payment system are correlated as in community or cooperative owned systems energy services are usually provided for a tariff or usage fee, while individually owned systems are commonly purchased by the user. In terms of payment methods for either the energy service or the energy systems established In terms of payment methods for either the energy service or the energy systems established within the projects correlations between the type of payment system and the type of productive use can be observed in the evaluation sample. Over 70% of projects that fostered productive uses in the agricultural domain delivered energy services based on tariff systems, while over 60% of the projects supporting food processing and preparation activities were pilot projects without regular payments for energy services. Small retail or handicraft businesses were predominantly developed in cases where the energy systems were purchased by the users (75%). While these findings are limited to the analysed project sample, they indicate that the specification of the energy delivery model can potentially have an influence on the type of productive activities that evolve.

4.2.2. Capacity-building

The general assumption behind this link is that the provision of capacity-building on the technical aspects of productive use activities, in combination with business and management training, will increase the uptake or improvement of these activities. Best (2016) [1] states that training is one of the complementary activities recommended in good practice, while Peters et al. (2009) [32] found in their study that vocational training and information campaigns are indispensable for successful energy delivery models. According to Attigah et al. (2015) [36], electrification programmes fostering productive uses often apply an approach that provides a set of complementary services such as business development services and technical training to help to establish these activities. Gouvello and Durix (2008) [37] found in their analysis on how to maximise productive uses in rural electrification programmes that one of the main limiting factors is the potential users' lack of technical knowledge and skills. This underlines the importance of capacity-building activities to increase the uptake or improvement of productive use activities.

The right people must be reached via the right approach for this to happen (see Table 2). The results from the evaluation show that all the projects provided capacity training for the energy system itself and all projects focusing on productive use also provided capacity training for the productive use activities. This could provide an insight into why the share of successful projects and uptake of new productive use activities is high. Furthermore, this is in line with evidence from other studies.

Kooijman-van Dijk [6], in her study on small-scale enterprises in the Indian Himalayas, reports that practical skills strongly influenced the uptake of productive uses in the carpentry, tailoring and welding sectors. In contrast, a UNIDO [38] report on a project in Kenya notes that a lack of entrepreneurial skills, marketing experience and technical knowledge hindered the development of productive use activities.

In terms of continued support, the evaluation indicates that for all the projects that are still operational the implementing organisations remain in contact with the beneficiaries or entrepreneurs (at least to some extent). This supports the assumption that the continuous involvement and commitment of the implementing organisation supports the successful establishment of productive use activities. This is because capacity-building activities are not simply a one-off activity at the outset but rely on continuous support during all phases of the enterprise's development. The capacity-building required may include information and problem-solving support, as well as on-going training, to adapt products to meet the market demand as required [5].

4.2.3 Financing options

In line with other studies [33, 34, 37], the provision of financing options such as microcredits, bank loans or subsidies is considered an essential link for the establishment of productive use activities in the ToC. The evaluation results for the overall sample show that in 65% of the successful projects financing options were available for at least some of the project components, while in 35% no financing options were available. In the subgroup of projects that are still functioning and included productive use in their project design, the results differ only marginally – with financing options available in 63% of the cases and unavailable in 37%. However, it is not only the availability of financing options but also their accessibility which is a critical factor. For several projects, it was reported that despite the availability of financing options, accessing these remained a huge barrier for small-scale entrepreneurs. The reasons given in the evaluation included difficulties in understanding the administrative procedures and challenges faced by the beneficiaries in completing the required documents. Moreover, the interest rates for credits are often high; this aspect was specifically identified as a barrier in relation to microcredits.

Comparable findings are reported in the existing literature, which frequently identifies the availability of financing services as a limiting factor to the uptake of productive use activities. According to Mayer-Trasch et al. (2013) [2], one of the major constraints to the growth of micro-enterprises that was frequently cited is the availability of financing options. Neelsen and Peters (2011) [35] found in their study on Uganda that access to finance for micro-enterprises both form conventional sources as well as form microfinance institutions was limited due to high interest rates and human factors such as mistrust. Likewise, for Uganda, Muhoro (2010) [39] showed in his study on off-grid electricity access and its impact on micro-enterprises that capital access was one of the hindering factors to enterprise development. In contrast to these mainstream findings, Kooijman-van Dijk [5] states that access to finance (micro-credits or other forms of finance) may not be the key complementary service necessary for fostering productive use activities. She found that the ability to pay back loans is more important than the availability of financing options [6].

4.2.4 Employment

With reference to the link between productive use activities and employment, the evaluation addressed the question of whether additional employment had been created since the completion of the project activities. The results show that most of the jobs that were planned and established during the implementation phase still exist and that additional employment opportunities have been generated in 38% of the overall evaluation sample since the end of the funding period. All in all, more than 2,200 people have been trained. In the overall sample, the number of entrepreneurs involved has remained the same for 46% of the projects. In 31% the number has increased, whereas the number of entrepreneurs decreased in 15% of the cases. For the subgroup of projects that included productive use in their project design, the results are comparable: the number of entrepreneurs involved remains the same in 47% of the cases, is increasing in 32% and decreasing in 11%. This shows that additional business opportunities were created by the provision of energy in one third of the projects, but the decrease in entrepreneurs involved indicate that not all productive use activities provided sustainable employment or income opportunities. However, as reported by some projects, there may be alternative explanations for this reduction. In one case, for example, the number of entrepreneurs decreased because the people who received training and gained experience in the project moved on to even more attractive jobs. This is a common problem for small-scale community projects. The risk is especially high if the operation and management of the energy system and productive use activities are tied to specific people, because in such cases only a small number of beneficiaries receive capacity training.

In the literature, several authors also report effects on employment from the productive use of energy.

As early as 2003, Fishbein [26] found in his survey on productive uses of electricity in rural areas in an Indonesian project a positive impact on employment in very small enterprises. However, if employment opportunities are created they are often not equally distributed between men and women [40]. For some professions and in some socio-cultural settings it is more likely for men to gain employment, but productive use activities can also create better employment opportunities for women. Dinkelman [27], for example, reports that in South Africa electrification results in increased employment opportunities for women in particular. Similar findings are reported by Grogan and Sadanand [28] for women in Nicaragua, where access to electricity increased the number of women working outside the home by about 23%. However, according to Rao et al. [31], the jobs created are often either unskilled or are self-employed positions. Consequently, in future studies the type of employment should also be evaluated to determine whether a certain productive use activity truly contributes to an improvement in livelihood [3]. Furthermore, it should also be kept in mind that new or improved productive uses of energy may not only create employment, but also replace employment opportunities.

4.2.5 Income

It is generally expected that if productive use activities are improved by access to modern energy services, this will lead to an increase in productivity and/or quality, which will increase sales and revenue and lead to higher incomes. Likewise, the establishment of new productive activities is expected to generate income. Considering the evidence from the evaluation of the link between the productive use of energy and increased income, one third of the projects reported such an increase. Unfortunately, it was not possible to gather data on the level of increase – except in one case where an increase of 25% was reported. In two other cases the increase was reported as 'high', while in two further cases only a 'small' increase in income was reported. However, these small increases were still perceived as substantial by the beneficiaries. The findings (i.e. that most of the projects did not report an increase in income) are in line with findings reported by other studies. Rao et al. (2016) [31], in their study on the impacts of small-scale electricity systems in India and Nepal, found no perceptible differences in income levels between households with and without electricity access. Kooijman-van Dijk (2012) [5] reported for the Indian Himalayas that "*impacts of rural energy supply on poverty reduction in terms of income generation are small for the typical rural entrepreneur who owns a small-scale enterprise targeting the local market*". Similarly, Neelsen and Peters (2011) [35] findings for Uganda suggest that the effects of electricity access on micro-enterprises measured by profits or employee's income are small. Equally, the assessment made by Obermaier et al. (2012) [29] on income distribution trends following rural electrification in northeast Brazil was unable to verify a direct link between electricity use and rural income generation in the short term.

In contrast, positive effects on income were reported by Mishra and Behera [41] for Odisha, India (where solar lights facilitated an extension to the working hours of fishermen) and by Chaurey and Kandpal [42] (for PV installations in Kenya and Zambia). One component identified as essential for supporting income generation is access to markets. Market access does not only mean physical access, but also social access [5]. The evaluation results emphasise that to ensure market access, energy projects must consider the subsequent value chain to enable beneficiaries to sell goods and services on the market and to prevent overproduction or false expectations regarding revenue and income potential.

Although this aspect was not reported in the impact evaluation, according to the literature analysis the productive use of energy can also have negative impacts on income generation [2,3]. Khandker et al. [43] found that in Bangladesh mainly the wealthier families benefited from improved income, while poor families actually had their income reduced because labour-intensive jobs were replaced by energy appliances. This negative effect on income was also noted by an Asian Development Bank (ADB) study [44] in Thailand and India, by Kooijman-van Dijk [5] in her study on the Indian Himalayas and by Rao et al. [31], who observed that some existing businesses in Nepal suffered from a decrease in sales of items such as candles. In these cases, modern energy services increased inequality rather than providing income-generating opportunities and improving livelihoods.

4.2.6 Influence of external factors

In addition to evidence of the different links, the evaluation results also provided insights into the influence of external factors on the productive use of energy. The evaluation shows that, for the subgroup of productive use projects, external factors caused the need for adaptations to the original project design in 27% of the cases. However, internal factors were more often the cause of change. Internal changes comprised technical components in the highest number of cases (23%), followed by adaptations to the business model (19%), management system (15%) and financing mechanism (10%). When directly asked about the influence of local or national programmes and policies on the projects, 54% agreed that these impacted on their projects while 42% of the projects were not affected by such factors (4% did not provide an answer to this question). Of those impacted, several interview partners reported that the projects were negatively influenced by the extension of the national grid, while others stated that they benefited from government programmes providing subsidies or micro-credits. This demonstrates that these types of influences can be both negative and positive. To reduce the threat of national grid extensions to small-scale systems, political and technical frameworks must be established to support the grid-interconnection of these systems. These findings are also supported by stakeholders who call for action, such as Lecoque and Wiemann (2015) [33]. They criticise the fact that in many developing countries political frameworks are still inadequate for supporting renewable energy technologies, let alone productive use activities based on modern energy services.

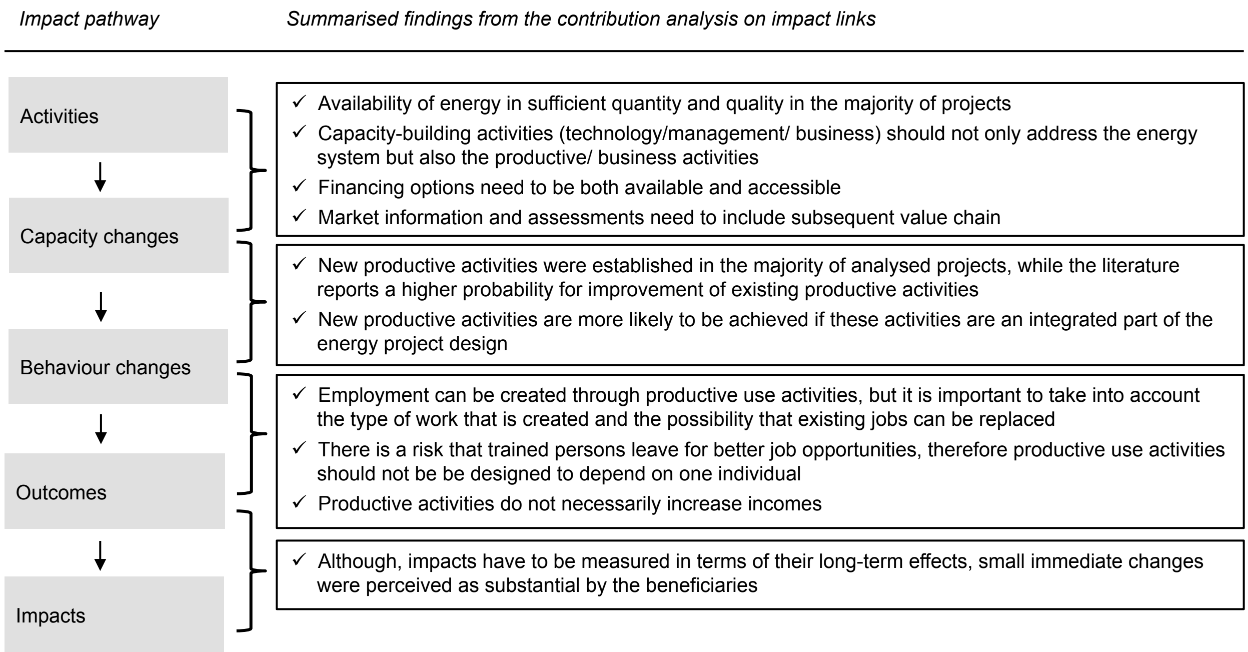
The evaluation also shows that external factors influence not only different links in the value chain, but provide alternative explanations for outcomes and impacts. In one of the evaluated projects in Peru, the increase in income observed was not based on the productive use of energy but was due to increased mining activities in the region which provided employment and income generating opportunities.

With regards to the potential for energy to create new productive activities, Rao et al. [31] note that energy alone is often not the most significant factor in a business start-up. Other infrastructure elements, such as access to roads and proximity to markets, play a more important role. In terms of the influence of the socio-cultural context, this can be a barrier to productive use activities, especially for women and other disadvantaged groups. Kooijman-van Dijk [6] reports that the level of formal education (above basic literacy) did not tend to be a relevant factor for the establishment of productive use activities targeting local markets, but was more relevant for entrepreneurs targeting distant markets.

4.3 Assembling and assessing the contribution story for the productive use of energy

Based on these findings, the contribution story can be assessed. Assessing the contribution story means reviewing the causal claims in the ToC based on the previous analysis. This allows to determine which links in the results chain are strong and which are weak in light of the available evidence; whether the assumptions made are valid; what risks exist regarding the links and assumptions; and which external factors are of relevance. Figure 3 summarises these findings for selected links.

Figure 4: Summary of findings on the contribution claim for the productive use of energy



(Source: own figure)

Figure 3 shows the different levels of the impact pathway, starting with activities which lead to capacity changes, followed by behavioural changes which are expected to create benefits and eventually result in positive long-term impacts. Focusing on these levels, several relatively strong links are evident in the impact pathway from the activity level to the capacity change level and from the capacity change level to the behavioural change level, while the links to the outcome level have higher risks and prove to be less robust.

In terms of capacity changes, most of the projects evaluated have been successful in fostering the development of competences among the beneficiaries. The risks associated with the links between capacity-building activities and actual capacity development (such as targeting the wrong people or limiting the scope of capacity-building) can generally be managed with effective planning. In addition to capacity-building, the results also indicate that the availability of financing options was an important element in the impact pathway development. The results also show that the assumption that availability of financing options supports the development of productive activities is high risk. Although financing options may be available, they are often not accessible for the beneficiaries of small-scale energy projects.

With regards to behavioural changes, which in this case describe the actual uptake or improvement of productive activities, the evaluation of the 30 energy projects and the literature analysis show that a relatively strong link exists between the availability of sustainable energy services and the improvement of existing productive activities. Compared to new productive activities, the risks associated with lack of demand, skills gaps or poor levels of business knowledge are anticipated to be lower. However, in contrast to findings from the literature analysis, a high share of new productive activities was established in the analysed sample. This underlines the fact that new productive activities are more likely to be achieved when these activities are an integrated part of the energy project – ideally from the early stages of project design and planning. Nevertheless, new productive activities are not easy to establish: the activities must fit the social and cultural context; there must be local demand and/or access to market channels; and the beneficiaries must be interested in operating these types of activities. In the sample analysed, it was clear that a careful project support selection process helped to ensure that the activities planned were based on user needs and the end-users played an integral part in planning the productive end uses.

In terms of benefits deriving from productive activities, the analysis showed that employment could be created but the skills and needs of the local beneficiaries must be taken into account at the planning stage or, as Kooijman-van Dijk [5] states, "*reduce barriers for local typical rather than exceptional entrepreneurs*". Furthermore, risks stemming from new and improved productive uses for certain groups need to be accounted for. This means taking steps to ensure the new activities do not simply benefit the wealthy at the expense of the poor losing their income and employment.

In terms of benefits in the form of increased income, the results show that the link is rather weak, while at the same time the risks associated with the assumptions behind this link appear to be high. Access to markets proved to be a critical issue for income generation. Energy projects often fail to consider the entire value chain necessary for bringing products to market. There can be different reasons for this; for example, creating the link between production and marketing is often not possible within a project's short time frame but requires long-term efforts and continuous support. Furthermore, creating this link requires additional analysis focusing on marketing as well as socio-economic aspects, which necessitates skills that are often beyond the capabilities and/or interest of technical project developers.

To summarise, the findings from the impact evaluation support the contribution claim but there are still many uncertainties with regards to the outcomes and impacts of access to sustainable energy on local economic and social development. This underlines the need for careful planning and monitoring to avoid associated risks and to allow for adaptations in response to internal and external changes. Consequently, overall expectations about the productive use of energy should not be too high. However, with the right approach, the productive use of energy has the potential to contribute to positive impacts and sustainable development.

5. Conclusion and recommendations

Despite the large number of small-scale sustainable energy projects that have been implemented in developing countries, surprisingly little empirical evidence exists about their achievement or non-achievement of livelihood outcomes and impacts after the completion of the initial project period. This is also the case for the productive use of energy, which is associated with positive outcomes such as strengthening the local economy, employment creation, increased local availability of goods and income creation. However, systematic evidence that this contribution claim holds true is lacking. This paper addresses these shortcomings by providing an analysis of the impact pathway for productive use activities based on the results from an impact evaluation of 30 small-scale renewable energy projects in developing countries in relation to findings from similar studies, scientific analysis and project reports. The assessment shows that the observed evidence supports the assumption that small-scale energy projects can lead to productive uses which, in turn, result in positive outcomes and impacts for local living conditions. However, for this to happen, aspects such as quality capacity-building, information provision, awareness-raising and market access need to be ensured while risks (especially those associated with the links to employment and income generation) need to be considered. Without these actions, the frequently cited positive outcomes and impacts of productive use activities will often not be achieved. However, these findings only allow for conclusions to be drawn for the analysed sample, which consists of projects addressing energy access using a holistic development approach. The findings cannot simply be generalised and transferred to other approaches to providing sustainable energy services. Despite this limitation, based on these findings this paper makes the following recommendations to improve the selection process, project design, implementation phase and follow-up of future energy development projects in order to support and increase the productive use of energy and enhance the positive outcomes:

- It is critical to consider the whole value chain in projects addressing the productive use of energy. This includes assessing the market potential, providing beneficiaries with market information and ensuring physical and social market access to enable beneficiaries to sell goods and services and prevent overproduction or false expectations regarding revenue and income potentials.
- Capacity-building should not only be adapted to the target group but should also be a continuous activity (not a one-off event), focusing on both technical training and on the management and business skills necessary to run a small-scale enterprise.

- An assessment of existing productive use activities and the potential and interest of beneficiaries to improve these activities, as well as an assessment of the potential and interest in new productive activities, should be part of a baseline study for each project prior to implementation.
- Furthermore, it is necessary to analyse the current value chain to determine who will/will not benefit from the productive use of energy to ensure that modern energy services do not increase inequality rather than improve livelihoods.
- In addition, further research should not only analyse the quantitative aspects but should also include qualitative aspects, such as the type of employment created.
- The first evaluation, conducted in 2012 [26], already indicated that the project design must explicitly incorporate activities that go beyond energy access in order to achieve productive use activities. The results from the second evaluation show that by applying an extensive and thorough project selection process a high volume of productive energy use activities can be achieved. This underlines the importance of applying a holistic approach to ensure the desired outcomes and impacts in the long run, focusing not only on the technical aspects of energy provision but also on the economic and social aspects at the outset of the project.
- Even if all the above factors are considered it is not always possible to establish the productive use of energy, as energy and capacity-building cannot always bridge the gaps and solve the problems faced by a community. However, in these cases the benefits of the consumptive use of energy should not be ignored, especially as these are often equally or even more important for the beneficiaries.

The analysis also highlights the need for additional research. Although this study provides new evidence based on the results from the impact assessment of 30 small-scale energy projects, further and more detailed empirical surveys and analysis over longer periods of time are still necessary. In particular, the questions of who benefits and whether differences between the type of energy technology and business activities promoted lead to different impacts require further analysis. In addition, collaborations between stakeholders involved in project design and implementation should be established to share experiences and best practice. Furthermore, with new approaches to sustainable energy access emerging (such as pay-as-you-go systems and swarm electrification) there is a need for further research into the socio-economic impacts of these approaches in general and specifically on the establishment of productive uses and the associated impacts. It is also necessary to compare different approaches to sustainable energy access in these regards to identify the best approaches for leveraging its full development potential. With many new private sector activities aiming to make financial profits from providing small-scale energy systems or services in developing countries, collaborations and supplementary programmes to support the creation of productive use activities should be established, otherwise the consumptive use of energy will often remain the only outcome.

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