Ministry of Foreign Affairs

IOB Evaluation

Access to Energy in Rwanda

Impact evaluation of activities supported by the Dutch Promoting Renewable Energy Programme

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August 2014

Preface

Global challenges such as inequal economic development, poverty, uncontrolled international migration and lack of food security are increasingly seen as directly related to climate change, environmental hazards and demand for energy. Access to renewable energy is recognised as contributing substantially to sustainable development, and the United Nations General Assembly has designated the current decade as the Decade of Sustainable Energy for All.

The Netherlands development cooperation has been active in renewable energy investments since 1968, initially in the context of the appropriate technology movement. In 2004, the Dutch Minister for Development Cooperation committed herself to providing access to energy to 10 million people by 2015. The operationalisation of that commitment was envisaged through a global sector-wide delegated cooperation agreement with Germany. With the launch of the Promoting Renewable Energy Programme in 2008, efforts intensified. From then on, there were several objectives: not only direct investment in renewable energy and biomass, but also the mobilisation of international awareness and resources to improve access to energy, and the strengthening of the knowledge base of national governments concerning the linkages between poverty, renewable energy and climate change.

Between 2010 and 2014, the Policy and Operations Evaluation Department (IOB) of the Dutch Ministry of Foreign Affairs evaluated the impact of four interventions in the area of renewable energy in Rwanda, which were selected on the basis of pre-established criteria concerning diversity in energy sources. The evaluation investigated the impact of the roll-out of the electricity grid, the national biogas programme, the marketing of personal solar lighting, and a project aimed at strengthening the energy authority. The findings of these studies complement those of comparable studies conducted in Burkina Faso and Indonesia and feed into a worldwide global assessment of Dutch policy on renewable energy and development.

IOB commissioned a consortium integrated by the German Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI) and the Institute of Social Studies (ISS) at Erasmus University Rotterdam in the Netherlands to do the quantitative studies. The studies were conducted by Jörg Peters, Günther Bensch, Maximiliane Sievert and Luciane Lenz (all RWI), Michael Grimm (University of Passau), Arjun S. Bedi, Lorenzo Pellegrini and Luca Tasciotti (all ISS). All surveys were conducted by interviewers from the Rwandan research company IB&C, under the supervision of Anicet Munyehirwe. Overall coordination and the implementation of qualitative studies rested with Willem Cornelissen (ERBS B.V., Erasmus University Rotterdam) assisted by Jolijn Engelbertink (IOB). Willem Cornelissen and Rafaëla Feddes (IOB) wrote the report.

Valuable comments and contributions were made by members of the Reference Group: Frank van der Vleuten (Ministry of Foreign Affairs), Pieter van Beukering (IVM, VU University Amsterdam), and Marcel Raats (Netherlands Enterprise Agency RVO.nl). Piet de Lange, Ferko

Bodnár and Antonie de Kemp (all IOB) provided useful commentary on the draft report. Last but not least, special thanks go to the Rwandan authorities and all approximately 2,500 interviewees and participants in focal groups.

IOB assumes final responsibility for the contents of this report.

Geert Geut
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List of acronyms and abbreviations

ABPP	African Biogas Partnership Programme
AfDB	African Development Bank
AFREA	Africa Renewable Energy Access programme
BEST	Biomass Energy Strategy
BMZ	*Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung* (German Federal Ministry for Economic Cooperation and Development)
BPR	*Banque Populaire du Rwanda*
BTC	Belgian Technical Cooperation
CBO	Community-Based Organisation
CITT	Centre for Innovations and Technology Transfer
CO_2	Carbon dioxide
DBM	Global Fund for Sustainable Biomass
DfID	Department for International Development (United Kingdom)
DGIS	Directorate General for International Cooperation
Diff-in-Diff	Difference-in-differences (method)
DOF	Daey Ouwens Fund
DPCG	Development Partners Coordination Group
EAC	East African Community
EARP	Electricity Access and Roll-out Programme
EC	European Commission
EDPRS	Economic Development and Poverty Reduction Strategy
EKN	Embassy of the Kingdom of the Netherlands
EnDev	Energising Development
ESMAP	Energy Sector Management Assistance Programme
EU	European Union
EUEI	European Union Energy Initiative
EUR	Euro
EWSA	Energy, Water and Sanitation Authority
FMO	Entrepreneurial Development Bank
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GIZ	*Gesellschaft für Internationale Zusammenarbeit* (prior to 2011: GTZ)
GMV	Good Governance, Human Rights and Peacebuilding (*Goed bestuur, mensenrechten en vredesopbouw*)
GoR	Government of Rwanda
GWh	Gigawatt hour
ICAP	International Carbon Action Partnership
ICS	Improved Cooking Stoves
ICT	Information and Communication Technology
IFDC	International Fertiliser Development Centre
IOB	Policy and Operations Evaluation Department of the Netherlands Ministry of Foreign Affairs

JICA	Japanese International Cooperation Agency
KIST	Kigali Institute of Science, Technology and Management
kWh	Kilo Watt hour
LDC	Least Developed Countries
LED	Light-emitting diode
LPG	Liquified Petroleum Gas
LV	Low Voltage
MASP	Multi-Annual Strategic Plan
MDGs	Millennium Development Goals
MINAGRI	Ministry of Agriculture and Animal Resources
MINECOFIN	Ministry of Finance and Economic Planning
MININFRA	Ministry of Infrastructure
MINIRENA	Ministry of Natural Resources
MoU	Memorandum of Understanding
MV	Medium Voltage
MW	Megawatt
NAFA	National Forestry Authority
NDBP	National Domestic Biogas Programme
NGO	Non-Governmental Organisation
OFID	OPEC Fund for International Development
OLS	Ordinary Least Squares
ORET	Development-Oriented Export Transaction
PAREF	Reforestation Support Project (*Projet d'Appui à la Reforestation*)
PPA	Power Purchasing Agreement
PPP	Public-Private Partnership
ppp	Purchasing power parity
PREP	Promoting Renewable Energy Programme
PSD	Private Sector Development
PSM	Propensity score matching
PV	Photovoltaic
RCT	Randomised Controlled Trial
REFIT	Renewable Energy Feed-in Tariff
REMA	Rwanda Environment Management Authority
RURA	Rwanda Utility Regulatory Agency
REST	Renewable Energy Strategy
RVO.nl	Netherlands Enterprise Agency (*Rijksdienst voor Ondernemend Nederland*)
RWF	Rwandan Franc (exchange rate: EUR 1 = 818 RWF on 1 May 2013)
SE	Standard error
SEDP	Sustainable Energy Development Project
SE4All	Sustainable Energy for All initiative
SNV	Netherlands Development Organisation
SWG	Sector Working Group
TCT	Tumba Technical College
ToR	Terms of Reference
TVET	Technical Vocational Education and Training

USD	United States Dollar
UN	United Nations
UNIDO	United Nations Industrial Development Organisation

Summary and main findings

In July 2008, the Netherlands Ministry of Foreign Affairs announced a EUR 500 million budget for renewable energy in developing countries through the 'Promoting Renewable Energy Programme' (PREP). PREP aims at:

1) Investing directly in the production of and access to renewable energy in priority countries and regions.
2) Improving the sustainability of production of biomass for energy purposes.
3) Influencing the policy of partners responsible for investment in renewable energy.
4) Developing capacity and knowledge in developing countries with regard to renewable energy.

PREP encompasses an array of sub-funds, programmes, projects and activities implemented in over 30 countries. The Ministry's implementation strategy was to work through a variety of existing channels, such as the multilateral channel, the private sector and non-governmental organisations (NGOs) and – to a lesser extent – the bilateral channel. In 2010, the Policy and Operations Evaluation Department (IOB) of the Netherlands Ministry of Foreign Affairs embarked upon a series of impact evaluations of activities in the field of renewable energy and development, in which both quantitative and qualitative research techniques were used to ascertain the magnitude of impacts of energy use at household and community levels. The impact studies were conducted in Burkina Faso, Indonesia and Rwanda. This report presents the findings of four impact studies conducted in Rwanda. The four evaluated interventions are:

1) Electricity access roll-out programme (EARP).
2) Biogas for cooking and lighting energy through the National Domestic Biogas Programme (NDBP).
3) The marketing of pico-photovoltaic (pico-PV) systems for lighting energy.
4) The strengthening of capacity of the electricity utility company (Electricity Water and Sanitation Authority: EWSA) through the Africa Renewable Energy Access programme (AFREA).

1. **EARP**. During the period 2009-2013, the Netherlands contributed EUR 30 million to the electricity subsector in Rwanda as part of the sector-wide approach, supported by EUR 338 million from development partners and financing institutes. Through the Electricity Water and Sanitation Authority (EWSA), the Government of Rwanda succeeded in increasing the national electrification rate from 6% in 2008 to 16% in 2013. Since EWSA tenders out part of the implementation to local companies, the market for entrepreneurs in energy services has expanded.

In addition to bringing lighting to households, social services providers and productive units (factories and businesses), electricity brings the opportunity to charge mobile telephones and power other means of communication (including television).The electricity can also be used for productive purposes, including for cottage industry.

2. **NDBP**. Through SNV, the Netherlands contributed to the establishment of the National Domestic Biogas Programme. For three years the programme was supported with approximately EUR 1.3 million through the Energising Development (EnDev) programme.

The objective of NDBP is to establish a sustainable market for biogas. SNV's reliance on 'best practices' from Asian countries contributed to high expectations. Notwithstanding downward adjustments in the targets set for the number of biogas digesters to be constructed annually, the programme did not take off as expected. Between 2008 and 2013, 3,517 digesters were installed nationwide (23% of the initial target). Despite the Government of Rwanda's strong promotion of the use of biogas, even after design modifications the uptake remained modest: some 60-70 digesters monthly (2013). Reasons for the low uptake are primarily price, combined with frugal credit opportunities and the users' perception of additional workload.

3. **Pico-PV**. Among the specific funds sourced by PREP is the Daey Ouwens Fund (DOF), which has provided subsidies to small and medium-sized enterprises and private organisations for disseminating renewable energy equipment based on acknowledged technologies. The Ministry of Foreign Affairs requested the Netherlands Enterprise Agency RVO.nl to apply 'light procedures only' in the management of DOF. One of the 31 awards was to the enterprise ToughStuff International, but only 50% (EUR 340,280) of this was actually disbursed. The 'social network' ('Tupperware') marketing system for the disseminating of pico-PV systems proposed by ToughStuff failed: only 8,000 units were sold out of the envisaged 166,200. In 2013 the parent company applied for liquidation.

4. **EWSA**. The Sustainable Energy Development Project comprises 25 different activities in support of the Electricity Water and Sanitation Authority. Through the Dutch-funded Africa Renewable Access Programme (AFREA) approximately EUR 3.1 million was spent. The programme was effective in solving ad hoc needs of EWSA and contributed to the capacity of the agency. Only a minority of the 25 activities were effective and sustainable.

Apart from the above-mentioned four programmes, other PREP-supported activities in the area of renewable energy concerned reforestation for fuelwood, the construction of hydroelectricity plants, the construction of a regional electricity transmission network, and environmental monitoring of methane gas extraction from Lake Kivu. The four interventions evaluated are not a statistically representative sample, but were chosen to illustrate the variety of activities in the area of renewable energy in Rwanda.

Findings

Policy relevance

1. *The interventions for promoting renewable energy in Rwanda were relevant to the objectives both of the Government of Rwanda and of the Promoting Renewable Energy Programme.*

Both the electricity roll-out programme and the reforestation programmes addressed key priorities of the Government of Rwanda; the biogas programme was a government initiative as well. Pico-PV systems do not address an explicit government priority, but fitted into the health-motivated 'bye-bye kerosene' campaign.

The Netherlands has played a catalytic role in the electricity subsector by funding the Investment Prospectus that appealed other partners to provide co-financing. In its division

of labour among development partners (the Accra Agenda for Action, 2008), the Government of Rwanda requested the Netherlands to assume a role in the energy sector: the Netherlands agreed.

The renewable energy activities have contributed to varying degree to the four specific objectives of PREP. The interventions have: (i) provided access to energy in a priority country to almost 300,000 households (electricity, solar lamps, biogas) or 1.5 million persons; (ii) contributed to the sustainable production of (woody) biomass for energy purposes through reforestation programmes; (iii) influenced – via the AFREA portfolio – the strategy of the World Bank; and (iv) contributed to the development of the capacities of the energy agencies by aligning the bilateral support and by the institutional strengthening provided by the Sustainable Energy Development Project.

Efficiency

2. *The interventions in the electricity roll-out programme have been efficient; those in the biogas sector and the Sustainable Energy Development Project have been less efficient.*

The aligned support to the electricity roll-out programme meant there were few transaction costs to the Embassy of the Kingdom of the Netherlands. The average cost per connection is comparable to elsewhere in the region and has declined gradually over time, and EWSA exceeded its ambitious targets by 10-12%. From a PREP perspective, the temporary funding of biogas activities was efficient, since it triggered the establishment of the NDBP, but uptake of digesters remained low. In the Sustainable Energy Development Project, strict tendering suggests an efficient price-quality relation, but in practice it has created inefficiencies, due to piecemeal implementation.

Effectiveness

3. *The electricity roll-out programme has been effective in providing access to energy. However, the biogas and solar lamp activities have been less effective. The electricity roll-out programme has influenced both public entities and development partners, while both the support to NDBP and the Sustainable Energy Development project contributed to the development of capacities and knowledge of partners in the area of renewable energy.*

The four programmes contributed to providing access to energy to some 300,000 households, 280,000 of which were given access to grid-supplied electricity. Approximately 60% of the households in electrified communities have been connected and use electricity. This contrasts sharply with the use of electricity from lower powered sources (solar home systems, pico PV systems). Most of the connected households pertain to higher income quintiles within the poor rural environment. Both biogas digesters and solar lamps registered a low uptake and have been less effective in providing access to energy.

The Investment Prospectus enabled by Dutch up-front payments had a catalytic effect on the support from development partners and the focus on the renewable aspects of energy supply. Dutch contributions enabled SNV to support the Government of Rwanda in the development and establishment of a domestic biogas programme. The Africa Renewable Energy Access (AFREA) fund appealed to the Resident Office of the World Bank in Rwanda to

establish the Sustainable Energy Development Project in support of the utility company EWSA. The Netherlands fulfilled a prominent role in the energy sector working group.

4. *The activities have been modestly effective in establishing a market for renewable energy.*

It was envisaged that the results of the interventions would be sustained by the development of a commercial market. Since EWSA contracts out components of the electricity roll-out programme to private enterprises, the market for construction and maintenance companies has expanded. To both biogas and solar lamps, the scarce subvention and financing mechanisms constrained the sales and markets have developed hardly. The NDBP has trained 300 companies and bricklayers, some 10-15% of whom are regularly contracted to construct digesters.

Impact

5. *The impacts of the interventions vary in terms of household income and expenditure. Grid-supplied electricity has had no impact on the household expenditure for energy, but to 10% of the households electricity is used for income generating micro productive activities. Biogas digesters have a long payback period for the investment, while the impact on income of a pico-PV system is small.*

To a rural household in Rwanda, the cost of electricity is compensated for by reductions in expenditure on traditional lighting sources. As electricity is not used for cooking, the impact on expenditure is marginal only. Access to grid-supplied electricity unlocks small domestic business activities, but few electric-powered devices are used for manufacturing. In communities with a lively market, new businesses emerge, such as copy shops, hairdressers and welders. Elsewhere in the rural areas, the productive use of electricity remains very modest.

Biogas digesters reduce the daily expenditure on energy for cooking by 30%, but the investment in a digester is high and takes 5 to 9 years to be recouped by the savings. Users did not perceive a clear impact of biogas slurry on the productivity of their agricultural plots.

Owning a pico-PV kit reduces expenditure on lighting (kerosene, small batteries and candles) by 40%, but the amount rural families spend on lighting is very low; the personal solar lamp is mainly the difference between having light or not.

6. *Welfare impacts are most pronounced in the case of grid-supplied electricity: electricity prolongs the day and has an impact on health, education, the access to information and human behaviour. The impacts of biogas and pico-PV systems mainly relate to comfort (a cleaner kitchen, indoor lighting) and on health aspects.*

Having electric light implies that household members stay awake between 14 and 40 minutes longer per day (with only minor differences between males, females and children), which allows the daily routine and chores to be organised differently. Although electric light brings a feeling of security both inside and outside the house (the toilets are outside) no statistically significant changes were found in the perception of safety. Grid electricity is important for health care services (medical equipment, sterilisation, cooling) and makes it more attractive for qualified medical staff to work in rural areas. Health care messages reach

households better, thanks to increased listening to radio and watching television. Comparable reasons explain why parents in homes with electricity are more likely to send their children to school. Children use the extended hours with light at home to study during the evening, but the total time they spend doing homework does not change; it is shifted by about half an hour from daylight to the evening. Educational centres with electricity do run more computers, but only 20% of them use electronic equipment actively in teaching. There has been a significant decline in the acceptance of domestic violence in households with electricity.

Both biogas digesters and pico-PV systems lead to reduced use of traditional fuels (firewood, kerosene) and hence contribute to the actual and perceived reduction of respiratory and eye diseases among women and children. Both in the case of biogas and pico-PV, users perceive the health aspects as unexpected benefits. In households with a pico-PV system there was no measurable impact on behaviour, despite the increased use of radio. It is possible that it is too early to see behavioural change, but it seems likely that watching TV has more effect on behaviour than listening to the radio.

7. *The environmental impacts are modest, both in positive and negative terms: only the biogas digesters reduce the use of fuelwood, but their dissemination is minor. Pico-PV sets lead to a reduction in the use of small batteries, but the battery of the set may end up in the environment.*

Households using a biogas digester save approximately 5 kg of firewood daily. Among the biogas owners, 80% identify a smokeless kitchen (inside the house) as the major benefit of using biogas. The current practice of disposing of used batteries is harmful to the environment; in the absence of a recycling system, the toxic metals end up in the ground water and surface water.

Sustainability

8. *The Government of Rwanda's strong commitment to develop the energy sector is an important precondition for sustainability. As the number of small clients with low electricity consumption grows, EWSA's operational financial balance will come under pressure. No sustainable biogas market has developed and although a market is emerging for small solar devices, better quality products need to be supported.*

Rwanda's performance in the energy sector is attracting new international and domestic financing for further investments. During the next EARP stages, EWSA will extend activities to remoter rural areas with a lower population density. The low electricity consumption of these new clients means that EWSA's operational costs will not be covered by revenue from sales and therefore cross-subsidies will be required to maintain the supply to rural consumers. Both the feasibility and sustainability of new generation capacity depend largely on the import parity price for electricity from neighbouring countries.

The high costs of domestic biogas installations are slowing down market development. To enable the market to expand further, subsidies may continue to be required.

The clients for higher quality pico-PV systems are the better-off, who use the lamp as stand-by or to illuminate outdoor activities. Low-quality products are penetrating the

market quickly, so to ensure the sales of higher quality products, support mechanisms continue to be required (regulation, guarantee systems). The rapid penetration of small solar equipment through private sector channels enables the public sector to restrict its presence to regulation and quality assurance.

Implications

1. *The Ministry's 'Management at arm's length'-approach brought with it risks regarding the accountability for the effectiveness of the resources deployed.*

The 2008 PREP brought a sudden increase in the financial resources available for energy-related schemes. 'Management at arm's length' kept the Ministry's operational and management costs low, but implied having to rely fully on partners for the appraisal at entry and for accountability for the effectiveness of the resources deployed. In practice this meant that quality at entry could not be taken for granted and that reports on the effectiveness of the activities were based on self-reported data or on indicators that had not been stringently selected. The approach brought with it risks regarding the accountability for the effectiveness of the resources deployed.

2. *Resource volatility could lead to reputational risk.*

With regard to the bilateral cooperation in the energy sector in Rwanda, the short-range time horizon of PREP meant a quick increase in the resource envelop that had to be accommodated within the existing sector choice for bilateral cooperation. Although the time horizon of PREP was known beforehand, the changes in Dutch policy on international cooperation that occurred in 2011 and 2013 resulted in energy being eliminated as a thematic priority. Consequently, the bilateral presence in the energy sector in Rwanda disappeared as quickly as it had emerged. This forced the embassy to disregard the division of labour and challenged the reputation of the Netherlands as a dependable development partner.

3. *A strict application of the market approach for small renewable energy interventions is at odds with aspiring to a significant reduction of CO_2 emissions.*

Regarding the interventions with smaller renewable energy devices, such as the dissemination of pico-PV or biogas digesters, the Ministry has pursued a market approach. This approach implies the development of a market mechanism in which supply meets the demand for the product. This evaluation does not affirm the presumption that this approach produces the most efficient results in terms of reducing CO_2 emissions, being one of the targets of the renewable energy programme.

The worldwide effort to combat the externalities of the use of non-renewable forms of energy is supported by public sector stimulus in terms of tax incentives and subsidies. Since the concern for CO_2 emission and climate change is not among the first priorities of a rural household in Rwanda, the choice for renewable forms of energy depends on price in the first place. The current approach may imply lost opportunities in terms of effectiveness in that respect.

Rwanda facts and figures

Source: UvA Kaartenmakers.

Energy

GDP growth 2012	8.0%[1]
GDP per capita 2012	USD 548
Use of non-sustainable biomass for all energy	85% in 2008, declining
Energy use per capita	22 kWh (among the bottom 15 countries) (IRENA, 2008)
Installed electricity generation capacity	97 MW (of which 87MW is available; 40 MW is diesel) (IRENA, 2008)
Electricity from hydro-electric plants	57 MW (58% of installed capacity)[2]
Micro-hydro	21 hydropower plants of below 50 KW
Generation capacity under construction	232 MW (2013)[3]
Electricity access rate 2012	16%[4], increased from 6% in 2008
Electricity from renewable sources (not hydro)	0.4% of installed capacity (CIA, 2012)
Carbon dioxide (CO_2) emission 2012	0.9 million tonnes (CIA, 2012)
Per capita CO_2 emission	0.65 tonnes (the global average is 4.63 tonnes CO_2/person) (Government of Rwanda, 2011)

[1] Source: http://statistics.gov.rw/node/804.
[2] Source: http://data.worldbank.org/country/rwanda.
[3] Source: https://energypedia.info/wiki/Rwanda_Energy_Situation.
[4] Source: http://www.newtimes.co.rw/news/index.php?i=15176&a=60668.

1

Introduction

1.1 Energy in Dutch development cooperation

Since the late 1960s, Dutch development cooperation has paid attention to renewable sources of energy, initially in the context of the intermediate technology movement, later more in relation to environmental concerns. In 1993 the first policy document on energy and development cooperation 'Sustainable Energy Economy' developed an explicit policy regarding the relation between poverty alleviation and renewable energy in developing countries. In 1998, the budget of the Netherlands Ministry of Foreign Affairs explicitly designated funds amounting to 0.1% of GNP for environmental programmes, among which are climate and energy programmes[5] – areas deemed indispensable for achieving the Millennium Development Goals. In 2004, the Minister for Development Cooperation formulated an output target of supplying 10 million persons in developing countries with access to energy by 2015. In 2008, the then Minister for Development Cooperation announced that the Netherlands would make EUR 500 million[6] available for renewable energy in developing countries.

The overarching objective of this Promoting Renewable Energy Programme (PREP, 2008-2013), was 'to promote the use of renewable energy in developing countries, which will propel poverty reduction, gender equality and a mitigation of the negative effects of the use of energy on the climate' (Ministry of Foreign Affairs, 2008). To achieve this, governments would be supported in jointly developing and implementing with private and public organisations 'good and coherent' policies with regard to renewable energy and poverty reduction. At the core of the Dutch approach were building on active channels of implementation, using existing capacity and knowledge, and enabling the governments of developing countries. The general objective was made operational through four interrelated specific objectives:

1) Direct investment in the production of and access to renewable energy in priority countries and regions.
2) Sustainable production of biomass for energy.
3) Influencing the policies of partners responsible for investment in renewable energy.
4) Developing capacity and knowledge in developing countries with regard to renewable energy.

PREP has a *container structure* that accommodates an array of sub-funds, programmes, projects and activities. The Ministry's implementation strategy was to work through existing channels covering the spectrum of actors in energy. For example: the private sector through public-private partnerships; the Dutch Entrepreneurial Development Bank FMO; the multilateral channel; NGOs; and the bilateral sector. Hence the vast majority of funds were either delegated or outsourced to third parties – mainly development agencies and international financing institutions (e.g. World Bank) for administration, the awarding of

[5] Letter from the Minister of Development Cooperation to Parliament, Determining Budget for 1998, TK 25 600 V, no. 78, May 1998.

[6] Approximately EUR 125 million were existing budget lines. EUR 375 million can be considered as 'additional' financial resources.

subsidies and/or the implementation of activities. PREP funds have enabled energy-related activities in over 30 countries, but have focused on Indonesia, the African Great Lakes region and Sub-Saharan Africa.

1.2 Access to energy

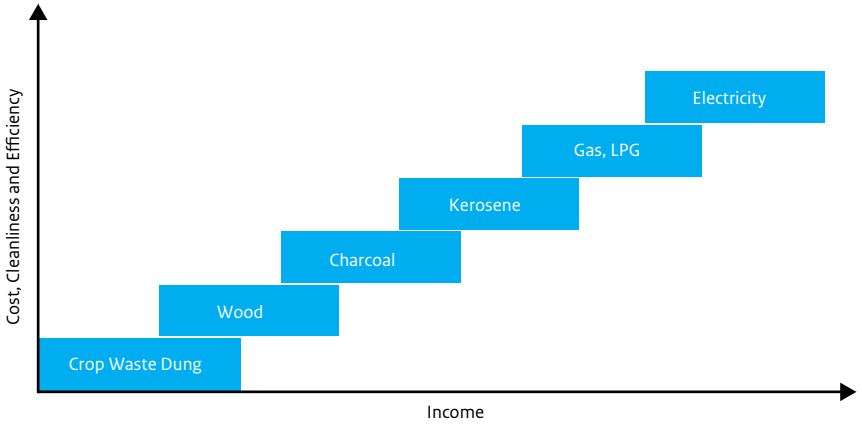
In the policy document on environment and renewable energy, the Ministry of Foreign Affairs underlines the direct relation between the lack of access to energy and poverty (Ministry of Foreign Affairs, 2008). The term 'energy poverty' is used, but in the literature this notion has different connotations (IOB 2013, p. 57). In general, it can be understood as the bare minimum of energy required to cook as well as the bare minimum of lighting to be able to read or to carry out productive activities after sunset. Described as such it matches well the distinction made for the analysis of the energy transition process from traditional towards modern forms of energy (Madubansi & Shackleton, 2006; Fall, Sarr, Dafrallah & Ndour, 2008):

(i) energy for thermal applications (space heating, cooking, water heating);
(ii) energy for lighting, safety, communication and entertainment; and
(iii) energy for productive use.

These three categories are not mutually exclusive, since some forms of energy for heating (for example, biogas) can be used for lighting as well, or even for productive purposes, such as to dry crops, cure tobacco and fire bricks. But in general, energy for productive purposes is in the form of a constant supply of electricity of sufficient power to drive equipment and machinery. This report distinguishes these three categories.

As Rwanda is located only a few degrees south of the Equator, the period of natural daylight is hardly longer than the period of darkness after sunset. To 80% of the households in small villages, the only illumination at night is the moon or the flickering light of the kitchen stove and a candle. Energy is needed for cooking as well as for lighting. Most of the energy sources used are biomass-based (fuelwood, charcoal, grass, dung, crop residues) or are extracted from the natural environment (peat, vegetable oils, beeswax). Changes in energy use patterns usually 'take the form of a gradual decline of biomass fuels, from exclusive use for all purposes by a large number of households, towards reduced use by a smaller number of households for fewer purposes, with the reverse trend for technologically more sophisticated fuels' (Madubansi & Shackleton, 2006, p. 4082). Whether households in rural areas change their energy sources or not depends on various factors, the most important being the options open to the household, and this implies an ability to make choices (Pachauri, Mueller, Kemmler & Spreng, 2004). Usually, there are more energy options in urban areas (LPG and grid-supplied electricity, for example) than in rural areas. A major determinant for the household's decision on fuel use is the price of fuel. Over time, a household may either add to its energy sources or appliances, or replace one by another. The determinants of this change, as well as the process of change are reflected in the concept 'energy ladder' (see figure 1).

Figure 1 *The Classic Energy Ladder*



Source: Holdren and Smith (2000) in Duflo, Greenstone & Hanna (2008).

The hypothesis about changes in energy use reflected in the energy ladder is one of a gradual shift from low-quality fuels, such as biomass, to more convenient, versatile and cleaner fuels such as paraffin, gas and electricity. The upward move can be made only if new opportunities come within reach of the potential user, i.e. have become physically accessible or financially affordable. The motivation for change is not exclusively economic. More expensive technologies are commonly perceived to imply higher status. Hence, a household does not move up the energy ladder solely because its motive is improved energy efficiency, but does so also to demonstrate an increase in its socio-economic status. This all forms part of a transition process, in which lower-end energy sources are gradually phased out and replaced by more modern and cleaner forms of energy. This ultimately leads to a change in 'energy regime', where higher-end, or less polluting forms of energy become 'mainstream' sources.

Households may move back and forth on the energy ladder (the movement is not one-way). With increasing income, households adopt new fuels and technologies that serve as partial rather than perfect substitutes for more traditional ones (Arnold, Kohlin & Persson, 2006). A rapid transition from traditional forms of energy to modern sources (e.g. electricity) is indicated by the term 'leapfrogging the energy ladder' (Murphy, 2001). This rapid transition is the aim of the Government of Rwanda, as will be explained in the next chapter.

Since energy sources are heterogeneous, the term 'access to energy' does not mean the same for a household equipped with a domestic solar system (known as solar home system – SHS) as it does to a household connected to the electricity grid. In the case of electricity, the Sustainable Energy for All Global Tracking Framework (2013, p. 79) distinguished five levels (or tiers) of electricity services, as shown in table 1.

Table 1	Levels of electricity services
Tier	Description
5	Use of devices that typically require several kilowatts, such as air conditioners, industrial equipment.
4	Use of devices that typically require a kilowatt, such as water heaters, irons, vacuum cleaners. At this level domestic solar systems are usually no longer sufficient.
3	Use of devices that typically require 100 W or more, such as rice cookers, refrigerators, freezers.
2	Bright light, use of radio and telephone and other devices requiring several tens of watts, such as small television, fan, or computer.
1	Pico-PV and battery charging stations.

Source: Sustainable Energy for All Global Tracking Framework, 2013.

1.3 Objective of the evaluation and research questions

In September 2009, the Policy and Operations Evaluation Department (IOB) of the Ministry of Foreign Affairs of the Netherlands embarked upon the evaluation of programmes in the area of Energy and Development Cooperation[7] as overarching framework for a series of impact studies of activities funded by the Promoting Renewable Energy Programme. The *central research question* for the impact evaluations was: 'What have been the effects – positive or negative, intended or not – on living conditions of target groups of the energy and development cooperation programmes and projects supported by the Netherlands, and how sustainable are the results achieved?'

For the evaluation of the Promoting Renewable Energy Programme, the concept 'impact' was restricted to the household and community levels and in consequence the impact on macro variables (such as the climate) was not directly included. The units analysed include affected individuals (m/f), households, public facilities and small enterprises. In this evaluation 'access to energy' is perceived from a demand angle, so it includes not only energy services that improve living conditions (e.g. electricity for lighting and fuel for cooking) but also energy services for social facilities or units of economic production (e.g. cool storage of medicines, communication, manufacturing) (Cornelissen, 2008, p. 1).

Between 2010 and 2014, impact studies were conducted in Burkina Faso, Rwanda and Indonesia on selected activities such as solar energy systems, biogas, improved cooking stoves (ICS) and rural electrification through micro-hydro plants. The results of these evaluations are intended to be input into a broader policy evaluation of the PREP.

7 See: www.iob-evaluatie.nl/node/331. Terms of Reference impact evaluation of Energy and Development Cooperation supported by the Netherlands, September 2009.

The PREP-funded interventions evaluated were selected to represent the diversity in energy sources, implementing organisations (public, private, bilateral, multilateral) and evaluation techniques. In consequence, the purpose of the present evaluation is not determined by any particular strategy for renewable energy in Rwanda.

From the overarching evaluation question mentioned above, three groups of questions were derived for Rwanda:

A *General and contextual questions concerning the energy sector and its institutions*.

- What are the main characteristics of the energy sector? Its main economic and environmental features? Its key problems and the government's main policies to overcome them?
- Which major public and private institutions are involved in the energy sector?
- What are the features of existing market mechanisms when it comes to providing energy to households?

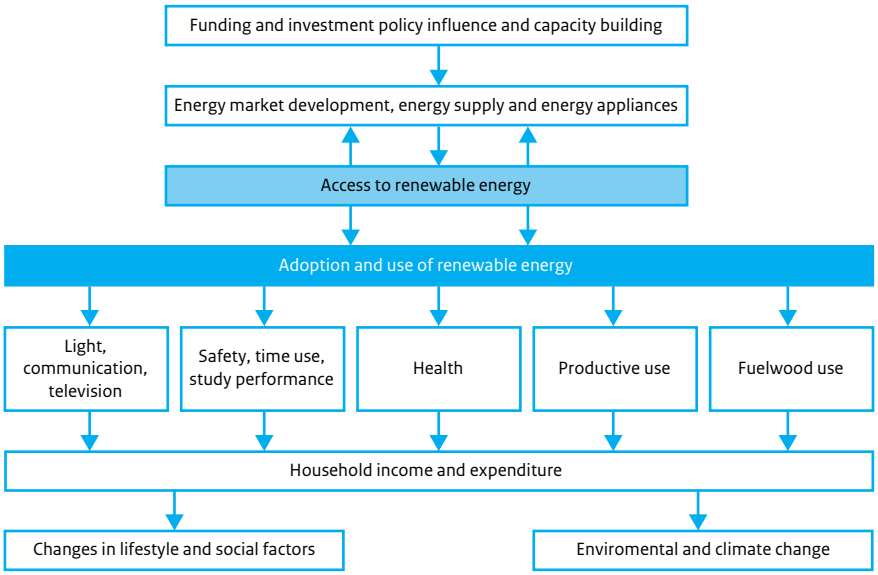
B *Questions concerning the renewable energy activities in Rwanda funded by the Netherlands*.

- What are the objectives of the PREP-supported programmes/projects identified? Which key problems are addressed?
- To what extent are the Netherlands-supported programmes and projects relevant and aligned to the Rwandan energy policies? Have the output targets been achieved and what has been the change in the numbers of individuals (m/f), households, communities and other beneficiaries that have access to and use the energy-related products and services provided?
- Has a financially self-sustaining market for the energy sources been established and, if so, how?
- To what extent have the programmes contributed to the fourth objective of PREP, i.e. 'developing capacity and knowledge with regard to renewable energy' in Rwanda?

C *Specific questions concerning the impact of selected programmes/projects in Rwanda*.

The specific questions per intervention are derived from the envisaged generalised results chain (figure 2).

Figure 2 *Generalised results chain for interventions in the energy sector*



The specific questions related to particular energy interventions encompass at least the following:

- How many connections were made (electricity) or installations placed (biogas) or units sold (solar lamps) or activities developed (institutional strengthening)?
- The impact on the household's total expenditure and on energy expenditure.
- The impact resulting from changes in time use and access to information, whether directly through radio and television, or indirectly through enhanced communication, and the knock-on effect on the behaviour of individuals and households (in terms of issues such as women's status).
- The impact of the intervention on household welfare in terms of health, education, security and comfort and on community welfare in terms of educational and health services.
- The impact on the environment in general and on air quality in terms of CO_2 emission in particular. (Note that the impact on climate change was not specifically addressed in this evaluation).

1.4 Methodology

The ToR specified that the impact evaluations should be done using a mix of methods (integrated qualitative and quantitative methods) and a variety of research techniques for the quantitative assessments. Studies were to be conducted in both rural and urban environments.

In 2009 PREP was implemented in 33 countries. A sample of three countries (Burkina Faso, Indonesia and Rwanda) was selected on the basis of the following criteria: the priority of the country or region in the programme[8]; the number of the activities in the country and their spread; the coverage of the main types of energy source; and the implementation of these activities through a mix of development partners.[9] Using pre-determined criteria[10], in 2010 a scoping mission to Rwanda identified three energy interventions for further evaluation. In December 2011 a fourth intervention was added as result of a Memorandum of Understanding between IOB and SNV for the joint financing of the evaluation of the biogas activities in Rwanda. This report does not provide details about PREP-funded interventions other than the four that are listed in table 2.

Table 2 Interventions selected for impact evaluation

Name	Energy activity	Implementing organisation	Target area or group	PREP contribution (EUR million)
Electricity Access Roll-out Programme	Grid electricity	National government (MININFRA) through utility company EWSA[a]	National programme, urban and rural	30.0
National Domestic Biogas Programme (NDBP)	Biogas installations	National government (MININFRA) through NDBP. Technical assistance from SNV and GIZ[b]	National programme, focus on rural areas	2.2
ToughStuff Rwanda	Personal Solar Lighting; pico-PV lamps	ToughStuff International[c]. Implementing agency of the Daey Ouwens Fund: RVO.nl	Focus on remote rural areas	0.34
Sustainable Energy Development project	Energy in general	World Bank Rwanda through EWSA[d]	National institutions	3.1

a Ministry of Infrastructure (MININFRA) and Energy Water and Sanitation Authority (EWSA).
b Netherlands Development Agency SNV; Gesellschaft für Internationale Zusammenarbeit (GIZ; prior to 2011: GTZ).
c ToughStuff Rwanda received an advance subsidy of EUR 340,280 ToughStuff International EUR 1 million support from the Entrepreneurial Development Bank FMO.
d Through the Africa Renewable Energy Access programme AFREA.

8 Priority areas mentioned in policy documents were Sub-Saharan Africa and Indonesia.
9 Development Partners are donors that align with the development policy of the Rwandan government.
10 These criteria were: (i) the relative relevance of the activity to the (written) energy strategy of the Government of Rwanda; (ii) the number and relative concentration of the installations with both urban and rural beneficiaries; (iii) the mix of implementing partners; and (iv) considerations for applying quantitative methods.

The main methodological thrust was to apply 'mixed methods'. *Qualitative* methods were used for the contextual analysis, i.e. for the descriptive components of each programme or project funded with PREP resources, as well as for the institutional analysis. Qualitative methods also encompassed a literature study (IOB 2013), desk research of secondary sources, a Web search, a reconnaissance field visit in 2010 and a verification field visit in 2013. Most of the interviews were conducted on the basis of semi-structured questionnaires. Qualitative methods were also used to generate input to help design the surveys: focus group discussions and interviews with key informants such as village chiefs, beneficiaries or local NGO representatives.

Quantitative techniques were used to measure the relationship between intervention and effect variables, and how much each of the interventions has contributed to the effects, while controlling for other factors that might have had an impact on the selected effect variables. Primary data was collected through surveys at household and community levels (in some cases also among workers in the health and education services) conducted by trained local interviewers. Table 3 presents an overview of the methods applied in the four evaluations presented in this report. For summarised information about the techniques see Annex 5.

Table 3 Main types of methods applied, by intervention

Methods	Sample size
Electricity Access Roll-out Programme	
Probability (proportional to size) of communities being selected for connection to grid. Baseline and follow-up surveys among households. Differences-in-differences at household and community levels. Willingness to pay (WTP) and willingness to accept (WTA).	30 communities newly connected, 20 control. 1,486 households at baseline. In 929 of these, women also surveyed. 974 households at follow-up.
Qualitative household interviews.	20 interviews.
Qualitative micro-enterprise survey.	100 enterprises.
Qualitative survey among community chiefs.	50 (baseline). 44 (follow-up).
Qualitative health centre survey.	16 (baseline). 26 (follow up).
Quantitative health centre survey (full census).	442 telephone interviews (+ 20 in-depth).
Qualitative interviews with EWSA branch members.	12 interviews.
Verification.	

Methods	Sample size
National Domestic Biogas Programme	
Single survey among households with and without a digester. Cross-sectional. Parametric (ordinary least squares). Non-parametric (propensity score matching).	305 households with digester. 295 in control group.
Verification.	
ToughStuff Rwanda	
Baseline and follow-up surveys among households. Randomised Controlled Trial.	Baseline: 300 households. 150 pico-PV lamps handed out. 150 control group. Follow-up: 148 (of whom 130 with lamp, 18 without). 148 control group.
Survey among buyers.	66 'real' clients.
Qualitative household interviews, focus group discussions.	37 interviews and discussions.
Semi-structured and open interviews.	39 interviews.
Verification.	
Sustainable Energy Development Programme	
Funnel approach: from broad to specific. Desk study, field visit, interviews.	12 interviews.

Specific Terms of Reference were drawn up for each of the four evaluations. IOB commissioned the Rheinisch-Westfälisches Institut für Wirtschaftsforschung (Germany) and the International Institute of Social Studies (the Netherlands) to carry out the impact studies in collaboration with the research company IB&C (Rwanda). Erasmus University Research and Business Support (the Netherlands) was commissioned to undertake the context analysis and the evaluation of the Sustainable Energy Development Project. Many practical hurdles had to be overcome prior to and during field work and therefore delays in the implementation of the surveys and reporting were unavoidable.

2

Energy in Rwanda

2.1 Rwanda

With an area two-thirds (26,338 km²) that of the Netherlands and a population of 10.5 million (2012),[11] Rwanda is among the most densely populated countries in Africa. Administratively, it is a presidential republic, subdivided into five provinces, in turn subdivided into 31 districts, further subdivided into sectors and cells, with the village (*umudugudu*) at the lowest level. The first local elections held after the traumatic events of 1994 were in 1999; a general election followed in 2003. Vice-president Paul Kagame became president in 2000 elected by the then transitional Parliament. The Constitution (2003) confirmed the re-establishment of a multiparty system (1991) but the single political party of importance is the Rwandan Patriotic Front (RPF).[12] The political participation of women is noteworthy: Parliament has the highest percentage (56%) of women in the world. Government's public finance management is aimed at fiscal discipline, with budget revenues that are high for Africa (25.7% of Gross Domestic Product – GDP) and low deficits (1.8% of GDP).

The economic structure of Rwanda is dominated by agriculture, which accounts for 43% of GDP. Most agriculture consists of cultivating subsistence food crops, the remainder is cash crops such as coffee, tea, pyrethrum[13], bananas, beans, sorghum, and potatoes. The country's natural resources (gold, cassiterite [tin ore], wolfram [tungsten ore] and methane) are not abundant, but nevertheless account for 38% of export earnings (Government of Rwanda 2011). Tourism is an increasingly important economic activity. Due to the population pressure in rural areas, free grazing of livestock is prohibited. Industry accounts for some 20% of GDP and services make up the remaining 37%. Over the last decade, the annual GDP growth rate has been consistently high: 4 to 8%. This resulted in a per capita GDP of USD 548 in 2012. 45% of the population (2012) lives below the national poverty line.[14] In that year the country ranked 167 out of the 187 in the Human Development Index.

The 1994 genocide temporarily stalled the country's ability to attract private and foreign investment. In June 2007, Rwanda joined the East African Community (EAC) and since then it has been aligning its budget, trade, and immigration policies with those of its regional partners. This move fits with Rwanda's aim to transform the country into a regional hub for distributing, banking and ICT services, by linking francophone Central Africa with Anglophone East Africa. Rwanda seeks to attract investment in all sectors, but specifically in agribusiness, mining, trade and logistics, tourism and construction, and information and communication technologies. The latter technologies are supported by increasing access to electricity and 2,300 km (2011) of fibre optic cables laid across the country and the rapidly

[11] Source: http://statistics.gov.rw.

[12] The Constitution (2003) forbids all acts of 'divisionism', i.e. any reference to ethnic differences, ethnic-based expressions, articles, meetings or political formation. The RPF is the only organisation with a political structure at local level.

[13] Chrysanthemum or Tanacetum are cultivated to extract insecticide (also used as repellent).

[14] Source: http://data.worldbank.org/country/rwanda.

improving capabilities of its population (with 95% of children enrolled in primary school in 2009).

2.2 Energy and development

Key problems in the energy sector

Rwanda's post-conflict recovery resulted in a strong growth in demand for energy. But until 2005, the country suffered from acute shortage of electricity supply, expressed by severe load shedding. The supply shortages and unreliability raised costs of doing business, and simultaneously harmed the prospects of attracting new investment. The country's electricity generation plants (mainly diesel) had insufficient capacity and suffered from insufficient maintenance, while the hydropower generation had been constrained by regional drought that had also affected Kenya, Tanzania and Uganda, leaving Rwanda with no option of sourcing electricity from its neighbours (2003-2005). In addition, a rather dilapidated transmission and distribution network caused technical losses of around 30%. By 2008, the electricity company had only 109,000 households connected to the grid (RURA, 2008), almost all in the urban area of Kigali, with almost no connections in the rural areas.

In general, the energy sector faces the following problems:

- The growing and gradually more urbanised population, coupled with rising per capita income has led to more demand for energy for cooking. Since in urban and semi-urban areas the cooking is done on charcoal, there has been a disproportional increase in demand for fuelwood. The government's attempt to ensure fuelwood supply by planting eucalyptus has been successful. Urban consumers have few alternative sources: biogas is hardly suitable in an urban environment, while imported LPG and also electricity are too expensive for most households.
- Access to electricity for lighting is low, particularly in the rural areas. Government is investing in generation capacity (see Chapter 3) and in the extension and densification of the medium (MV) and low voltage (LV) distribution. But even if access to the grid is provided, connection of households to the grid cannot be taken for granted: in 2013, the cost per connection was approximately EUR 750 (RWF 600,000), while the price to the consumer was EUR 60, the difference being paid for by the public sector and development partners. Since additional connections will gradually be removed from the high voltage lines and have to cover areas with less population, the per unit cost price will increase to EUR 920 per household. If the electricity roll-out continues as planned, by 2020 over 40% of the population will be without grid-supplied electricity and will require other sources to meet electricity needs.[15]
- Commercial enterprises are hardly interested in investing in energy generation, since feed-in tariffs are kept low by the import parity price for electricity from neighbouring countries.

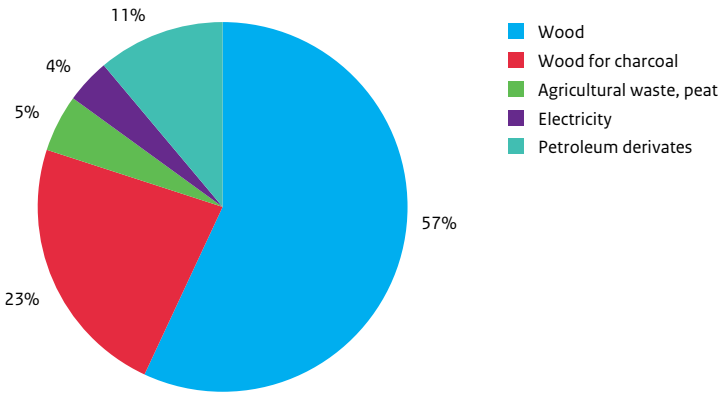
[15] The Rwanda Vision 2020 white paper envisages that by 2020 35% of households will have access to electricity; EWSA envisages 48-60% by 2020.

- The market for solar energy is incipient. Enterprises focus on the market for larger systems for public institutions, e.g. hospitals and schools, through public tenders; in urban areas there is a thriving market for solar water heating systems. Few solar home systems are sold to private customers, let alone in rural areas, but the market for personal solar lighting (lanterns) is emerging (see chapter 5).

Energy sources

Access to energy is important for economic development and hence for poverty alleviation, but low energy consumption patterns are related to poorer strata of the population who depend mainly on biomass. In Rwanda, biomass is the most important energy source: in 2011, some 94% of all households used biomass for cooking (Ministry of Natural Resources 2009, p. 28); in total, 85% of primary energy is derived from biomass sources (wood, charcoal and agricultural waste) (Government of Rwanda 2011) (see figure 3). While the use of briquettes or industrial waste as sustainable biomass energy sources is hardly developed, approximately a quarter of all woody biomass energy can be considered as sustainable, since it is harvested from controlled plantations (MININFRA 2009c). With the relatively fast economic growth over the last decade, the demand for power, mainly electricity, has increased by 7% annually. The two-way relation between access to clean and reliable energy and economic development was also noted in an IOB systematic literature review (IOB 2013).

Figure 3 *Main energy sources in Rwanda*



Source: Based on MININFRA 2012.

Rwanda's main energy sources and the trend in demand and supply are summarised in Annex 2a.

Electricity generation has to keep up with the demand resulting from economic development, population increase, urbanisation and the electricity dependency of modern technology. Rwanda faces a shortfall and is a net importer of electricity. The Government of Rwanda intends to increase the generation capacity from 97 MW in 2011 through 562 MW in

2013 to 1 GW by 2017, and intends to achieve this by hydro generation (333 MW), geothermal generation (310 MW) and methane-powered capacity (300 MW). By 2013, most electricity was still diesel generated. But the strategy focuses on renewable sources: the rehabilitation of existing hydro plants at Rusizi and new regional programmes (Rusizi III and IV), shared with the Democratic Republic of Congo and Burundi, and Rusumo plant, shared with Burundi and Tanzania.

Main stakeholders in energy sector

The energy sector is composed of a large number of private and public stakeholders. Obviously, the policy and regulatory framework is the domain of the public sector, with the Ministry of Infrastructure (MININFRA)[16] leading. The Ministry is responsible for initiating and developing sustainable power generation facilities to supply clean, cost-effective and uninterrupted energy for the country. MININFRA is responsible for the development of institutional and legal frameworks, national policies, strategies and master plans related not only to energy, but also to transport, habitat and urbanisation, meteorology, and water and sanitation. Biomass is the main source of energy to households but the biomass policy is the responsibility of the Ministry of Natural Resources (MINIRENA). The Energy Water Sanitation Authority (EWSA) is responsible for the implementation of the energy policy, in particular the electricity subsector. It is particularly responsible for the transmission and distribution of electricity. The role of other public entities is summarised in Annex 3b.

Up to 2004, the role of the private sector in the electricity subsector was limited, since electricity supply was perceived to be a public sector responsibility. Nevertheless, part of the diesel electricity generation was privately owned by local investors and was rented out to the utility company for feeding the grid. The Energy Policy 2004 encouraged private investment in: (i) the exploration of new energy options; and (ii) the generation of energy (mainly electricity). Both transmission and distribution remained largely within the public domain, but the role of the private sector is still mainly in energy generation. Nowadays, private companies no longer invest in diesel electricity generation because fuel has to be imported and is expensive and the price of electricity is largely set by the import parity price. Nevertheless, independent power producers (IPPs) generate electricity, licensed by the Rwanda Utility Regulatory Agency (RURA). To that end, the Ministry actively attracts private sector investment and negotiates with investors about power purchase agreements (PPAs). International private investment takes place through Public-Private Partnerships (PPPs) in the Lake Kivu methane project, in peat to power pilots, in large-scale hydropower installations and in solar energy (the Kigali Solair [2008] and the new GigaWatt Global [2014] 8.5 MW photovoltaic park).

To trigger private investment in renewable energy sources, the Government of Rwanda issued the Renewable Energy Strategy (EWSA 2012), one of the products of which was the revised regulatory framework for small and mini-hydropower (Renewable Energy Feed-in

[16] Since Independence, the Ministry has had eight names (see: http://mininfra.gov.rw). It has been known as MININFRA since November 2002.

Tariff – REFIT 2012). The regulation obliges the national utility company EWSA to purchase the renewable energy generated by hydropower plants ranging in size from 50 kW to 10 MW, even if the price is higher than the import price.[17]

Both MININFRA and the private sector focus on new energy sources, provided the costs of exploitation are competitive. These alternative sources (not all are renewable or sustainable) have been found in peat, methane and hydropower.

2.3 National policy and strategy on renewable energy

Over the period 2008-2013, the activities of the Government of Rwanda in the energy sector were guided by four interrelated policies and strategies at national and sector levels (figure 4).

The most leading policy document has been the long-term Rwanda Vision 2020 (Ministry of Finance and Economic Planning 2000). Its overall objective is to double the per capita income within two decades, thereby transforming Rwanda from a low-income into a middle-income country. This would require a sustained economic growth of 8-9% in GDP annually. Energy is a component of one of the three so-called 'flagships' (sustainable growth for jobs and exports; poverty reduction through public works like roads and energy; and good governance) (Ministry of Finance and Economic Planning 2000, p. 11). The specific energy targets are first, to reduce the use of wood energy for cooking and industrial processes from 94% in 2000 to 50% in 2020, and second, to increase the proportion of the population connected to the electricity grid from 6% to 35% by 2020 (2000, p. 17). To achieve this, the existing sources of energy have had to be diversified into alternative sources such as hydroelectricity, the exploitation of methane gas in Lake Kivu, and photovoltaic energy.

In Rwanda's subsequent Poverty Reduction Strategy Papers (2002-2005 and 2008-2012), GoR linked the extension of the national electricity grid to poverty reduction through its expected impact on health, education and productivity. This required the generation capacity to be increased from 45 MW in 2008 to 130 MW by 2012. By that year, some 200,000 additional households were to be connected to the grid. All health and social centres and administrative offices and 50% of the approximately 1,000 schools would be either connected to the grid or equipped with PV systems. (Ministry of Finance and Economic Planning 2007). A third PRSP 'Shaping our Development' was approved in May 2013 (Republic of Rwanda 2013).

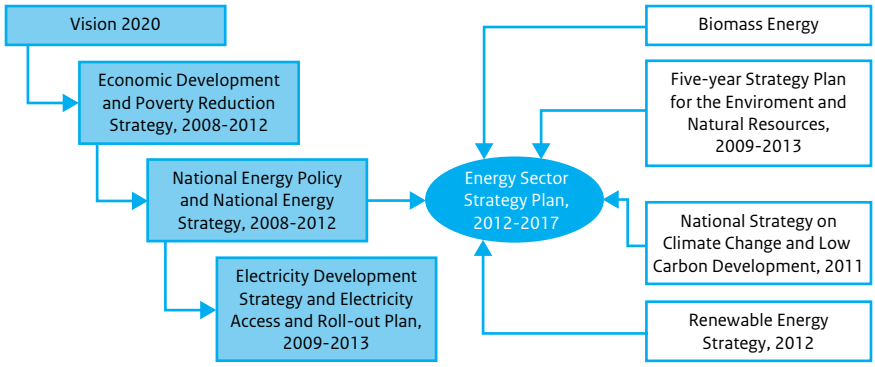
In 2008, MININFRA updated its energy policy into the National Energy Policy and National Energy Strategy 2008-2012, linking the energy strategy to the Economic Development and Poverty Reduction Strategy and the Millennium Development Goals (MININFRA 2009a, p.

[17] The REFITs are calculated on a cost plus return basis, to ensure sufficient incentives for private investors. The PPAs are valid for a period of 3 years, after which they will be subject to review by RURA. Source: http://www.rura.rw/fileadmin/docs/REGULATIONS_ON_FEED_TARIFFS_HYDRO_POWER_PLANTS.pdf.

20). New elements were the more explicit attention to gender dimensions, to private sector involvement, and to regional integration in the generation and transmission of electricity. An important element was the new regulatory framework implemented by the Rwanda Utility Regulatory Agency (RURA), which determines the roles of the public and private sectors in the area of energy generation, transmission and distribution. The 2008 strategy was updated in the Energy Sector Strategic Plan for the period 2012-2017 (MININFRA 2012).

The five-year Electricity Access Roll-Out Programme (EARP) 2009-2013 (2009) was elaborated to implement the targets set in the National Energy Policy. It created a new and more decentralised institutional framework for extending access to electricity. The costing of EARP was further elaborated in an Investment Prospectus (Castalia Strategic Advisers 2009). The implementation of EARP started in 2009 (see chapter 3). These main policy documents are shown in figure 4.

Figure 4 *Main policy documents issued by the Government of Rwanda 2008-2013*



In addition to the abovementioned general policies and strategies, a number of subsector strategies were elaborated, such as the Biomass Energy Strategy (BEST) for Rwanda (MININFRA 2009c), which encompassed a forest inventory. BEST indicates that the country had reached a certain balance between fuelwood production and consumption, thanks to Eucalyptus plantations on public land and strict regulation. The Five-Year Strategic Plan for the Environment and Natural Resources Sector, 2009-2013 (Ministry of Natural Resources 2009) analysed the effects of a growing population on natural resources and aimed at further increasing tree cover from 21% in 2008 to 30% by 2020. This strategy introduces domestic biogas digesters as alternative to the traditional hearth. The Republic of Rwanda National Strategy on Climate Change and Low Carbon development (MINIRENA 2011, p. iii) stresses Rwanda's vulnerability to climate change and argues that Rwanda has untapped clean energy resources in geothermal, hydro and solar, as well as the methane gas resource in Lake Kivu. Together, these sources could replace oil-fuelled power plants and reduce greenhouse gas (GHG) emissions. The report stresses the need for investment in low carbon domestic energy resources and technologies such as solar energy.

International support to energy programmes and projects

The National Energy Policy and Strategy is supported by various development partners. Most support is directed to energy in general and not restricted to renewable energy. The various programmes and projects (in addition to those funded by the Netherlands government) are listed in Annex 3c.

The World Bank is by far the largest external financier, followed by other development investment banks. Between 2008 and 2013, the European Commission and the Netherlands were the development partners that supplied the largest volume of grant aid to the energy sector in Rwanda. While most lending arrangements are aimed at electricity generation infrastructure, the largest grant-loan blending is for the electricity roll-out programme EARP. Neither the energy generation programme nor EARP are by definition 'green' energy programmes, but in both cases a substantial share is aimed at renewable energy.

Over time, well-organised coordination mechanisms have developed between the GoR and the main development partners active in the energy sector. After the Paris Declaration (2005), the Ministry of Finance and Economic Planning (MINECOFIN) translated the alignment principles into an Aid Policy Document, indicating General Budget Support as preferred aid modality.

GoR and development partners meet quarterly in the Development Partners Coordination Group (DPCG) to discuss general development issues, whereas sector matters are elaborated in one of the nine Sector Working Groups (SWG). At the beginning of each calendar year, MINECOFIN and development partners work out a harmonisation calendar. Towards the end of the year, GoR (President, Prime Minister, Ministers) and development partners (including representatives from abroad) meet in the DPCG. DPCG and SWGs are chaired by GoR, co-chaired by UNDP (DPCG) or the lead donor in the respective sector (SWG). Rwanda is one of the few countries in the world to have taken a strong lead in the division of labour (2010). There is also a Donor Energy Working Group (excluding MININFRA) chaired by the World Bank, as instrument to facilitate donor harmonisation and to define common positions in relation to MININFRA and EWSA. The group feeds its conclusions into the SWG. In interviews, most stakeholders were sceptical about harmonisation and considered that from the government's side information was provided, but that the coordination mechanism was no platform for discussion or policy debate.

2.4 Policy of the Netherlands regarding Rwanda

After 1994, the Netherlands was among the first development partners of Rwanda, initially through non-governmental organisations and a UNDP Trust Fund, and later through support to government. All these aimed at building a state able to deal with its past. A solid judicial system would contribute to respect for the rule of law in which genocide would never be repeated. In the Netherlands, the early and substantial support was not without political criticism. In 2000, the Netherlands Ministry of Foreign Affairs placed Rwanda on its

'GMV list'[18], thereby confirming its intention to come to a more stable bilateral relation for support to rural transformation, decentralisation and good governance / justice. At the start of the structural bilateral partnership a delegated budget of EUR 40 million was assigned to the embassy, but the House of Representatives of the Dutch Parliament refused to endorse bilateral development assistance to Rwanda. The next year (2001) Parliament endorsed the proposal to insert Rwanda as partner country on the condition that a Memorandum of Understanding would stipulate progress indicators for democratisation and peacebuilding. Energy played hardly a role in the embassy's multi-annual strategy for Rwanda over the period 2005-2008 that focused on rural transformation, decentralisation and justice, or in the multi-annual strategy over the period 2008-2011 in which the only two sectors remaining were justice and good governance, and sustainable economic and private sector development. Under the heading of private sector development there was only one programme in support of the then utility company Electrogaz: it was for EUR 4.1 million.

The African Great Lakes Region policy became effective in 2003, so since then there have been two closely interrelated but financially separate strategies: one for the African Great Lakes Region (Rwanda, Democratic Republic of Congo, Burundi) and one specifically for Rwanda. The regional programme was developed with the aim of 'contributing to environmental goals, reduced tensions and enhanced cooperation around natural resources as well as to peace dividend and sustainable income based on natural resources' (EKN, 2008). These goals led to a focus on land, national parks and energy. The Dutch Minister for Development Cooperation had identified the African Great Lakes region as one of the areas with the highest potential for sustainable energy management. Many of the largest and cheapest options for electricity generation were located in border areas and rivers. Hydro electricity generation in the border river Rusizi could bring the neighbouring countries closer to each other because of shared interests. The planned support to the rehabilitation of the Rusizi II power plant was cancelled in 2010 however, due to difficulties in establishing a multi-country institutional set-up (EKN, 2011). The hydroelectricity generation projects in the border rivers are a good example of the regional African Great Lakes policy matching the PREP policy that also explicitly aimed at large-scale renewable energy projects to be realised in a multi-actor setting with private sector investment. The Dutch participation was managed by the Entrepreneurial Development Bank FMO.[19] For the regional strategy 2012-2015, EKN applied a '3D' (diplomacy, defence and development) approach 'to increase stability and security through fostering economic development, self-reliance and job opportunities'. Projects were foreseen that should address constraints in regional energy infrastructure and contribute to food security in the region. Carbon credits could be generated from climate change funds for tree planting at large scale in watersheds and for financially viable fuelwood plantations[20] (EKN 2011, p. 22).

[18] The three focal areas on this list are good governance, human rights and peacebuilding.

[19] Since in 2010 none of these projects had yet started, these large-scale generation projects were not selected for impact evaluation.

[20] Late 2013, the second stage of the other large energy programme (the regional biomass programme PAREF) was approved and given a budget of EUR 6 million.

The general policy changes in Dutch development cooperation, introduced in 2011 in the Focal Letter on Development Cooperation (Ministry of Foreign Affairs 2011), implied less attention would be given to energy in development cooperation. Since the 'two sectors only' approach was no longer being adhered to, the embassy in Rwanda decided to select three priority areas for the period 2012-2015: Security and Justice, Water Resources Management and Food Security (EKN 2011). In 2013, another change of government brought a further change in general policy on foreign relations, which combined foreign trade and development cooperation into a single strategy as reflected in the new white paper *A World to Gain: A New Agenda for Aid, Trade and Investment* (April 2013). One of the characteristics of that policy is that it explicitly discontinues Dutch support to the energy sector in developing countries. For the 2014 budget the embassy found a creative way out by linking energy to food security, arguing that one of the constraints in food security is the deficient energy supply. By improving the enabling environment (amongst others by assuring electricity supply) the agro-processing, storage and food-related trade could prosper.

Mid-2013, the embassy informed the Rwandan authorities about the policy changes that had taken place, as explanation for the lower than envisaged financial contribution to the electricity roll-out programme (see chapter 3).

Renewable energy

In 2004, the Ministry of Foreign Affairs of the Netherlands approached the German Gesellschaft für Internationale Zusammenarbeit (GIZ; prior to 2011 known as GTZ)[21] to come up with a unique single-sector delegated cooperation programme at global level: the Energising Development (EnDev) programme.

In line with concepts of delegated cooperation, the Ministry's approach was to rely upon the implementation capacity of partners like GIZ and the World Bank. At country level, the Ministry would intervene only if disputes occurred. This was extended to the implementation of the PREP, where delegation and outsourcing were required to manage a much larger portfolio.

In addition to the EnDev activities, the first activities of the Dutch Development Organisation SNV in the area of biogas (see chapter 4) were implemented without direct involvement of the Embassy of the Netherlands. Within the bilateral programme, there was only one project in the energy sector: the support to Electrogaz (predecessor of the current EWSA). This project was a positive reaction to an emergency appeal by GoR for support to solve the electricity problem in the country that had been aggravated by the drought of 2004 and 2005 that affected the hydro generation capacity. The Netherlands contributed EUR 4.1 million.

[21] In a second stage through the *Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (BMZ)*.

Box 1 *Energising Development*

Energising Development started in 2005 as a German–Dutch collaboration aimed at providing access to modern energy to poor households in developing countries. In 2008 this was narrowed down to 'renewable' energy, while in 2013 'providing access' was amended to 'facilitating access'. The 2011 Focal Letter on Development Cooperation of the Dutch government at the time indicated that support to the energy sector would be discontinued. Since then, the *Gesellschaft für Internationale Zusammenarbeit* has succeeded in involving more contributing partners: Norway, Australia, the United Kingdom, Ireland, and the European Commission. Late 2013, EnDev was guided by a Governing Board, and managed by GIZ, assisted by RVO.nl. At any moment in time, the programme is active in over 20 countries, but not always the same ones. EnDev is not bound to the focal countries of the German development cooperation, but in countries outside these focal countries it may commission development organisations such as the Dutch organisations SNV and HIVOS (Indonesia, Vietnam and Cambodia) to implement activities.

In Rwanda, EnDev has been active mainly in micro-hydro energy generation, but temporarily supported the National Domestic Biogas Programme as well.

Alignment

In May 2008 a Memorandum of Understanding was signed between the GoR and development partners for support to the energy sector, in particular the electricity roll-out programme. According to the Memorandum, the subscribing development partners would adhere to the principles of the Paris Declaration. While all development partners aligned to the GoR policy, only the Netherlands made use of the administrative and financial systems of the country.

The policy dialogue in Rwanda was considered open and constructive by both the embassy and the GoR. The Dutch contributions influenced GoR's policies and practices[22], in particular in areas of Dutch interests, such as the generation of renewable energy, harmonised and simplified regulations in the woody biomass and charcoal chain, effective coordinated institutions, and reliable reporting on progress information from the Management Information System.

In January 2010, the Rwandan government presented a proposal for the division of labour among the development partners. The Netherlands was requested to support three sectors: Justice, Decentralisation and Energy. While the request for support for the justice sector matched the Dutch sector choice, energy was considered a theme that could be

[22] Interviews MININFRA, embassy, EC delegation, World Bank, June 2013.

accommodated in the sustainable economic and private sector programme. Both the Embassy and the Ministry accepted GoR's proposal.[23]

Interventions

The Dutch support to the Rwandan energy sector encompassed: (i) electricity generation, transmission and distribution; and (ii) biomass and cooking energy.

Energy generation was supported through activities by EnDev in its 'Private Sector Participation in Micro-hydropower Development' (PSP Hydro) project, which provides technical and financial advice as well as limited financial support to private companies that wish to develop hydropower plants (micro-hydro installations, EUR 3 million). More indirect support to electricity generation was provided through the involvement of the Entrepreneurial Development Bank FMO that considered issuing loans for the rehabilitation, expansion and construction of the regional hydroelectricity generation plants Rusizi (various stages) and Rusomo. In 2013, FMO discontinued its participation in both, due to lack of progress in reaching an agreement among the countries involved regarding energy distribution and revenue sharing. FMO did invest in the KivuWatt methane to power project (2011) and the GigaWatt Global solar plant (2014). Another project for marketing solar lamps in rural areas was also funded (EUR 0.3 million): ToughStuff (see chapter 5).

Through the Daey Ouwens Fund (DOF) three companies were selected for generating hydroelectric power: the Rwanda Mountain Tea project (EUR 2 million), expected to produce electricity by late 2014; the Société de Gestion de l'Énergie et de l'Eau en milieu rural (SOGEMR) and Calimax. Ultimately, no funds were disbursed to the latter two initiatives, either because of changes in the institutional structure or because of difficulties in securing the required co-finance. The SOGEMR hydro plant was constructed without DOF funds and became operational in late 2013.

Funds totalling EUR 15 million from the African Great Lakes region portfolio were used to provide support to regional networks for electricity transmission. The bilateral support was focused on electricity distribution through the electricity roll-out programme (EARP, see chapter 3). In June 2009 a commitment was made for EUR 30 million for a three-year period.

AFREA was established through a EUR 24 million contribution to the Clean Energy Investment Framework Multi-Donor Trust Fund of the Energy Sector Management Assistance Programme (ESMAP).[24] That contribution was intended to make the World Bank Africa Energy Unit in general and ESMAP in particular more aware of renewable energy. AFREA is in turn the main contributor to the Lighting Africa initiative that promotes solar energy. Amongst others, Lighting Africa supports small entrepreneurs and certifies solar

[23] Source: memo EKN Kigali (17 mei 2010) *Arbeidsverdeling Rwanda en Nederlandse sectorkeus.*

[24] ESMAP is implemented by the World Bank and funded by Australia, Austria, Denmark, Finland, France, Germany, Iceland, Lithuania, the Netherlands, Norway, Sweden, the United Kingdom and the World Bank.

equipment. In Rwanda, two social companies (Light for Life and Great Lakes Energy) were supported through Lighting Africa awards. Using AFREA funds, the Sustainable Energy Development Project (EUR 3 million) (see chapter 6) provided institutional support to the electricity utility company EWSA.

Biomass and cooking energy

To support the Biomass Energy Strategy 2009, the embassy funded the reforestation and woody biomass production on public land through the PAREF project (EUR 10 million). PAREF is based on a Memorandum of Understanding between the Belgian Technical Cooperation and the Government of Rwanda (MINIRENA) (Ministry of Foreign Affairs, 2009). Funds from the African Great Lakes regional programme were used to support comparable activities for private land, implemented by the International Fertiliser Development Centre[25] (EUR 19 million for two countries). Through the Biomass component of AFREA, the non-governmental organisation Adenya was supported for activities concerning cooking energy (EUR 0.1 million); the Sustainable Energy Development Project also has components (improved cooking stoves, charcoal production) concerning cooking energy.

The Netherlands Development Organisation, SNV, assisted in the establishment of the Domestic Biogas Programme (EUR 2.2 million). The biogas component is described in chapter 4.

The total budget allocated to energy in Rwanda, funded by PREP and committed between 2008 and 2013 was EUR 106,358,000. Some programmes have continued activities beyond the cut-off date for the evaluation, which was 31 December 2013. The total disbursements made over the period 2008-2013 sum to EUR 85 million or 80% of the committed funds and 17% of the PREP resources. Table 4 provides an overview of the PREP-supported activities in renewable energy in Rwanda.

Table 4 Overview of Dutch-funded activities in renewable energy in Rwanda, 2008-2013

Intervention	Implementing Agency	Period	Expenditure in EUR
Direct funding Embassy of the Kingdom of the Netherlands - Rwanda			
Electricity Access Roll-out programme	Ministry of Infrastructure	2009-2013	29,937,329[a]
Reforestation	Belgian Technical Cooperation	2008-2013	9,856,242[b]
Subtotal			39,793,571

[25] The CATALIST and Sustainable Energy Production through Woodlots and Agroforestry (SEW) projects.

Intervention	Implementing Agency	Period	Expenditure in EUR
Direct funding by Embassy of the Netherlands for Regional Programme			
Reforestation (woody biomass)	International Fertiliser Development Centre	2009-2013	9,729,182
Reforestation (woody biomass)	International Fertiliser Development Centre	2009-2013	9,276,563
Interconnection Democratic Republic of Congo - Rwanda	Ministry of Infrastructure	2011-2013	14,991,511[c]
Subtotal			33,997,256
Central funding by the Ministry of Foreign Affairs			
Biogas, micro-hydroelectricity (Energising Development)	Gesellschaft für Internation-ale Zusammenarbeit	2009-2012	5,150,000[d]
Sustainable Energy Development Programme (Africa Renewable Energy Access Programme)	World Bank	2009-2013	3,149,578[e]
Lights for Life (Lighting Africa)	World Bank	2010	161,216
Great Lakes Energy (Lighting Africa)	World Bank	2010	160,839
Kitchen energy reliability 'cooker' (Biomass Energy Initiative for Africa)	World Bank, Association pour le Développement de Nyabimata with CARE International	2010	86,000
Hydropower at Rwanda Mountain Tea (Daey Ouwens Fund)	Netherlands Enterprise Agency, Rwanda Mountain Tea	2008-2013	2,247,000
Personal solar lighting (Daey Ouwens Fund)	Netherlands Enterprise Agency, ToughStuff International	2008-2013	340,280[f]
Subtotal			11,294,913
Total			**85,085,740**

a Prior to the Electricity Access Roll-out Programme, the Embassy of the Kingdom of the Netherlands contributed EUR 4.1 million to an emergency programme (2004-2008). In 2013 an additional budget of EUR 4 million was committed to EARP for 2014 implementation.

b In 2013 an additional budget of EUR 6 million was committed for 2014 for PAREF.

c The commitment was EUR 24,937,500, but only part of the programme was implemented.

d The budget committed was EUR 7,000,000, of which EUR 2,954,244 was spent on three commissioned micro-hydro plants, including capacity development at MININFRA. The expenditure on biogas was approxi-mately EUR 2.2 million.

e Source: ESMAP (http://www.esmap.org/sites/esmap.org/files/activities/P097818.pdf). Total budget committed including 2014 is EUR 3,800,000.

f The 50% advance disbursement of the committed subsidy of EUR 674,154 by the Daey Ouwens Fund.

Source: financial administration system Ministry of Foreign Affairs.

2.5 Findings

The energy sector has high priority in all policy documents published by the Government of Rwanda since 2000. GoR elaborated policies and strategies relate to different aspects of energy, among them renewable energy, biomass and electricity distribution, and also climate change and low carbon development. Rwanda has a high potential for clean energy generation, in addition to non-renewables (peat, methane).

In reaction to an emergency request from the Government of Rwanda in 2005, the Netherlands embassy provided support to the electricity utility company. In 2008 the embassy had no specific intention to support the energy sector, but the launch of the PREP coincided with the priority placed on energy in the new Economic Development and Poverty Reduction Strategy 2008-2012 and the World Bank's initiative to come to a sector-wide approach for the electricity subsector. The embassy indicated that 'drastic stop-and-go approaches will not be conducive to sustainable impact' (EKN 2009). Between 2008 and 2013, the Netherlands was the largest donor in terms of grants in the energy sector, with a portfolio of EUR 54 million for electricity and EUR 31 million for cooking fuel.

The Netherlands was the single development partner that administratively and financially aligned its support to Rwanda's electricity roll-out programme. Within the division of labour among the development partners, the Government of Rwanda requested the Netherlands to be present in the energy sector, and the Netherlands consented. As a result of the 2011 and 2013 changes in Dutch global policies on international cooperation, the energy sector was no longer eligible for funding. The Government of Rwanda viewed this retreat as undesirable and in breach of the principles of the Accra Action Plan, but expressed its understanding.

3

Energy for lighting and power: the electricity grid roll-out

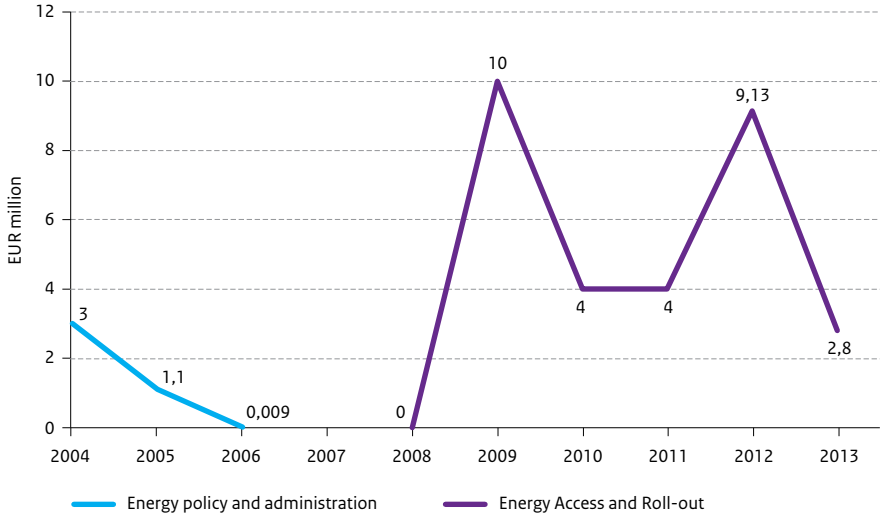
3.1 Introduction

This chapter deals with the electricity distribution, in particular the Electricity Roll-out Programme EARP. Electrification has three dimensions: generation, transmission and distribution of electricity. In Rwanda, the production, transmission, distribution and trading of electric power are governed by the Electricity Law of November 2008. The Law established two new entities: the Rwanda Electricity Corporation (RECO) and the Rwanda Water and Sanitation Corporation (RWASCO). In 2012 these two were merged into the Energy, Water and Sanitation Authority, EWSA. Late 2013 a process was started to split up EWSA again into an Energy component and a Water and Sanitation component. The Law set the framework for the liberalisation of the electricity sector and explicitly aims to promote private investments in the sector.

The Netherlands has supported all three dimensions of electrification, in which the generation of electricity was seen as an area in which the private sector could play an important role; for this reason, loans through FMO were considered as a logical modality, while transmission and distribution were seen as areas within the domain of the public or semi-public sector. Dutch development cooperation supported both the elaboration of the Energy Policy and the design of the electricity roll-out plan and played a pivotal role in getting development partners interested in a joint support programme.

Between 2004 and 2007 the Netherlands supported the then national electricity company Electrogaz. Since 2008 the Netherlands has been the largest provider of grant resources to EARP, using fully aligned pool funding as modality (see figure 5).

Figure 5 *Dutch financial contribution to electricity distribution in Rwanda*



Source: Ministry of Foreign Affairs of the Netherlands.

In July 2008 the Rwandan Ministers of Finance and Energy together with representatives of the then development partners to the energy sector (World Bank, African Development Bank, European Commission, United Nations Industrial Development Organisation, the governments of Belgium, Germany and the Netherlands) signed a Memorandum of Understanding. The World Bank and the Netherlands suggested the elaboration of an 'Investment Prospectus' (Castalia Strategic Advisers 2009) for the electrification programme, in order to attract additional external resources. The Dutch up-front payments enabled GoR to contract the Investment Prospectus[26] that provided the details on the geographical expansion of the grid, the selection criteria to be applied and investment estimate. For construction works and wiring USD 348 would be required and for technical assistance USD 28 million was needed to connect 260,000 new customers at an average cost of USD 1,185 per connection. The international donor community pledged USD 228 million. This support had reached approximately USD 338 million by 2013, with the Netherlands contributing EUR 30 million. In practice, not all pledges by the development partners led to timely disbursements, while simultaneously some development partners had suspended their general budget support. In order to address the expected financial shortfall, GoR opted to place a USD 400 Eurobond in the capital market. With the Citibank as the main lender, GoR got the credit against a 6% interest rate.

The Dutch up-front payment in the form of aligned pool funding had a catalytic effect, since it enabled the elaboration of the Investment Prospectus that pulled in other financiers to implement EARP.

3.2 Organisation and activities

During the period 2009 to 2013, EARP aimed at increasing the total number of electricity connections from around 100,000 to 360,000 households (in practice this number was exceeded), which corresponds to an electrification rate of 16% by 2013. In addition, all health stations and administrative offices as well as half of the schools in the country were intended to be electrified by late 2013. It was envisaged that 53% of health centres would have access to grid-supplied electricity, with the remainder being served by solar PV systems.

To avoid political influence when determining which communities would be connected, priorities and criteria were set beforehand. The strategy was 'low-hanging fruit' first: priority was given to areas close to medium voltage (MV) lines (so only low voltage lines had to be installed), particularly to existing *umudugudu* (grouped households living near facilities such as a market, schools, health centre or administrative entity). Another priority was connection of administrative offices, hospitals and health centres. Technical criteria encompassed distance from the grid, and norms and standards for reducing energy loss;

[26] In 2011, the Audit Department of the Netherlands Ministry of Foreign Affairs commented that the Embassy failed to reclaim the advance payment of USD 10 million that should have been spend by the Government of Rwanda within 6 months. It took MININFRA longer to spend, since time passed between the elaboration of the Investment Prospectus and the start of field activities.

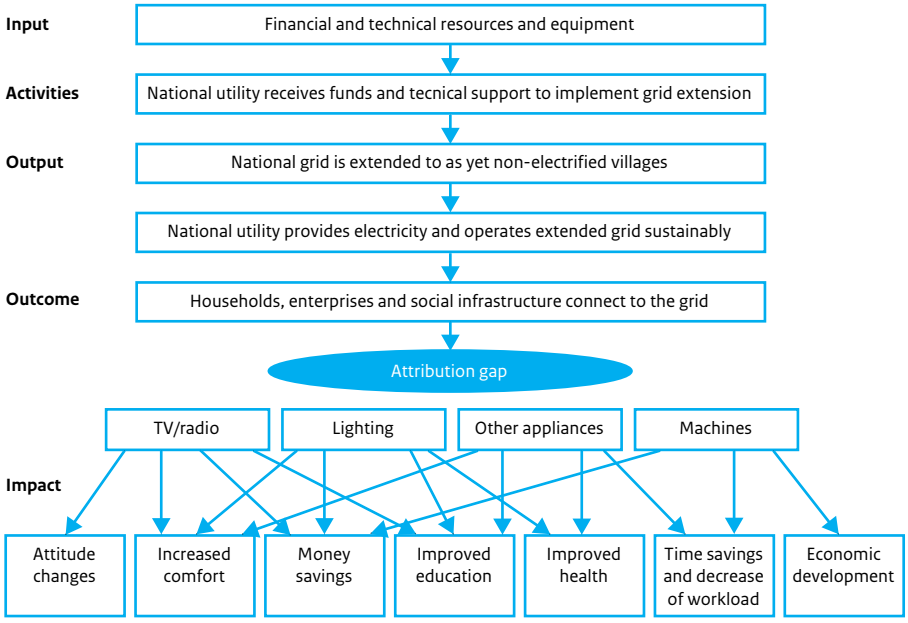
financial criteria encompassed assessments of whether customers could afford the connection tariff and maintain consumption of electricity (sites where 50% of the customers would be unable to buy electricity for less than RWF 1,000 monthly were considered unviable), while commercial criteria required that the site should have at least 50 potential customers. Low-income households could opt for ready-to-use switchboards to connect to grid-supplied electricity without the need for expensive house wiring. These households could pay the connection costs in instalments over a 12-month period. In addition, each newly connected household would receive three free energy-efficient bulbs that help reduce consumption.

EARP implements the programme in three ways (i) 'turnkey' contracting out of components, including the connection to the house; (ii) EWSA supplies building materials to contractors who do the construction works; and (iii) EWSA teams install the power lines and set up the connections). There are now approximately 100 local electricity installation firms in Rwanda.

3.3 Evaluation methodology

The rationale of electrification programmes is founded on the awareness that access to electricity is essential – but not enough – to achieve development. Figure 6 summarises the underlying theory of change and describes which outcomes and impacts are expected to result from the activities enabled by the input.

Figure 6 *Results chain for renewable energy*



The GoR and the development partners provide policies, strategies, financial resources and technical knowledge. EWSA uses these to implement electrification activities such as the extension of the transmission lines (MV) and distribution lines (LV and transformers) and the connection to the customers (meters, switchboards, in-house supplies). The outcome is households that are consuming the electricity for lighting, TV and radio and other appliances. Impacts occur when human behaviour is affected in terms of (i) income, expenditure and time management; (ii) welfare aspects such as health or comfort, which in turn may affect lifestyle aspects; and (iii) impact on the environment.

A quantitative household survey was central to the evaluation.[27] A so-called *non-randomised difference-in-differences approach* (Diff-in-Diff) was pursued (for methods, see Annex 5), involving both household and community level comparison before and after the electrification. Project communities are those EARP sites scheduled for electrification after the baseline in 2011 and prior to the follow-up survey in 2013. For the parallel trend assumption, control communities were carefully selected based on similarity criteria such as road access, community size, and income patterns. The impact of the electrification intervention can then be 'differenced out' based on the data from the two points in time and the two compared groups.

Based on socio-economic characteristics, 15 communities with electrification and 29 control communities were selected and analysed. The socio-economic characteristics of the sampled households measured during a baseline are shown in Annex 4.

Differentiation between community electrification and household electrification is necessary, since impacts of community electrification may spill over to non-connected households. For example, street lighting or lighting outside the house from neighbours or a shop may increase the perceived security level of neighbouring households without electricity. And non-connected neighbours will find TVs in the village, or may charge their phones at their neighbours' houses and benefit from newly established or improved enterprises. The disaggregation of communities and households reveals what could be expected: it is the better-off households that are connected to the grid; on average they are better educated and can afford to spend more. All households are relatively small and mainly headed by males. The predominant activity is farming.

3.4 Access

Households in rural environments may have different motives than those in urban environments for applying to be given electricity. Lighting is the rather obvious first one (and related to feeling secure), but the requirement for communication and entertainment is increasingly important. A third motive found in the literature is a collective (and less

[27] For details on methodology and sampling techniques applied, see Peters, Lenz, Munyehirwe & Sievert, 2014: http://www.iob-evaluatie.nl/content/impact-evaluation-electricity-access-roll-out-programme-rwanda.

individual) strive for 'modernity': a feature of increasing importance resulting from the intensifying contacts between rural and urban areas (transport, telecommunication and television) (IOB 2013, p. 63).

The access to energy is provided by both densification and extension of the distribution grid (photos 1 and 2).

Photo 1 *EARP grid extension*

Photo 2 *EARP grid densification*

Photos: RWI, 2013.

In principle, all households in newly electrified communities that are within a certain range of the LV line are eligible to be connected to the grid, but not for free. The connection fee is RWF 65,000, which is equivalent to EUR 80, of which at least RWF 15,000 has to be paid up-front. The remainder can be paid in instalments at a 10% interest rate. 85% of all newly connected households make use of this payment arrangement. Electricity use is pay-as-you-go: consumers buy vouchers for specified amounts at EWSA selling points. Any time a quantity of electricity is bought, the consumer automatically pays part of the connection fee as well. This means that a household cannot consume electricity if it does not repay the loan for the connection cost. According to EWSA branch managers, it usually takes a household about 12 months to repay the loan in full. This user-friendly and reliable payment scheme contributes to the fact that 60% of households living in newly electrified communities sampled for this study had been effectively connected and had started to use electricity. This contrasts sharply with the use of electricity from lower powered sources (solar home systems, pico-PV systems, car batteries) in control communities (6% of all households, with a 2% increase compared to the baseline survey of 2011 due to the penetration of pico-PV systems).

The 60% of households that effectively started to use electricity is not a very high figure. A World Bank study in various countries concludes that 'in communities with electricity, between 15 and 20% of the households remain without connection' because they cannot afford to be connected (IEG 2008, p. 23). The ability to pay for the new energy source and also the ownership of appliances that go with it are strongly related to income (Louw, Conradie, Howells & Dekenah 2008). However, in the case of Rwanda more factors are involved. The subsidised connection fees offered by EWSA applied only to households living a short distance from the LV line, while households living outside the 'reach' of that line

had to pay for the additional costs. The largest obstacle to being connected is the connection fee (78%). Next came the fear that expenditure on electricity would be high (mentioned by 38% of interviewees).

Field research suggests that in day-to-day practice, EWSA engineers do not apply the connection policy strictly. For example, households do not always have to pay the up-front connection fees at the moment of connection. There are various reasons for that. First, it is easier and cheaper for EWSA branches to connect entire groups of houses at the same time instead of connecting them one by one and having to return to connect a few households that pay late. Second, EWSA branches frequently contract out the connection work to private enterprises and these are paid according to the number of connections made. EWSA branch managers expect households to start using electricity and pay the connection fees later. The experience is mixed: in some branches in the Eastern Province only a fraction of the households managed to pay the connection fees and became electricity consumers, while in other branches between 50 and 90% ultimately became EWSA customers.

The survey data indicate that in 64% of the connected households, the decision to connect was made solely by the male head of household. Female household heads (mostly widows) or spouses took this decision in 16% of the cases. A joint decision made by the head of household and spouse together is less frequent (11%). In a few households the children, the owner of the house or community authorities were also consulted.

Since the EARP programme mainly focuses on rural areas, it is obvious that most beneficiaries are rural households. According to the survey data set, virtually all of them qualify as poor. Within the communities, the households that do connect are indeed the better-off, such as civil servants or shop keepers who do not depend fully on subsistence farming but have some cash income. This agrees with the findings from a systematic literature review (IOB 2013, p. 93). The differentiation also reveals that the payment capacity of a household influences not only whether the household effectively connects, but also its consumption of electricity. The worldwide phenomenon that electricity usage increases with income applies to poor communities too, as illustrated in table 5. In the table, the sample households have been divided into five groups of equal size, so-called quintiles, for which the average household expenditure has been computed. The first quintile represents the poorest 20%. Electricity consumption increases considerably with wealth (expressed in terms of expenditure). Connected households consume on average 11 kWh per month.[28]

Table 5 Electricity consumption among connected households, by expenditure group

		Expenditure Quintile				
		1st	2nd	3rd	4th	5th
kWh per month		3.7	6.0	9.2	13.9	19.0

Source: IOB. EARP follow-up dataset 2013.

[28] An average household in the Netherlands consumes 280 kWh/month.

Since procedures for implementation had been prepared beforehand, the number of new connections per year could increase rapidly: from about 23,000 in 2008 to 60,000 in 2013. The approximately 260,000 new connections envisaged in the EARP Prospectus were exceeded by 24,000. By September 2013 about 384,000 connections were realised (World Bank 2013). Transmission and distribution lines were constructed or rehabilitated, which resulted in an increase from nationwide 1,800 km in April 2009 to 3,450 km in September 2013 (World Bank 2013). By 2013, the number of rural households connected to the electricity grid had more than doubled. EARP aims at ultimately achieving an electrification rate of 35% by 2020.[29]

The objectives relating to social infrastructure have not been fully met. The target was that 50% of all educational centres would be supplied with electricity. According to World Bank data, by September 2013 37% had been connected (from 21% in 2009), but that does not mean that other schools are totally deprived from electricity, since simultaneously a nationwide EU-funded programme has been installing solar energy equipment in schools and health centres. 56% of health facilities and 58% of administrative offices, for which full electricity coverage had been envisaged, had been connected (compared with respectively 38% and 39% in 2009) (World Bank 2013). The IOB census among all health centres in Rwanda comes to a slightly higher share of electrification of health centres and a comparable percentage for schools. In addition, construction or rehabilitation achieved a 100% increase in transmission and distribution lines, thereby achieving the target.

3.5 Efficiency

The EARP Investment Prospectus (2009) estimated that on average USD 1,185 (or some EUR 900) would be required for each new connection. The World Bank calculated the real average cost per beneficiary over the period 2009-2013 to be USD 980 (including technical assistance costs). Over time, EARP managed to gradually reduce its costs per connection. The Investment Prospectus estimated that the customer would pay some 7.5% of the total investment or 10% of the hardware component. The connection fee of EUR 80 exceeds that share. Of the remainder, 80% would be paid by financiers and donors and 10% by EWSA though earnings from the sales of services. The EARP cost-per-beneficiary is comparable to other on-grid electrification programmes in Africa. The EARP brings in other efficiency gains as well: the transmission quality in the existing grid is improved and reduces technical losses; EARP promotes energy-saving appliances (bulbs, LED lights) and thereby contributes to more efficient energy consumption.

An alternative to grid electrification is off-grid power supply by mini-grids or domestic solar systems. While there are sound arguments for electricity supply through stand-alone mini-grids in many parts of Africa, this is less the case for Rwanda. An assessment of least cost electrification options conducted in 2009 (Castalia Strategic Advisers 2009) showed that

[29] Target varies by source. The Vision 2020 refers to 35%, p. 17; in 2013 EWSA referred to 60%.

for 95% of the 9,300 planning cells in which the country has been divided, grid-supplied electricity was the economically most advantageous option. For 4.5% of the planning cells, off-grid micro-hydro systems turned out to be the least cost option, while diesel generator mini-grids and domestic solar systems would be the least-cost option in only 1%. The reason why isolated mini-grids are hardly feasible is that it is not attractive to private parties to invest if the generated electricity that is surplus to requirements cannot be fed into the grid. In remote communities the consumption of electricity is too low to recoup the investment if the generated surplus cannot be sold.

There are good arguments for parallel development, however. First, the grid will take many years to be rolled out over the entire nation. Solar home systems may satisfy pre-electrification needs of households, while hydro mini-grids may satisfy needs in particular areas over a few decades. Second, in the first implementation stage EARP opted to 'pick the low-hanging fruit' in terms of geography and population. In the current stage (which started in 2013) EWSA will have to reach out to potential customers living further away at lower density and in geographically more difficult terrain. This increases the cost per connected household, making alternatives like solar home systems more competitive. Third, the average consumption of a rural household of 11 kWh per month (survey data) is very low. The revenues from sales of 11 kWh at 0.21 USD per month are insufficient to cover EWSA's operational costs. This consumption level could be satisfied with solar home systems. For the same cost of making one connection to the grid, four households could be supplied with a solar home system of 50W peak.

3.6 Effectiveness

Among the major motives of households in Sub-Saharan Africa to achieve access to electricity is the ability to use means of communication, such as television and internet (Chaury & Chandra Kandpal 2010; Olken 2009; Kemmler 2007). In Rwanda, both television transmission and the mobile phone network have almost national coverage. Although a mobile phone can be charged with a small manual dynamo or a pico-PV set, and black and white television sets can be powered by car batteries, electricity with sufficient power is preferred.

In rural Rwanda, however, households use electricity mainly for lighting, followed – a long way behind – by communication and information. As shown in table 6, the total number of lighting devices increased substantially after electrification. Connected households use 4.3 lighting devices, which is more than twice the number (1.9) of devices in non-connected households, and they consume on average 22 lighting hours more per day, which means exposure to lighting has multiplied, given that families in non-electrified villages use their lamps for 8 hours in total per day. Significant effects can also be observed on lighting quality as measured in terms of lumens, the measure of visible light emitted by a lighting source. Since electric lamps emit more light than non-electric devices, connected households consume over 50 times more lighting in terms of lumens.

Table 6 Effects on lighting usage					
	Household Diff-in-Diff	**significance**	**Community Diff-in-Diff**	**significance**	**Households in non-electrified villages** follow-up mean
Number of lighting devices	4.3	***	2.4	***	1.9
Daily lighting hours per lamp	0.7		-0.7		3.9
Sum of lighting hours per day	21.6	***	10.7	***	8.1
Lumen hours per day	28,300	***	16,600	***	526

*Note: *** indicates a significance at p < 1%.*
Source: EARP baseline and follow-up datasets 2011 and 2013.

The effects on lighting hours and number of lighting devices are greater than those found in other countries. Studies in Senegal (Bensch, Peters & Sievert, 2012) and Zambia (Gustavsson & Ellegård 2004, p. 1087) did not show a similar increase in lighting hours, but mainly an improvement in the light brightness: the lumen hours. The reason why the number of lighting hours hardly increased was that families had already extended their lighting hours by using battery-powered torches or other lighting devices. In Rwanda, the number of lighting devices in non-electrified villages is very low, so the effect of electricity in terms of lighting hours has been high.

At the baseline, 55% of families had at least one mobile phone. In the following two years, this increased substantially across all surveyed communities, to around 72%, especially in the connected households, which averaged 1.8 mobile phones per household. The increase in mobile phone ownership was seven percentage points higher among connected than among non-connected households. Households in communities with electricity have fewer radios than households in control communities (57% versus 71%). Connected and non-connected households in communities with electricity have similarly low numbers of radios. Although in connected households battery-powered radios have been abandoned and replaced by electric radios, the major shift is the replacement by TV sets.

Concerning the use of electricity in social services, in all health centres (full census) electricity was used primarily for lighting, followed by the use for medical equipment (79%) and for sterilisation and cooling (fridges for storing vaccines, 28%). To most health centres, electricity is not new: they are equipped either with small generators or have solar panels. For those centres that used generators, important effects are the cost reduction and the higher reliability of grid-supplied electricity. Electricity from the grid supplies more power and hence enables the use of equipment such as centrifuges. To 43% of the respondents the use of computers and printers is important for administration.

To educational centres, light is important as well, and 73% mentioned the benefits of electricity for running computers and printers. Only 20% referred to the active use of electronic equipment (mainly radio) for teaching; another 20% are simply relieved to be able to charge phones at school. The option of offering computer science classes is seen as a tool to train students to have an open mind, but in reality few schools are equipped to teach computer sciences.

3.7 Impact

Potential impacts were subdivided into: (i) economic impacts, such as household expenditure, time use and use of electricity for productive purposes; and (ii) impacts on convenience and welfare.

Economic impacts

If a household changes its source of energy, particularly when it climbs up the energy ladder from a lower energy source to a higher one, one could expect it to encounter higher costs. In Rwanda, however, overall expenditure on energy has hardly been affected. The increase in expenditure on electricity is largely compensated for by reductions in expenditure on the traditional energy sources, as shown in table 7.

Connected households spend on average RWF 1,500 per month (equivalent to EUR 1.80) on electricity. The total energy expenditures including traditional energy sources are substantially higher, amounting to RWF 5,600 among communities with electricity and RWF 5,500 among the control communities (equivalent to EUR 6.70).
To connected households the expenditure for kerosene, batteries and mobile phone charging have decreased significantly.

Table 7	Impact on expenditure of energy (monthly expenditure in RWF, by energy category)				
	Household with electricity	**significance**	**Average for community with electricity**	**significance**	**Households in non-electrified villages** follow-up mean
EWSA electricity	1,512	***	904	***	0
Batteries	-1,457	***	-1,045	***	1,331
Kerosene	-1,163	***	-1,068	**	899
Mobile phone charging	-718	***	-529	***	583
Candles	-148		-81		307
Decentralised electricity sources	-214		-371		59
Liquefied Petroleum Gas	-0.58		-0.38		36
Total	**6,957**		**5,656**		**5,535**
Share of energy in total expenditure (%)	**0.14**		**0.11**		**0.10**

Note: On-off connection costs for electricity are not included. Cooking fuels like firewood and charcoal are not shown in the table, but are included overall expenditure on energy.
*Note: *** indicates a significance at p < 1%; ** indicates significance at p < 5%.*
Source: EARP baseline and follow-up datasets 2011 and 2013.

The availability of electricity changes the daily routine of rural dwellers. All villagers in communities with electricity are awake between 14 and 40 minutes longer per day. The extension is more pronounced for connected households. This shows a spill-over to non-connected families. Among the arguments used for electrification is the claim that households use this additional time for productive activities or for study. These arguments are further explored in the paragraphs below.

The justification for proposed electrification programmes and projects is frequently their assumed positive impact on productive activities and hence on employment and income generation. The distinction between consumptive and productive use is far from clear-cut, however (Obeng & Evers 2010). In Rwanda, access to electricity unlocks low-key home business activities. Whereas only 5% of households in the control communities use an electrical appliance for productive purposes, the figure is 10% in electrified communities (16% among connected households). The average time spent on income-generating activities at home in houses with electricity is higher for both household heads and their spouses, but that has no effect on the total time worked, since the average time spent in the field decreases accordingly. The appliances used in home businesses are mostly electric communication and entertainment devices, half of which are mobile phones (making phone calls that are charged for). In addition, TV or DVD is watched in small cinemas, which

screen films and, more frequently, football matches. Only a few devices (sewing machines, mills) are used for manufacturing or services. Among the 974 households surveyed, only two had a grinding machine and one soldering equipment and an electric mortar.

Apart from these micro home businesses, the term 'productive use' also refers to activities such as pumping water for agricultural use or small-scale agro-processing (drying, curing, cooking). This differs from the use of electricity by small enterprises for productive purposes, such as manufacturing or providing communication services. A study in 10 African countries showed that immediately after electricity arrived in an area, the number of newly established enterprises increased. But various initiatives were discontinued soon afterwards, amongst others as a result of the 'myopia factor' (connecting to the electricity grid because it is there, without knowing what electricity is needed for in the production process). While production could expand with the availability of electric power, undefined and isolated markets frequently impede sales of the resulting products (Arnold, Matto & Narciso 2008). After the energy switch, these small firms run their business at higher costs without having improved either their productivity or their turnover (Peters, Vance & Harsdorff 2011). With higher costs and a constant return, these investors are known as 'energy losers'.

The survey revealed that in communities given access to electricity there was a modest increase in activities by micro-enterprises. Table 8 lists the common types of enterprises and shows to what extent they are present in electrified and non-electrified communities. The enterprises' main products and services are summarised.

Table 8	Rural enterprises and the effect of electricity					
	Percentage of communities with enterprises		Products and services offered	Observed effects on enterprises in villages with electricity		
	Without electricity	With electricity		Percentage of connected enterprises	Electric usage beyond lighting	Magnitude of effects
Small shops	90	100	Rice; oil; batteries; biscuits; soap.	45	Radio.	Greatly affected; increased convenience and opening hours.
Bars	79	100	Sodas; local beer; bottled beer; snacks.	57	Refrigera-tor; radio; TV.	Large variation among bars; increased opening hours.
Mills	54	64	Milling of maize, sorghum, manioc, cassava, others.	78	Electric motor for mill.	Greatly affected; cost reductions; higher speed and better quality of milling.
Hair-dressers	65	87	Haircuts; radio and TV; phone charging.	96	Electric clippers; radio; TV.	Greatly affected; cost reductions.
Tailors	83	71	Mending; dressmaking.	13	Electric sewing machine.	Not affected.
Carpen-ters	55	73	Gates; doors; beds; benches.	17	Wood cutting machine; sander.	Hardly affected.
Welding shop	0	47	Windows; gates; roofs; repair (e.g. of bikes).	100	Sander; soldering-iron.	Dependent on electricity.
Copy shops	0	26	Copying; printing; photography.	100	Printer; scanner; computer; camera.	Dependent on electricity.

Source: survey data, RWI and ISS.

In many cases the connection to the grid has increased the comfort and convenience of entrepreneurs but has not affected their productivity. Constraints such as lack of demand for the products or services, lack of capital, distance to the market or supply of raw material may be more important to the enterprise than energy. At community level, the connection of part of the business and manufacturing sector often results in a redistribution of income

rather than an increase in total community or regional income. Context is important: while some communities have a thriving centre, others have little or no business culture. The cases in boxes 2 and 3 are illustrative of contrasting experiences.

Box 2 *Portrait of a miller*

The miller Jean Bosco and his mill connected to an EWSA pay-as-you-go meter. Photo 3: RWI, 2013.

Jean Bosco lives in a community that was electrified a year ago. He was among the first to connect and immediately bought a dynamo for his grinding mill, which was previously run on diesel. A few other millers followed his example, so there are now seven electric mills in his community. Nevertheless, he has attracted a few more customers and is making more profit than before. He has been able to reduce the price for his services and thanks to two energy-saving bulbs that illuminate the shack where he operates his mill he has extended operating time by two hours per day. He wants to buy a more powerful electric engine, but lacks the necessary capital. He is very satisfied with the arrival of electricity and proud of his achievement. The higher profits from milling have allowed him to buy health insurance for his children and he has bought some land for his family.

Box 3 *Portrait of a carpenter*

Jean de Dieu's carpenter's shop. Photo 4: RWI, 2013.

Jean de Dieu started working as a carpenter 13 years ago. Two years ago his workshop was connected to the grid. The electric devices he uses are light bulbs and a radio. He bought an electric sander to increase his productivity and the quality of the carpentry products, in the expectation that that would attract more customers. The sander, however, was of bad quality and soon broke down. He cannot afford to buy new machinery and in the meantime many of his clients have left him in favour of competitors in town. The electric lighting has neither affected his regular working hours nor those of his four employees. He stresses that electricity has not changed anything for his business, or for the other two carpenters in his community.

Impacts on convenience and welfare

Access to electricity does not have economic impacts only, it may also affect welfare in terms of health, education and access to information. It may also have an impact on convenience, such as feelings of security and even may indirectly affect attitude and expectations in life.

The well-known impact of modern forms of energy on health is that cleaner devices replace polluting ones (firewood, kerosene). The main source of indoor air pollution is cooking with firewood, which, in turn, is typically not affected by an electrification intervention. Kerosene smoke is another danger to health. This evaluation did not medically test impacts on health, but interviewees reported that they believed that indoor air pollution had decreased. An indirect impact of electricity on health is that information on health reaches the household by radio and television, while mobile phones allow medical assistance to be called if and when required.

The impact of electricity on education is usually attributed to longer study hours of children, since electricity allows them to study at night. In Rwanda there are significant effects on school enrolment and attendance as well as on studying hours. Families with electricity are more inclined to send their children to school at primary school age. At the follow-up survey, 75% of households with electricity were sending all their children in the age bracket of 6 to 11 years to school, as compared to 61% in control communities. Twenty percent more families send all their children to school if they have access to electricity compared to households that are not connected. This could be because households with electricity pertain to 'the better off' in the rural society and these families would have sent their children to school anyhow. However, other possible explanations are that the availability of electricity attracts better qualified teachers (more appealing living conditions and teaching opportunities) and hence it makes more sense to send children to school (IOB 2013, p. 102). Others argue that exposure to television brings a change in norms and attitudes, with urban attitudes and lifestyle being copied, including sending young children to school (Jensen & Oster 2009).

The survey shows that the total time children devote to their homework or study does not change with the advent of electricity. Children in households with electricity shift their study time from daytime to evening time; this applies to both boys and girls.

Regarding access to information, the survey focused on the media used in the rural areas: mobile phones, radios and TV sets. In connected households not only did the number of mobile phones increase over time, but so did the intensity of their use. Households that use a mobile phone at least three times a day increased by 15% thanks to electrification. In non-electrified communities, only 6% of households have an electricity source that allows them to charge the phone at home. In connected households 72% use the phone for money transfers, which is significantly higher than in control communities (51%).

In rural areas, listening to the radio is highly valued. It is a link with the outside world. Even though TV has gained in importance in electrified communities, radio remains the dominant information source. In villages lacking electricity, 64% of surveyed households

report relying on the radio as main source of information, while in villages with electricity this is 1-3% less. The only significant difference is in watching television. People watch TV primarily in their own home. Few people watch TV in bars, or at the houses of neighbours or friends. The use of TV as source of information (among household heads) in communities with electricity is slightly higher than the TV ownership. Given that a relatively high proportion of Rwandan TV broadcasting is news, TV is actually used both for entertainment and to obtain information.

Only 24% of the connected households own a television set. This is very low compared to other countries in Africa. Almost half of the rural households in Kenya (Gustavsson & Ellegård 2004) and Zambia (Gustavsson 2007) own a television set.

Table 9 Impact on main information sources relied upon

	Household Diff-in-Diff	significance	Community Diff-in-Diff	significance	Households in non-electrified villages follow-up mean
Radio	-0.03		-0.01		0.64
TV	0.16	***	0.10	***	0.01
Neighbours and friends	0.00		-0.02		0.15
Community gatherings	0.03		0.06		0.35

*Note: multiple answers possible; *** indicates a significance level at p < 1%.*
Source: EARP baseline and follow-up datasets 2011 and 2013.

The literature about the impact of television and other media on social behaviour is vast. Well-known are studies from Brazil, Venezuela and Mexico about the impact of soap operas and the role models they portray on lifestyle, women's status and expectations in life (La Ferrara, Chong & Duryea 2008). Television exposes rural households to urban lifestyles, values and behaviours that are radically different from their own, and rural households begin to adopt or emulate some of these (Jensen & Oster 2009). The Independent Evaluation Group of the World Bank found a positive association between watching television and fertility in nine countries studied, largely attributed to better knowledge about contraceptives and health in general among the more literate women (IEG 2008). Jensen and Oster (2009) also highlight the impact of television in that respect. Using data from India they related the roll-out of cable TV to women's attitude and vision and found that women's acceptance of domestic violence decreased substantially and the preference for having sons instead of daughters declined. These findings inspired IOB to survey women seperately.

EARP has no particular gender policy. In general, given that Rwandan rural houses are small and have few rooms, all household members benefit more or less equally from electric lighting. An additional survey was conducted among 929 women to ascertain their perception of female roles and rights. The implicit assumption was that increased media exposure (mainly radio and television) would contribute to a more urban lifestyle. It was assessed whether women would be given more freedom outside the house in the sense that their husbands would allow them to work outside the house. No significant changes can be reported over the short period between the surveys. Not only the short period is of influence, but also the fact that alternative employment opportunities in rural areas are scarce and that woman seek to generate income at home. The survey did find a modest shift in working time from agricultural to non-agricultural income-generating activities.

No significant effect was found on the women's opinion about the age a woman should marry or have her first baby. What did change was the acceptance of domestic violence against women. In connected households, violence against women was significantly less accepted. It should be noted however, that women's acceptance of violence in connected households was already less prior to electrification: a possible explanation is that these households are more modern in their thinking. Nevertheless, women were asked whether they thought it is justifiable for a husband to beat a woman in certain circumstances (neglecting the children, leaving home without informing the husband and arguing with the husband). As many as 40% of interviewed women in the control communities think it is justifiable to beat a wife when the children are neglected.

Table 10 Impact on perception of domestic violence against women, in %

Woman thinks it is justified that husband beats a woman if...	Household Diff-in-Diff	significance	Community Diff-in-Diff	significance	Households in non-electrified villages follow-up mean
... she neglects her children	-10		-13	**	40
... she leaves home without telling him	-6		-12	**	31
... she argues with the husband	-7		-10	***	22
... the food is burnt	-1		-5		15

*Note: *** indicates a significance at p < 1%; ** indicates significance at p < 5%.*
Source: EARP baseline and follow-up datasets 2011 and 2013.

In the literature there are also reports of negative impacts of watching television, such as reduced social integrity (Köhlin, Sills, Pattanayak & Wiflong 2011), but the survey did not reveal explicit signs of such negative impacts.

In sum, the access to electricity has had little impact on the household expenditure on energy. Since more light is available and the use of light is longer, there are changes in the daily routine of rural families. The connection to the grid has had no observable effects on feelings of safety or on health, but parents of connected households send their children to school more frequently. Enhanced access to information (radio, TV) seems to have had an impact on attitude (less acceptance of domestic violence, for instance). Electrified communities show a slight increase in activities of micro-enterprises. Enterprises most positively affected by electrification are mills and hairdressers, while enterprises dependent on electricity are copy shops and welding workshops.

3.8 Sustainability

When the electricity service is offered, many households grasp the opportunity and apply for connection even if they are not sure whether they can afford the service over time. During the first year, the household discovers what it can do with grid-supplied electricity and whether it can afford it. The pay-as-you-go metering system as used by EWSA makes it easier for customers to control their spending. The system keeps track of usage and allows accounts to be recharged with small amounts. When a person recharges, the system automatically takes part of the payment to repay the loan for the connection fee. The system is designed to restrict to the bare minimum the number of forced or voluntary dropouts. According to the survey results, there is another factor that discourages voluntary dropout: the connection to the grid had no significant impact on the household's total energy expenditure and hence there is little to be gained from returning to the traditional sources of energy for lighting.

Of all connected households, 80% report being satisfied with their electricity connection and are able to use electricity at any time every day. Respondents accept the level of outages, if these do occur. Of all connected households, 93% had experienced outages during the previous month. Voltage fluctuations seem to be a larger problem and in 62% of the households some appliances had broken down as a result (mainly light bulbs, but also phone chargers and radios).

With the rapid expansion of the grid and the swift increase in number of small customers, it becomes questionable whether EWSA will be able to sustain the system financially and to maintain it physically. EWSA branch managers stressed that their human and technical resources had increased in response to the increase in maintenance requirements. At the time of the follow-up survey, 90% of households indicated they would inform EWSA if problems occurred, but only 47% knew how to reach them. Of all connected households, 23% reported having experienced technical problems, mostly in the form of short-circuits that burnt cables, or problems with the meter. In 58% of these cases EWSA was called to fix the problem; in other cases, independent electricians solved the problems.

Both the short- and long-term reliability of the electricity grid depend on two factors: (i) sufficient electricity generation to meet rising demand, and (ii) the transmission and

distribution system. Although EARP has succeeded in achieving its targets, there are quality issues, such as fluctuations in the supply of electricity.[30] Concerning the demand, most new clients exhibit low electricity consumption profiles, but between 2009 and 2012 the customer base trebled. At the national level, demand for electricity is expected to come from a rapidly developing industrial and commercial sector that is growing at an annual rate of 14%. A huge investment programme is in place to expand the generation capacity. The crucial factor to MININFRA will be how much subvention EWSA will require over the years to come, in particular since the electricity demand from most new domestic customers is not enough to cover the operational costs of EWSA.[31] The low consumption customers will have to be cross-subsidised by the sales of electricity to the rapidly developing industrial and commercial sector that is growing at an annual rate of 14%. By mid-2013, RURA proposed to 'differentiate' consumers on the basis of their electricity consumption. For the very small consumers the first 10 kWh would be free, while the connection fee would be included in the service charge of RWF 500. According to MININFRA management, this investment in development pays back in the medium term.

3.9 Findings

Rwanda is striving for national coverage of its electricity grid. During the process of roll-out, parallel systems such as mini solar systems and micro-hydro systems may respond to the demand for electricity needs in those areas not yet covered by the grid. The Dutch up-front payment for fully aligned sector support to the roll-out programme had a catalytic effect, since it enabled the Government of Rwanda to attract more grant and loan capital for EARP. The concept of an Investment Prospectus is now a best practice in rural electrification programmes of the World Bank and has been incorporated in the country programming of the SE4All initiative.

During the period 2008-2013, EWSA exceeded the targets set for the implementation of the EARP. In rural communities with access to the grid, approximately 60% of all households were connected. Schools and health centres were given access to electricity, although the targets set were not entirely met. Most of the beneficiary households can be characterised as poor, although within their context they pertain to the 'better off'. The EWSA system allows customers to consume small quantities of electricity and to repay the loan for the connection fee simultaneously. Once connected to the grid, households not only replace their lighting source, they also use much more light. They own four times more lamps, use light five times more frequently and have 50 times more light in terms of lumens. TV partly replaces the radio as a means of information.

[30] Japanese (JICA) experts monitoring the voltage supply in the urban electricity system registered frequency fluctuations (150-190V instead of 220-230V) in 2012 and 2013.

[31] Source: interviews EWSA, MININFRA and World Bank, June 2013.

Households do not spend more on electricity than they did on traditional sources of energy. In terms of productive use of electricity, enterprises that benefit most are those that are dependent on electricity, such as mills or copy shops. Enhanced access to information (radio, TV) seems to have an impact on attitude, for example on gender relations (less acceptance of domestic violence).

In health and educational centres electricity is mostly used for lighting, but also for running computers and printers. Since electricity is not new to many health centres, the connection to the grid implies a cost reduction and the option to use more power-consuming equipment. In educational centres, electricity is hardly used for education. Parents of connected households tend to be more likely to send their children to school.

The rapidly increasing number of customers in an expanding grid requires a generation capacity that keeps up with the demand, organisational management, maintenance and financial sustainability. Crucial will be the financial sustainability. Although the EARP cost-per-beneficiary is in line with experiences in other African countries, the electricity consumption of new customers is low and the proceeds from sales of electricity do not fully cover the operational costs of EWSA. The largest bottleneck for the sustainability of the network is the connection fee, which is too high for the strata with the lowest purchasing power.

4

Energy for cooking and lighting: biogas

4.1 Introduction

This chapter presents the findings of the impact evaluation of Rwanda's National Domestic Biogas Programme (NDBP) (Bedi, Pellegrini & Tasciotti 2013).[32] It describes the underlying arguments for biogas as energy source, the policies of the Government of Rwanda and the Netherlands regarding biogas. Moreover, it discusses the constraints experienced in the uptake of biogas by the target group and it analyses the impact of using biogas at household level.

The MININFRA Biomass Energy Strategy (BEST) (see section 2.3) stated that the use of firewood could be reduced by a 'large-scale dissemination of efficient stoves and improved charcoal-making techniques' as well as by replacing firewood by alternatives such as biogas, carbonised peat and papyrus, liquefied petroleum gas (LPG), and solar energy.

In 2001, the Kigali Institute of Science, Technology and Management (KIST) piloted biogas in the Cyangugu Central Prison. Later some schools and hospitals were also supplied with biogas installations at the initiative (and cost) of the state. While the technology was known in Rwanda, there was little experience with its use at domestic level. In 2004, the Rwandan Minister for Energy and Communications while visiting the Netherlands, expressed interest in developing a domestic biogas sector. Given its experience, the Dutch development organisation SNV was requested to conduct a feasibility study (Dekelver, Ruzigana & Lam 2005). Next to the study, SNV developed a pilot for domestic biogas installations in 2005. MININFRA, SNV and GIZ agreed to establish a National Domestic Biogas Programme (NDBP) aimed at 'developing a commercially viable and environmentally sustainable market-oriented Rwandan biogas sector […]' (Dekelver 2008). The objectives were to: i) install a total of 15,000 family-sized, quality biogas plants within the country by the year 2011; ii) ensure operation of all installed biogas plants; and iii) maximise benefits from the operated plants, in particular the use of digester effluent (Ndayambaje & Mohren 2011). In 2007, GoR started to promote biogas digesters in boarding schools, health centres and institutions with canteens. Private companies started manufacturing domestic digesters in 2008. In Rwanda, the primary input to a domestic biodigester is animal manure; toilets are usually not connected. The waste product, slurry, can be used as fertiliser.

The political commitment to biogas is high and the NDBP is directly linked to the 'zero grazing' policy (result of the high population density and pressure on arable land) that forces owners of cattle to keep the animals in sheds and feed them there. The policy is applied strictly and enforced. Another strategy, the 'one cow, one family programme' forms part of the poverty alleviation strategy and has been in operation since 2006. The programme has had a clear effect on the number of families owning cows.[33] One cow is

[32] See: report available at http://www.iob-evaluatie.nl/en/node/763.

[33] MINECONFIN launched the 'one cow, one family' policy (2002) targeting 257,000 poor households and aimed at: i) supporting crop production by the use of manure as fertilizer; ii) helping reduce soil erosion; and iii) reducing malnutrition through milk consumption.

insufficient for a digester, however (at least two cows are required), but related families share a single cowshed.

Dutch support to the biogas sector in Rwanda

In 2006 the Ministry of Foreign Affairs had increased its budget allocations to the energy sector and had delegated most support in the energy sector worldwide to GIZ. The joint programme was the Energising Development (EnDev) programme. EnDev support augmented a Government budget allocation of USD 14.1 million, enabling NDBP to start up in 2007 (Landi, Sovacool & Eidsness 2013). SNV provided advisory services. The initial target was to construct 15,000 family-sized biogas plants by 2011.[34] However, by the end of 2011, the NDBP had installed 1,846 units only. The low uptake in combination with high costs made EnDev and the Netherlands Ministry of Foreign Affairs to withdrew their support. The GoR decided to continue the programme with its own resources and with technical assistance from SNV.

Table 11 shows the disbursements to the NDBP over the period 2008-2011. MININFRA only spent a fraction of the initial budget allocation (EUR 0.4 million), while the Netherlands' contribution (EnDev) over the period was approximately EUR 1.3 million (out of an allocated EUR 2.2 million); according to SNV its estimated contribution was over EUR 1.0 million (mainly manpower). Excluding the SNV contribution, over the first years of the programme the gross cost per biogas digester was close to EUR 900.

Table 11 Contributions to National Domestic Biogas Programme (in EUR thousand)

	2008	2009	2010	2011	Total
Government of Rwanda	37	20	161	159	377
Energising Development	195	118	805	138	1,256
Total	**232**	**138**	**966**	**297**	**1,633**

Source: NDBP 2012. Data exclude contributions in kind, financial contributions from clients and SNV's technical assistance.

In addition to the Dutch support, NDBP also receives support from the MasterCard Foundation for youth employment opportunities through enterprise development. The NDBP gave impetus to the development of a larger biogas programme in Africa, the African Biogas Partnership Programme (ABPP 2008, see box 4).

[34] The GoR increased the target to 100,000 by 2017 as stated in the draft Energy Policy 2012-2017.

Box 4 *African Biogas Partnership Programme (ABPP)*

In December 2008 DGIS, SNV and HIVOS launched the ABPP, aimed at supporting the biogas technology in African countries over a period of 5 years, funded by PREP. ABPP started in Ethiopia, Kenya, Uganda, Burkina Faso and Senegal (the programme in Senegal was discontinued in 2012) and is being implemented with HIVOS as fund and programme manager, and SNV as provider of know-how and capacity-building services. ABPP's target is to have constructed 70,000 domestic biogas plants for about half a million persons by the end of 2014. On average, ABPP provides a subsidy of 30% of the construction cost as an incentive to households to procure a biogas plant. By late 2013, only just over half of that number had been realised (38,000). The stakeholders involved decided to extend the programme to 2017 with EUR 20 million for constructing an additional 100,000 digesters by that year. (Source: SNV ABPP).

4.2 Organisation and activities

Initially, MININFRA managed the NDBP, but in 2011 the management was delegated to the Energy Water and Sanitation Authority (EWSA). Almost simultaneously, a National Domestic Biogas Steering Committee was established as supervising entity, integrated by representatives from the Ministry of Agriculture, the Ministry of Local Government, the Private Sector Federation[35], women's associations and the Banque Populaire du Rwanda. MININFRA defines the policies, coordinates the various public entities and provides budget. There is an EWSA District Office in each district in Rwanda and per two District Offices there is one staff member (technician) responsible for NDBP.

NDBP applies a multi-stakeholder approach that brings together partners from the private sector and public entities. This also encompasses credit institutions, institutes for training, research and development (such as the Centre for Innovations and Technology Transfer – CITT, and the Tumba Technical College – TCT), NGOs and community-based organisations. NDBP receives advisory services from SNV including: i) support in establishing digester construction companies, to encourage private sector development; ii) technical support (by providing quality control and engaging in research and development aspects); iii) promotion, marketing and networking to foster market linkages between NDBP, companies and farmers; and iv) access to finance (by helping to establish a subsidy scheme and a biogas credit scheme through the *Banque Populaire du Rwanda* [BPR]).

[35] The Private Sector Federation of Rwanda is an umbrella organisation of several private sector associations. The associations involved in the NDBP are farmers' associations and women's associations.

Implementation

The core approach is 'development through the market' and to achieve this, private actors (construction companies and financing entities) provide services under a regulatory framework set by the public sector.

NDBP promotes biogas and use of bio-slurry in pre-selected geographical areas. Interested households should have at least a bank account, a terrain suitable for the construction, enough water and a minimum of 2-3 cows, depending on the size of the digester (2 cows for a 4m^3 biogas digester). Two to three cows corresponds to a minimum of 40 kg dung per day, which can produce sufficient biogas for 3 hours of cooking or 9 hours of light daily.

If NDBP has assessed the application positively, trained construction companies build the digester. The company also provides user training, quality control and after-sales services. NDBP delays the final payment to the contractor for up to 12 months until the digester is working well and the user knows how to use and maintain it. To the buyer this is equivalent to having a one-year warranty. The client buys the digester and thus owns it.

4.3 Evaluation methodology

The impact study[36] comprised a survey comparing households owning a digester with others who do not, but have applied to acquire one. The evaluation did not involve technical measurements (for example of gas production). To control for factors that might have a confounding effect on the outcomes of interest, linear multiple regression analysis was conducted on the survey data. To relax the assumption of a linear relationship between the intervention and outcomes, propensity score matching (PSM) was applied; this entails matching each owner of a biogas digester with an applicant with similar socio-economic characteristics (see Annex 5). This was done to reduce observable heterogeneity between owners and control group. The survey among 600 households in 20 villages was conducted in June-July 2012. Table 12 presents the number of households with a completed digester plant, the distribution of digesters among provinces and the sampled households.

[36] The impact study was funded jointly by IOB and SNV.

Table 12 Distribution of households with a digester and control households, per province				
Province	**Number of households with digester**	**Distribution of digesters over provinces**	**Sample of households with biogas (number)**	**Sample of control households (number)**
Eastern province	604	35.1	112	103
Kigali city	166	9.6	25	27
Northern province	478	27.7	85	82
Southern province	279	16.2	50	48
Western province	195	11.3	33	35
Total	**1722**	**100.0**	**305**	**295**

Source: IOB database. Data as at December 2011.

4.4 Access

Livestock, especially cattle, are an important part of Rwandan farming systems. A government aim is for each farming family to have at least one cow. Since free grazing is prohibited, the cattle must be fed with fodder grown on the small plots. Over 80% of the farmers cultivate plots of less than 2 hectares (Musahara 2006) and less than 15% of all farmers have two cows or more, which is the minimum requirement to feed a biodigester. Although cattle are kept in sheds, these are not always next to the house: they may be next to the field, which makes it easier to feed the animals with fodder and crop residues and to use their manure as fertiliser.

The initial target of 15,000 digesters had to be adjusted downwards via 5,000 (2009) to 3,000 (2010). In general, the uptake of 60-70 new digesters monthly remained below expectations (see table 13).

Table 13 Projected and installed biogas plants								
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**total**
Preparation phase	150							
Implementation phase planned		1,150	2,300	4,200	7,200			**15,000**
Implementation phase realised	101	120	213	627	785	773	898	**3,517**

Note: Data for installed biogas plants from https://sites.google.com/site/biogas4all/overview/biogas-africa-overview. The plants also include 77 glass-fibre digesters donated by the Chinese Government.
Source: SNV.

The single most important explanation for the low uptake is the cash outlay required to buy a biogas digester. Other reasons mentioned by the interviewees are the perceived trebling of the workload (taking manure from the shed to the house, fetching water to feed the

digester and transporting the slurry from the house back to the field) as compared to buying or collecting firewood. As a result of the government's settlement policy, in some cases the fields and cowsheds are at some distance from the houses. In hilly Rwanda, carrying manure, water and slurry up and down is heavy physical work. A third reason mentioned is that the installation is a fixed asset that cannot be moved or sold.

In 2013 the selling price of a 6m^3 digester was RWF 800,000, or roughly twice the price in real terms calculated in the SNV feasibility study (Dekelver, Ruzigana & Lam 2005).[37] After deducting the subsidy of RWF 300,000, customers have to pay between RWF 350,000 (4m^3) and RWF 800,000 (10m^3). About RWF 140,000 can be saved if customers contribute their own construction material. Even then the smallest digester requires a cash outlay of 1.4 times the annual per capita expenditure of a rural household.[38] On top of this, the gas stove and new pans have to be bought. Rather late in the process, NDBP started to offer credits through the Banque Populaire du Rwanda[39] for a maximum of RWF 300,000 for 3 years at 13% interest (four percent less than the market rate) with a monthly repayment of RWF 11,000.

Most of the households with a digester that were surveyed stated that they first heard about biogas digesters from NDBP representatives or field workers (slightly more than 50%); the other first sources of information were local authorities (20%), friends and relatives (11%) and neighbours (10%). Armed with this information on the digesters, households then had to make two decisions: first, whether to purchase a digester, and second, what size to purchase. In 45% of the cases, the first decision was made jointly by the household head and spouse. In only 1.3% of cases was the female spouse solely responsible for the decision. The second decision was usually made together with the NDBP technician.

Of all the surveyed households with a digester, 62% relied on their own financial means and did not enter into any credit facility to purchase the digester. An additional 6% raised the necessary cash by selling an asset, 12% used a combination of their own savings and credit, while only 14% relied exclusively on credit.[40]

37 SNV calculated the price at RWF 260,000 in 2005. The accumulated price index inflation over the period 2005-2013 is 76%.

38 The per capita annual consumption (adult equivalent) in rural areas is valued at RWF 247,240 (including the valorised subsistence production and consumption of food and other products). A 4m^3 digester costs 1.4 times this amount (RWF 350,000). National Institute of Statistics (2012).

39 In 2007 it was envisaged that the Banque Populaire du Rwanda and the Netherlands Entrepreneurial Bank FMO would enter into a EUR 4 million liquidity assistance arrangement to enable BPR to issue 3-year micro-credits to households to enable them to buy a biogas digester. However, since the uptake of digesters remained low, BPR had sufficient liquidity.

40 In interviews in June 2013, BPR argued that the low loan uptake was due to the long payback time required. But local government officials argued that BPR was too selective in accepting loan applications. Whatever the reason, the financing of bio-digesters is low compared to other countries, for example Bangladesh (80% of customers buy the digesters on credit).

4.5 Efficiency

From a PREP management perspective, it has been efficient to temporarily fund the biogas activities in Rwanda, since with a relatively modest investment the national biogas programme could be established.

A different question is whether it is efficient or cost-effective for a household to use biogas for cooking. Various aspects play a role here. First, the right size of the digester (and hence the investment) has to be determined. This is done by NDBP, based on the supply of dung (i.e. the number of cows). Factors taken into account are the volume of manure available to be fed into the digester (hence that is not used for other purposes or that can be carried daily if the cattle and the house are some distance apart); the envisaged use of the gas by the household (only for cooking or also for lighting); and the household composition. Initially, NDBP offered two size options: 10m^3 and 6m^3. In 2010 an EnDev internal monitoring mission observed that the price of a digester was a constraint and that a smaller size could open up the market for a larger number of potential customers. In 2011, the mission reported that "Rwanda has the highest costs for digesters in Africa. Reducing costs, and affordability, of digesters is therefore key in developing the market. The recommendation from the previous mission to include 4m^3 digesters in the programme portfolio, reducing costs from RWF 800,000 to 650,000 as compared to a standard 6m^3, was actively followed up" (Raats & Andreas 2011).

The smaller 4m^3 digester, developed with support from SNV and the Tumba College of Technology, was between 27% and 36% cheaper. To reduce cost, the construction of this digester is different: it requires more bricks and less cement.[41] It requires to be fed with 30 kg cow dung and 30 litres of water daily. The Kigali Institute of Science, Technology and Management observed, however, that this small digester produces insufficient power to enable an average family to cook three meals daily.[42] About 60% (i.e. 189) of those households with a digester surveyed by IOB had opted for a 6m^3 digester; a further 18% (56) had opted for the 4m^3 digester. The payback period for a 6m^3 model, without discounting future benefits, is about 5.4 years with the subsidy of RWF 300,000 and 8.7 years without the subsidy (table 14).

[41] Local sand is not always suitable as masonry sand and therefore it cannot be assumed that it can be provided by the beneficiary rather than bought. According to KIST, fibre glass digesters are not an option in Rwanda, since there is no local manufacturer and due to their volume the transport costs are too high. Source: KIST interview, June 2013.

[42] Based on three meals per day, 0.6m^3 per person per day would be required, assuming the digester is properly fed and the correct temperature is maintained (Kossman, Habermehl, Hoerz & Kraemer 1999).

Table 14 Payback analysis for a 6m³ digester (for 189 functioning digesters only)				
	Cost (in RWF)		Payback Period (years)	
	With subsidy	Without subsidy	With subsidy	Without subsidy
With discounting future benefits	800,000	500,000	6.8	12.7
Without discounting future benefits	800,000	500,000	5.4	8.7

Note: The benefit of operating a digester, which is the reduction in annual expenditure on energy, is equivalent to RWF 91,633, excluding maintenance costs. Discount rate set at 6%.

Source: Biodigester Rwanda dataset 2012.

Since a farmer does not know in advance whether it will be profitable to invest in a digester and because the repayment period is long, buying a digester entails financial risk and has opportunity costs. Only if a long-term perspective is taken, the decision to change to biogas is rewarding for a rural household in Rwanda. In the assumption that a lower price to the customer would lead to a higher uptake, NDBP has varied (downsized) the scale of the digester, but did not experiment with the subsidy level.

4.6 Effectiveness

The two major issues related to effectiveness are: (i) whether a market has been established for biogas, as was the intention of the NDBP and the support provided by EnDev and SNV; and (ii) whether the biogas digesters are actually used by households who own them.

Market development

The training activities took place in all 30 districts and were directed to construction companies and individual bricklayers. At the end of the EnDev support in 2011, 300 bricklayers had received training. In June 2012, 42 out of 94 companies were active (not all bricklayers considered building digesters a profitable option). About 20 companies accounted for 80% of the digesters while two of these companies had constructed well over half of all digesters. The most important reason for the low involvement of companies is the low uptake of digesters, i.e. not enough guaranteed work for all trained companies and bricklayers. An SNV case study (Binamungu & Owekisa 2011) provides insight into success and failure factors of these companies, such as commitment, access to working capital, geographical focus, relationship with local authorities, and regular payment of personnel.

Although private companies construct the digester once the application has been approved by NDBP, it cannot be said that a free (commercial) market has been established, because every digester depends on NDBP's approval and supervision.

Use of biogas digester

Of the 305 households in the survey that had owned a digester for at least six months, 274 were actually using biogas. In 31 (i.e. 10%) of the digester-owning households the digesters were not producing. In 9 cases the construction had not finished or there was no gas stove; in 7 cases the digester or stove or pipe was damaged; in 3 cases there was not enough cow dung to feed the digester and in one case the household was altering their kitchen set-up. In the remaining 11 cases no reason was given. This situation is particularly harmful for households with a completed but not properly working digester, who had either repaid their loans or still had to do so and were meanwhile continuing to buy or collect firewood. This is an unexpected finding, since NDBP offers a one year warranty that includes three visits from the construction company to check the digester is functioning properly.

Two-thirds (64%) of the 274 owners that actually use the digester were satisfied with the volume of biogas produced, but that implies that one-third were not fully satisfied. Over half of the households (55%) mentioned issues other than gas supply as being the reason for their dissatisfaction, such as the lack of a second stove, the poor quality of the biogas stoves due to corrosion and leaky pipes, and the poor quality of the biogas lamps.[43]

Two-thirds (67%) of households use biogas for both cooking and lighting, the remaining third do so for cooking only. In two-thirds of households (64%) the volume of gas supplied matches expectations and needs. In qualitative interviews, owners of 4m^3 digesters mentioned that insufficient biogas was produced for the two-hour cooking time needed to cook beans – a staple of the Rwanda diet. The volume of gas available depends on various variables[44], such as the quantity and quality of the dung collected, the initial feeding (for about three months) and the subsequent daily feeding. In the daily feeding, the minimal amount of cow manure in combination with water/urine depends on the size of the digester and varies from 30 kg to 90 kg of dung and the same amount of water. According to the survey, 21.5% of the 305 owners had insufficient cows to feed the digesters properly. In absence of proper feeding, the plant will not produce sufficient biogas and the owner is likely to be disappointed with its performance (ECOregon 2009).[45]

The main motive for purchasing a digester is the envisaged reduction in firewood consumption (76.1%) and a reduction in energy-related expenditure (84.9% of the 305 surveyed households). A small proportion of households mention a smokeless kitchen (3.3%) or faster cooking (3.4%). There is an enormous difference between the expected

43 Initially, lighting was not a target for NDBP. Due to high priority given by households to lighting and because a 4m^3 digester does not produce sufficient gas for both cooking and lighting, NDBP promotes the use of photo-voltaic lighting systems.

44 By June 2013, NDBP indicated to IOB that it questioned the findings of the survey, since NDBP installs a digester only after ensuring that sufficient manure is available to feed it. In the survey, however, over 20% of the owners of digesters that had been in use for more than 6 months reported that this was not their experience.

45 IOB did not determine the quantitative relation between feeding and gas production. Underfeeding results in a reduction of microbial population and hence also of methane production.

(ex ante) benefits and the benefits experienced (ex post): once the digester is in use, the major benefits experienced are a smokeless kitchen and faster cooking (table 15).

Table 15 Main advantages ex ante and ex post of having a digester, in %		
	Ex ante	Ex post
Number of observations	305	274
Reduction in firewood collection	76	90
Reduction in energy-related expenditure	85	89
Smokeless kitchen	3	80
Faster cooking	4	18

** Multiple answers were possible.*
Source: Biodigester Rwanda dataset 2012.

The dominant stove for cooking all meals used by digester owners is the biogas stove followed by improved stoves (ICS). The biogas stove is the main stove used to prepare breakfast in 80% of the biogas households; whereas it is the main stove used to prepare lunch and dinner in only 50% of the households. The declining use of the biogas stove over the course of a day may be attributed to digester feeding patterns (mainly in the evening) and the time gap available for gas production between dinner and breakfast. Hence, the biogas stove is not a complete substitute, since other stoves (mainly the metal charcoal stove) continue to be used.

Biogas is used for lighting in 67% of the 274 households. While the average electrification rate in rural Rwanda is approximately 10%, it is noticeable that about half of all owners of biogas digesters have access to electricity and only about 15% use traditional lighting sources. On average, the biogas lamp is used for 1.6 hours a day, and since owners tend to use lighting for about 5 hours a day as opposed to 3 hours in the control group, it can be concluded that the biogas lamp is used additional to the existing lighting sources and not to replace them.

4.7 Impact

Impact on household economy

The use of a biogas digester leads to a statistically significant and substantial reduction in annual *expenditure on energy* of about 30-32%. The main saving is, as expected, in the expenditure on firewood (RWF 39,800): see table 16. The use of a digester is associated with a 4.7 kg reduction in the daily consumption of firewood; that consumption is 35% less than in the control group. There is some evidence for a reduction in the use of charcoal: the effect is not statistically significant for daily consumption, but it is for the yearly expenditure. The charcoal burner continues to be used in addition to the biogas stove, but

less charcoal is purchased. The indications of the volume of firewood saved are consistent with findings of other studies (Arthur, Baidoo & Antwi 2011) (Msandete & Parawira 2009).

Table 16 Impact of digesters on consumption and expenditure on energy		
Variable **Digester owner**	**Propensity score matching N = 595 (standard errors in parentheses)**	**significance**
Yearly expenditure on energy (in RWF)	57,800 (22,800)	***
Yearly expenditure on firewood (in RWF)	-39,800 (20,600)	*
Daily consumption of firewood (in kg)	-4.7 (1.3)	***
Yearly expenditure on charcoal (in RWF)	-19,500 (6,000)	**
Daily consumption of charcoal (in kg)	-0.3 (0.4)	

*Note: *, ** and *** indicate significance levels at p < 10%, 5% and 1%, respectively.*
Source: Biodigester Rwanda dataset 2012.

Changes in *time use patterns*, such as in collecting firewood (a chore done mainly by children) and cooking (a chore done by women) are less among digester owners[46], but are statistically different for cooking only. Women who have access to digesters spend about 31-37 minutes less per day on cooking (18% reduction) compared to the control households. The time saved for cooking is balanced out by the additional time required to feed the digester and in some cases to carry the manure and slurry between the house and the field.

While the use of a biogas lamp increases the hours of lighting for digester owners, there is no evidence that this translates into changes in study hours or reading time.

Due to the limited number of digesters installed, in only three cases was it reported that *new economic activities* had been established. These were micro enterprises dealing with the transportation and sales of bio-slurry. In eight villages (the ones with the highest concentration of digesters), additional jobs had been created in constructing and repairing digesters. On the flip-side, in two villages there seem to be signs of reduced business for firewood vendors. In any case, the impact on economic activities is limited.

An important by-product of biogas is the slurry that can be applied as fertiliser. Studies conducted by the Higher Institute for Agriculture and Animal Husbandry (2013) and Fashoho, Habimana & Karemangingo (2013) show that the quality of bio-slurry in Rwanda varies enormously among farmers and depends on whether the manure is mixed with urine or with water. Bio-slurry applied on maize and potatoes boosts yield, because of its high nitrogen content. Chemical fertiliser is hardly used in Rwanda and owners of digesters and applicants both tend to rely on cow manure. There is no evidence that the use of bio-slurry leads to higher yields than those obtained after the direct application of manure to crops.

[46] The evaluation did not consider the effects on time related to slurry application in agriculture.

Owners of digesters use slurry almost exclusively on their own plots. There is no statistically discernible difference in terms of household expenditure on fertilisers.

Impact on household welfare

In Rwanda, toilets are not connected to the digesters, so there is no direct health effect as a result of sanitation. Since the use of biogas leads to a less smoky cooking environment, a reduction of eye and respiratory diseases was expected. The cleaner kitchen may also reduce the danger of food and water contaminants. 84% of women without digesters reported that their kitchens were always smoky, while this was the case for only 56% for owners of biogas digesters. The entire 28% difference can be attributed to owning a digester. Among the owners, 80% identified a smokeless kitchen (inside the house) as the major unexpected benefit of using biogas.

The perceived health effects are modest: a 2 percentage point reduction in self-reported eye diseases for women older than 18 years but otherwise no statistically significant effects. Within the short time frame covered by the evaluation, no links were discernible between digester access and other health conditions, such as respiratory diseases, headaches, diarrhoea, the incidence of malaria and intestinal worms. Access to biogas may also lead to better hygiene: indeed, digester-owning households are about 8 percentage points more likely to boil water prior to drinking it. Digester owners are about twice as likely as the control group to heat water for cleaning milk cans and for bathing.

The impact of biodigesters on health in Rwanda seems to be less prominent than that found in studies conducted in Asian countries (e.g. Nepal). In Rwanda, the toilets are not connected to the digester, while in Asia it is precisely that aspect that leads to improved sanitation, as it safely disposes of human excreta. In Nepal 85.5% of households reported an improvement in health after the installation of the biodigester (Katuwal & Bohara 2009).

Impact on the environment

The use of a digester is associated with a 35% reduction in consumption of firewood. The consumption of charcoal does not change significantly with the use of biogas, as summarised in table 17. The total number of digesters in operation in 2013 would then save about 64 tonnes of fuelwood annually or 58 tonnes CO_2[47], which is a negligible impact on the environment.

[47] The carbon content of firewood varies between 47 and 53%. One ton of carbon produces 3.66 tonnes CO_2, so one tonne of firewood produces 1.83 tonnes of CO_2.

Table 17 Average household consumption of biomass fuel per day, in kg			
	Owners of biogas (standard deviation in parentheses)	Control group (applicants) (standard deviation in parentheses)	significance
Firewood	9.8 (18.2)	14.9 (10.4)	***
Charcoal	0.9 (4.7)	1.1 (3.4)	
Crop residues, sawdust	0.1 (0.7)	0.0 (0.0)	*

*Note: * and *** indicate significance levels at p < 10% and 1%, respectively.*
Source: Biodigester Rwanda dataset 2012.

4.8 Sustainability

The biogas installation is made from bricks and cement and should last for several decades. Its durability depends on maintenance of piping, stove and the proper feeding. The feeding process is not always optimal, particularly when the digester, the cowshed, the water source and the field used for cultivation are far apart from each other.

Without firm ongoing government support in terms of institutions and subsidy, the market for biogas digesters will struggle even more, since the modest demand from rural families has not established an attractive market for suppliers (companies and bricklayers) and maintenance services. Increasing interest from some foreign private investors (Simgas, Q-Energy and Biogas International) in the Rwanda biogas market may result in some competition, expressed by falling prices, better credit facilities and hence greater uptake of biogas digesters.

4.9 Findings

The Government of Rwanda is strongly committed to diversifying the energy sources for cooking. In 2004, the support of SNV was called in, contributing to the establishment of the National Domestic Biogas Programme. This support was later financially underpinned by allocations from the Energising Development programme. The support to the biogas programme complied with the fourth objective of PREP, being the 'development of capacity and knowledge with regard to renewable energy' and to the first objective of providing access to renewable energy.

Since the biogas programme was among the first of this nature in Africa, SNV used its experience gained in Asian countries to establish the programme. In hindsight, that experience led to far from realistic expectations for the uptake in Rwanda. The biogas programme was slow to start, and various constraints still prevail: only 15% of the rural households own two or more cows, which reduces the potential market; digesters are expensive and credit facilities are inadequate. So-called soft factors are also influential, such

as the distance between the house and the cowshed and the reluctance of households to invest in a non-tradable fixed asset.

Whether the use of biogas slurry as compared to direct application of manure leads to higher crop yields in Rwanda is not known. The programme reaches people in the middle and higher income brackets in the rural areas. As a consequence of the slow uptake, the bricklayers trained in digester construction had no guaranteed work implying that no proper market has been established. The impact of biogas use on the environment in terms of reduced CO_2 emission is very small.

5

Energy for lighting: pico-PV systems

This chapter presents the evaluation (Grimm, Peters & Sievert 2013)[48] of a small-scale intervention in the area of energy for lighting. The Daey Ouwens Fund, which received funds from the Promoting Renewable Energy Programme, provides subsidies to initiatives of small and medium enterprises intended to provide access to renewable energy in developing countries. One of the subsidies awarded was to the company ToughStuff, for marketing small photovoltaic systems.

5.1 Introduction

An 'electricity ladder' similar to the energy ladder described in chapter 1 can be used as a conceptual framework. On the bottom rung are standard dry-cell batteries used for radios and torches. Next come car batteries used to run a small black and white TV set or to charge mobile phones. These are followed by small solar equipment, either for one device (like a solar lamp) or for more devices (solar home system). Then come generators or local mini-grids at household level, after which community level supply (generators, micro-hydro) follows. At the top of the ladder is connection to the electricity grid (Van der Vleuten, Stam & Van der Plas 2007). In recent years, a significant transformation has occurred in the market for electricity sources: the costs of solar systems and light-emitting diodes (LED) have diminished considerably, making new lighting devices accessible to low-income households.

Photovoltaic (PV) technology is among the first renewable energy technologies available to rural areas not connected to the grid. PV technology has been introduced in developing countries via a strong donor-pushed strategy in terms of Research & Development support, fiscal and financial incentives and marketing (Chaury & Chandra Kandpal 2010). The funding organisations (governments and international donors), NGO sector, microfinance institutions, local energy enterprises and private sector have all contributed towards innovations, both in technical aspects and financing mechanisms for dissemination of PV systems.

The usual pico-PV system is equipped with a 1-5 Watt solar panel that powers LED lamps; more advanced systems can be used to charge mobile phones and radios as well. A pico-PV system is substantially smaller than a solar home system, which usually has one or more panels of 10-250 Watt. Since in markets with low purchasing power clients opt for the lowest price, the quality of the devices may disappoint consumers and that may hold back acquisition of renewable energy products. The international development community has responded to that hazard by promoting pico-PV systems that meet sufficient quality standards. The production and marketing of robust and low-priced solar lamps designed for developing countries has become a specific niche in the energy product market. These lamps are mostly produced outside the consumer markets, with the advantage of economies of scale, but the disadvantage of lack of country-specific adaptation. A

[48] See full report at http://www.iob-evaluatie.nl/en/node/762.

prominent example is the Lighting Africa programme supported by the Netherlands[49], which is jointly managed by the World Bank and the International Finance Corporation (IFC) and envisages building up sustainable pico-PV markets and disseminating pico-PV kits to 250 million households in Africa by 2030. Lighting Africa has established quality standards for portable solar lighting products in Africa in collaboration with governments and private companies such as Philips.

A portable solar lamp provides cheaper, cleaner and brighter lighting than traditional sources of light. This may translate into a change of activity patterns after nightfall, such as users staying awake longer, or becoming involved in social or productive activities during the evening hours. The lamp may have a beneficial effect on the user's health because it replaces kerosene wicks or candles and thus the emission of harmful soot and particulate matter is reduced (IOB 2013, p. 89). In addition, the solar kit is used to charge radios and mobile phones. Radio use enhances access to information, which may lead to changes in people's behaviour. And there is an environmental impact: kerosene combustion emits black carbon, which warms the atmosphere by absorbing heat. The reduction of black carbon emissions has been identified as a quick remedial action against climate change (Shindell 2012).

Up to 2013 there was debate about whether pico-PV systems should be considered as forms of modern energy, since in the global endeavour to achieve universal access to electricity by 2030 the role of pico-PV remained rather undefined. However, in 2013, the Sustainable Energy for All Global Tracking Framework acknowledged the technology as a 'transitional alternative to grid-based electricity' that offers a potential long-term solution for remote areas and as such is recognised as a tier 1 energy service (see table 1).

The Government of Rwanda pursues an 'electrification for all' policy basically aiming at tiers 4 and 5. Although a focus of the National Energy Policy and Strategy is the supply of electricity to remote rural areas, no particular role is envisaged for solar lamps.[50] These devices are available to consumers through the usual retail channels and, like other solar products, have been exempted from import tax since 2011. In 2012, the Ministry of Health launched the 'bye-bye kerosene' campaign to phase out kerosene lamps; solar lamps were presented as one of the alternatives. The Netherlands supported the dissemination of pico-PV systems in Rwanda along two lines: Lighting Africa, which is supported through AFREA[51], and the Daey Ouwens Fund.

[49] The Promoting Renewable Energy Programme supports Lighting Africa through AFREA.

[50] Neither the *National Energy Policy and National Energy Strategy 2008-2012* (2009) nor the *Electricity Development Strategy* (2008) refer to solar lamps as an electricity option.

[51] The third support was to Philips through a public-private partnership, the Sustainable Energy Solutions for Africa (SESA), initially envisaged for 11 countries. The programme was implemented in Ghana, Kenya, Tanzania and Mali, but support in Rwanda was for two specific events only.

5.2 Organisation and activities

The Daey Ouwens Fund

In 2006, while the proposed 2007 budget for the Ministry of Foreign Affairs was being debated in the House of Representatives in the Netherlands, Members of Parliament Samson and Ferrier tabled an amendment[52] aimed at allocating budget for the promotion of small-scale projects in the area of sustainable and job-creating energy supply in developing countries. As a result, the Ministry of Foreign Affairs established the Daey Ouwens Fund[53] in 2008. At the time, access to renewable energy in rural areas did not receive the national and international attention it currently enjoys. The market was small and immature and there was limited knowledge about market opportunities and appropriate business models for developing countries. The DOF subsidises small and medium-sized enterprises and also NGOs to a maximum of 50% for eligible proposals ('let a thousand flowers bloom') related to electricity supply or to bio-fuels. The simultaneously launched Sustainable Biomass Fund (DBM) (APE Onderzoek en Advies 2013) focuses on bio-fuel initiatives.

The Ministry of Foreign Affairs wanted DOF to be a flexible 'low-threshold' instrument that would appeal to smaller companies, encouraging them to present proposals for innovative approaches based on proven technologies. The Ministry of Foreign Affairs assigned the management and execution of both DOF and the DBM to the Netherlands Enterprise Agency RVO.nl, of the Dutch Ministry of Economic Affairs. Management was deliberately kept light in order to avoid burdening the proposing enterprises with red tape and to keep down the transaction costs. The Ministry of Foreign Affairs informed RVO.nl to focus on the legitimacy of the proposals, not on their subject matter. The total subsidy budgeted for between 2008 and 2014 amounted to EUR 22,475,000; by late 2013 70% (EUR 15,658,140) had actually been committed. Between 2009 and 2011, a total of 119 proposals had been appraised, of which 31 projects actually received an advance on the subsidy: 13 of these projects concerned solar energy.[54] The provisionally approved proposals for subsidy were submitted to the embassies for comments or objections. One of the 13 solar projects proposed was to be implemented in Rwanda: ToughStuff, for which a subsidy of EUR 674,154 was approved, of which EUR 340,280 was actually disbursed. The mother company, ToughStuff International, received a subsidy for EUR 576,790 for a comparable project in Madagascar.[55]

52 Amendment TK 30 800 No. 43, 31 October 2006.

53 Prof. Kees Daey Ouwens († 2007) was the promulgator of the green economy vision in the Netherlands.

54 The other projects are in biomass, Jatropha bio-fuel and hydropower.

55 The Netherlands' FMO Access to Energy Fund allocated EUR 2.4 million to ToughStuff International (of which EUR 1 million was actually disbursed) and the company received a subsidy from the Norwegian Investment Fund for Development Countries. These moneys were acknowledged as counterpart contribution for receiving the DOF subsidy. It is not known whether these funds were actually used for the pico-PV in Rwanda.

The Ministry defined three quantified outcome targets at programme level for the envisaged end-date of December 2014:

- 425,000 people given access to renewable energy;
- An additional 5.7 MW of capacity of renewable energy installed; and
- An additional of 8,500 new jobs created.

The mid-term review concluded that the effectiveness had been modest as compared to the project plans, but satisfactory as compared to the outcome targets mentioned above (see table 18).

Table 18 Effectiveness of DOF projects (based on 23 completed projects in 2013)

Objectives	DOF target	Achieved at completion	% of DOF targets	Target as per project plans	% of targets compared to project plans
Number of persons with access to energy through social infrastructure / productive use	No target	1.152	NA	10,089	11
Number of persons with access to energy in households	425,000	2,069,041	487	2,480,079	83
Amount of installed capacity (MW)	5.7	2.1	38	12	18
Energy generated annually (kWh)	8,200,000	23,217,580	283	66,488,375	35
Number of jobs generated (full- and part-time)	8,500	4,141	49	11,589	36
Kton CO_2 avoided, assuming conversion factor 2.67	22	62	276	178	34

Source: Budding & Duursema 2014, p. 46.

ToughStuff

In Rwanda, LED lamps are sold in markets and in small retail shops. The proportion sold of these 'Chinese lamps', as they are known by customers, is still lower than in countries such as Senegal and Burkina Faso (Bedi, Pellegrini, Peters, Sievert & Taciotti 2012). The subsidy DOF provisionally allocated to ToughStuff was intended to help ToughStuff start and expand a sustainable marketing approach for its pico-PV kit in Rwanda. In June 2008, ToughStuff International (based in England and Mauritius) was founded as a social enterprise providing affordable solar-powered products to low-income people. ToughStuff started trading in Madagascar in July 2009 and moved into Kenya in July 2010. In addition to the DOF subsidy, ToughStuff also received significant subsidies from the United States' Marshall Fund.

The company marketed a Lighting Africa certified pico-PV kit comprising a small 1W panel (in late 2012 replaced by a 1.5W panel), a 40 lumen lamp, a mobile phone charger and a radio charger[56] (see photo 5). After one day of solar charging the lamp provides lighting for 6 to 30 hours, depending on the chosen intensity. The entire package cost around EUR 23[57], the smallest version with only the solar panel and a LED lamp was sold at around EUR 12.

Photo 5 *ToughStuff pico-PV kit*

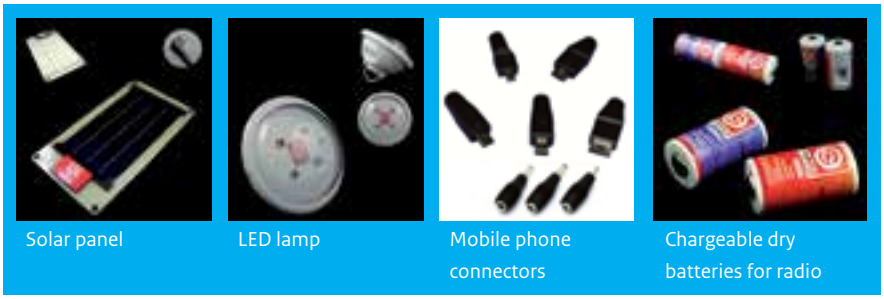


Photo: ToughStuff online (2012).

To start activities in Rwanda, ToughStuff needed EUR 1,340,000. The activities started early 2011. The approach was to sell PV kits through a grassroots distribution system, with coordinators in every district of the country and numerous sales agents who promote and sell the product through direct contact in small gatherings (an approach modelled on that used by the US company Tupperware). The intention was to recruit and train 1,046 agents, all female, who would demonstrate and sell the products to their peer group (family, friends, clubs, churches). ToughStuff planned to sell 166,200 solar kits in two years and to cover all districts of the country.

By 2012, only about 60 agents had been recruited, of whom only a few were female. The target group was not reached, since the informal contacts of the sales agents were largely restricted to family members and church communities. In absence of an accompanying credit facility, interested persons could not afford the lamp. The disappointing sales figures made ToughStuff change its strategy and to focus on organised groups through the Rwanda Cooperative Agency (RCA) that unites 4,700 cooperatives throughout the country. Cooperatives and associations with at least 50 members became the new target group, so that sales in bulk would allow the lamp to be offered at a discount. The cooperative could issue a credit arrangement to its members.[58] Late 2012, RVO.nl and ToughStuff were of the opinion that the new strategy, combined with technical improvements and more attention to after-sales services would satisfy 'the tendency of the population to opt for higher-end

[56] In January 2013, the chargeable radio batteries were taken off the market.

[57] Although at the higher end of the range, the selling price is comparable to that of competing products, such as the Sunking products sold by Great Lakes Energy.

[58] The strategy was inspired by the one applied by Philips Lighting through the National Teachers' Savings and Credit Cooperative (SACCO) (Kesreliglu 2012). Interview ToughStuff Rwanda, May 2013.

quality products'.[59] Cooperatives, however, were not eager to provide credit, the after-sales services were never implemented, and after a short period of recovery the parent company applied for liquidation mid-2013. The liquidation encompassed both ToughStuff Madagascar and ToughStuff Rwanda.

5.3 Evaluation methodology

The evaluation comprised a survey among actual users, an analysis based on open-ended interviews with the target group and ToughStuff staff and policy makers, and interviews with competing pico-PV marketing companies. The experimental part of the study encompassed a randomised controlled trial (RCT). To implement the RCT, four regions were chosen: two in the Southern Province, one in the Western Province and one in the Northern Province.[60] In 15 sites in each of these regions, 20 households were selected using simple random sampling (approximately every 5th household was included) giving a total of 300 households. After a baseline survey in late 2011, 150 ToughStuff pico-PV kits were randomly distributed among these 300 households. The pico-PV system was presented to participants not as a gift, but as compensation for participating in the survey (the other households received a different reward of comparable value). The 300 households were revisited in June 2012. In addition, 66 households that bought a ToughStuff pico-PV kit (real users) during the same period were interviewed (Grimm, Peters & Sievert 2013).

5.4 Access

In 2011, pico-PV systems were systematically sold in Kigali through only two social enterprises. In 2013, sales took place through bigger retail shops, while three enterprises had a distribution strategy to outreach to rural areas: Great Lakes Energy, Solar Sisters and Barefoot Power. These three sell products certificated by Lighting Africa. Other players, such as Philips, are either not permanently active in Rwanda or donate pico-PV systems.[61] As a new company, ToughStuff had to position itself within this market.

Of the envisaged sales of 166,200 solar kits, over the first year the number sold was only 1,400 devices (June 2012). After the change in marketing strategy, the sales increased to about 1,500 kits per month during the first months of 2013. Up to the moment of breach of the company, its total sales in Rwanda were approximately 8,000 kits.

59 Meeting DME and RVO.nl. November 2012.

60 The eastern region was deliberately left out, since the solar radiation level is the highest in that part of the country, and also the purchasing power of the population is higher and for that reason both private companies and societal organisations are active in the sales and dissemination of solar equipment.

61 Nuru Energy provides another LED-based lighting, rechargeable through a pedal generator. Philips donated 300 panels with a LED reading lamp in 2010, when Rwanda hosted the United Nations World Environment Day. See: http://www.newscenter.philips.com/main/standard/news/press/2010/20100605_rwanda.wpd.

In the RCT, the socio-economic characteristics of households in the group that received a lamp and its control group are, by design, the same. Over 90% of the household heads are subsistence farmers of on average 47 years old, who grow crops and own only a few cows and goats as livestock. The households use artificial light for an average of 3.1-3.2 hours per day, for which they use half a litre of kerosene monthly. Of all households, 36% used homemade LED torches (see box 5), while only 4% used shop-bought portable LED lanterns. The households own on average 0.48 mobile phones.

The socio-economic characteristics of the 66 households that actually purchased ToughStuff kits differ from those described above: the actual buyers are on average younger, have a higher level of education and only 53% are subsistence farmers. The remainder are government employees (mostly teachers) or self-employed (mostly shopkeepers and traders). Some real users have another source of electricity at home, such as a connection to the grid or a solar home system.

Box 5 *Homemade LED lamps in Rwanda*

Photo: Maximiliane Sievert.

In recent years, the use of homemade LED lamps has increased substantially in Sub-Saharan Africa. These lamps are mostly used as portable ones, but can also be installed as permanent fixtures on walls or roofs. They are assembled from a few LEDs, some cables and a set of batteries. Schoolchildren experiment with the LEDs and bring the know-how to their homes.

Most radios are powered by larger dry-cell batteries. When the battery becomes too weak to operate a radio, it still has sufficient energy to light LEDs. A homemade lamp has on average 3-4 batteries to power 3 LEDs. On average, 40% are used radio batteries and 60% are new. If too many new batteries are used, the LEDs break due to voltage overload. On average these devices emit 10 lumen only, slightly less than a candle. In the survey households, the use of homemade LED lamps in the control group increased from 34% to 46% within six months.

5.5 Efficiency

The efficiency of the marketing approach

The envisaged marketing strategy was supposed to rely on women's networks; ToughStuff intended to create employment for women and also primarily targeted women in rural areas. This approach was low-cost, but after one year was found to be not effective. First, only few women could be recruited and second, the social networks (for example, in church communities) lacked potential clients with purchasing power. A modification in the marketing strategy was necessary: ToughStuff started to focus on individuals within groups

with more purchasing power, such as teacher unions and tea companies. In a subsequent change, the social network marketing approach was abandoned, and – with endorsement by DOF – a shift was made to direct sales to institutions and cooperatives. If organisations were interested, they could buy the lamps in bulk at a lower price for their employees or members. The organisations would pre-finance the kit and subsequently deduct instalments from their employees' salary or members' payments.

The DOF subsidy is intended to support an enterprise in its initial effort to enter a new market. In this case, both ToughStuff and DOF miscalculated the cost-benefit relation. The selling price of the solar kit was expected to cover all costs, so the company could sustain itself after the initial take-off. By mid-2013 however, the company's costs could be covered only if the price per kit averaged EUR 31 instead of EUR 23, assuming the envisaged sales of 166,200 kits. But that was optimistic: sales were low and costs could not be covered (Grimm, Peters & Sievert 2013, p. 50).

The efficiency of solar lamps

The roll-out of the electricity grid implies costs of USD 700-1,000 per household, while pico-PV systems cost between USD 15 and 75. Although this might be a false comparison due to the different characteristics of the electricity supply, high-quality pico-PV products do satisfy the electricity needs of most rural households and are less expensive. LED technology has achieved a place in many rural households, and the households' willingness to pay is relatively high (see box 6).

Box 6 *Willingness to pay*

Since households selected for the RCT did not have alternatives to electricity, it was expected that a pico-PV kit for lighting would be appreciated, but that financial needs might tempt them to sell it. Households signed a pledge not to sell the kit, and every two months the field team checked that the kit had not been traded. Only 19 out of the 150 households had sold the kit at the moment of the follow-up survey. After a year, respondents were asked to imagine that they would have to hand in the PV-kit and to say how much they would be willing to pay in order to keep it. These households were not aware of the selling price. On average, heads of households were willing to pay RWF 15,300, i.e. RWF 3,000 less than the actual selling price. Although 38% of the respondents were willing to pay more, 12% were unwilling to pay anything. Willingness to pay does not imply that the respondents could indeed afford the device, since RWF 15,000 constitutes approximately half of the average total monthly expenditure of the households surveyed.

The cash outlay is a burden to the rural customer and the purchase is efficient only if the household can save sufficiently on traditional fuels for lighting. But expenditure on energy needs in the lowest income quintile in society is very small: a maximum of RWF 770 on lighting, RWF 150 on mobile phone charging and RWF 210 on batteries for the radio. Together this is EUR 1.50 monthly. In consequence, the repayment period is over a year for

the ToughStuff kit of EUR 23 (much longer than the two months envisaged by ToughStuff in 2011).

In Rwanda there is no strategic pathway incorporating pico solar energy in the broader effort towards electrification of the country, for example in a pre-electrification programme. ToughStuff's chosen marketing strategy did not produce sufficient results to sustain the operations.

5.6 Effectiveness

In rural areas the demand for electricity is for lighting, radio and mobile phone charging. Although the ToughStuff kit had been designed for these functions and its quality had been tested by Lighting Africa, it had technical deficiencies: the solar intensity in Rwanda is less than that in the test environment (Kenya) and the capacity of the 1W panel was too low to power all devices used by the household.

Of the 150 households that obtained the kit through the RCT, after one year 131 still had the kit: 86% of them used it at least once per day, 85% used it for lighting, 68% for listening to the radio and only 10% for charging mobile phones. The 66 households that bought the kit used it less frequently than households given the kit in the RCT (table 19).

Table 19 Usage of ToughStuff pico-PV kits

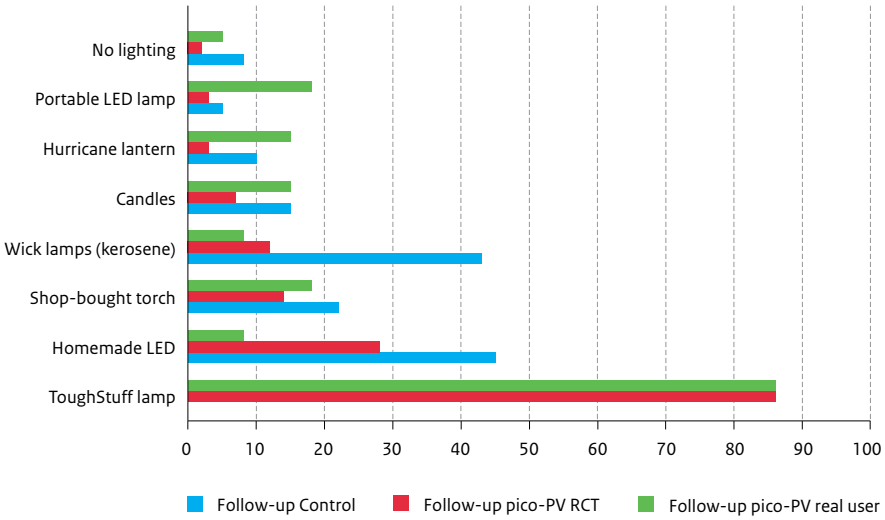
Percentage of households that...	Real user	Trial user
	N = 66	N = 150
...bought the entire kit	82	
...bought the lamp	99	
...use the kit at least once a day	70	86
...use the kit for lighting	85	85
...use the kit for listening to the radio	39	68
...use the kit for charging mobile phones	12	10
...use the battery pack	35	62

Source: survey data, RWI and ISS.

The lighting function was effective. Traditional lighting sources are wick lamps, candles, hurricane lanterns, homemade LED lamps, and shop-bought torches. Among the buyers, the solar lamp was never the sole lighting source, but to 47% of the households who obtained the solar lamp in the RCT, it was the single source of lighting. Households with a pico-PV system used on average 0.8 traditional lamp (of any type), while the control group used 1.43 traditional lamps per household. Thus the solar lamps replaced half of the traditional lighting sources, and the traditional lamps still in use were being used at the

same intensity as before the acquisition of the solar lamp. Households replace a particular source (kerosene wick, candle) rather than reducing the time all lighting sources operate (see figure 7). This observation supports the 'energy ladder' theory mentioned in chapter 1.

Figure 7 *Usage of lighting sources, as percentage of three groups of households*



Note: Three households used rechargeable lamps or gas lamps. These are not included in the figure.

Both real users and RCT users operated the lamp for around 2.8 hours per day. The solar lamps were mainly used by women (for cooking and general domestic chores, 30% of all activities) and by men for general activities inside the house (31% of all activities). Teenagers used the lamp more frequently than younger children (table 20).

Table 20 Main users of the ToughStuff lamp and their activities

ToughStuff lamp is mainly used by..	%	Main activities (all users)	%
Woman >17 years old	37	General (inside the house)	28
Man >17 years old	31	Used for cooking	25
Collectively used by whole family	10	Used for studying	20
Teenage male (12-17 years old)	9	Used while eating	12
Teenage female (12-17 years old)	8	Used while doing domestic chores	5
Children between 6 and 11 years old	5		

Source: survey data, RWI and ISS.

The women that used the lamp while cooking are mainly those who did not previously use light: 52% of the women in the control group did not use any lighting device while cooking, compared with only 22% in the group of pico-PV users. And the lamp used by women in the control group was mostly a kerosene lamp (27%), which had been largely replaced by the solar lamp in households with a solar lamp (6%).

The kit's drawback for charging mobile phones is striking: it does not have a connector that is compatible with Motorola phones, one of the most used and popular brands in Rwanda. News of this shortcoming spread quickly, and households did not want to risk damaging their phone so decided not to use the kit for charging. There is no doubt that this technical imperfection is reflected in the answers to the survey questions.

In the baseline situation, 52% of the households owned a radio. Thus for the households in the RCT, the free radio distributed with the pico-PV kit became an additional radio. Radios are mostly used to listen to informative programmes. By far the most popular programmes among adults are news, followed by music, current affairs, public information programmes (such as on health) and '*théâtre*' (radio plays that raise awareness of topics such as reconciliation, attitude to work, or justice).

Almost the entire territory of Rwanda is covered by the mobile phone networks. Mobile phones were used in all villages surveyed, and in both the group with a pico-PV and the control group about a third of all households owned one or more mobile phones. Most of the households charge their mobile phone at local shops that have a generator, paying RWF 100-200 for this service. The alternative is to go to a neighbouring electrified village (which involves walking one hour on average). Since the pico-PV kit enables phone charging, it was assumed that the number of phones per household and also the frequency and duration of calls would increase. However, since charging the telephone with the pico-PV was cumbersome, only 15% of the owners did so. Both the households with a pico-PV kit and those in the control group charged their phone between one and seven times per week, the average being 2.3 times per week (see table 21).

Table 21 Radio and mobile phone use			
	Households	With a pico-PV (RCT)*	Control group
Radio ownership.		95%	52%
Listening to the radio, hours per day.	Household head	4.3	3.2
	Spouse	3.3	2.7
	Boys 12-17 years	2.1	2.0
	Girls 12-17 years	1.7	2.1
	Children 6-11 years	1.9	2.2
No mobile phone in household.		64%	64%
One mobile phone in household.		26%	28%
Two or more phones in household. (Second phone is used by spouse.)		10%	7%
Number of charges per week.		2.3	2.3
Times used per week.		51.3	41.4

** Each kit came with a radio.*
Source: survey data, RWI and ISS.

The pico-PV lamp reduced the number of dry-cell batteries used from an average 3.7 to 3 per month. The reduction was mainly of small batteries (over 90% of these batteries are used in shop-bought torches), but there was hardly any difference in the use of big batteries for the radio (2.5 batteries monthly): this can be explained by the charging problems encountered with the solar panel.

5.7 Impact

Impact on the household economy

Users of a pico-PV kit reduced expenditure on kerosene, small batteries and candles by 40% (this ignores the depreciation of the lamp), while expenditure on cooking fuel and on large batteries remained the same. The difference between pico-PV users and control group in expenditure on charging telephones is not significant (see table 22). The value of the total saving (RWF 5,000 monthly) is too small to determine its alternative use (food, goods). One could expect that the impact would be greater among poorer households, but that is not the case, since poor households spend little on light and the difference made by having a pico-PV system is close to the difference of having light rather than no light.

Table 22 Expenditure on lighting and electricity			
Monthly expenditure per category (in RWF)	**With pico-PV**	**Control**	**significance**
Candles	42	109	**
Kerosene for lighting	155	609	***
Big batteries	358	352	
Small batteries	30	72	**
Mobile phone charging	137	169	
Total traditional energy sources (excluding energy for cooking)	**723**	**1311**	***
Total expenditure (excluding energy for cooking)	**34,739**	**29,731**	
Expenditure on energy as proportion of total expenditure, in % (excluding energy for cooking energy)	**0.03**	**0.07**	***

*Note: ** and *** indicate significance levels at p < 5% and 1%, respectively.*
Source: survey data, RWI and ISS.

Impact on household welfare

The pico-PV lamp could be expected to have an impact on the household's welfare in terms of lighting hours per day and feeling safe at night, the time used by children to study during evening hours, the access to information and aspects of health.

Fear of the dark is expressed in many beliefs and traditional stories. All the households (99%) thought that darkness is dangerous. Pico-PV lamps were mainly used inside the house and not outside. The pico-PV had not replaced the torch for outside use. Among households with a pico-PV, 13% less families were fearful in their home after nightfall, but there is no significant difference in behaviour in terms of going out after nightfall between owners of a pico-PV lamp and the control group.

A pico-PV improves the quality of lighting, since the lamp emits 40 lumens, which is a medium lumen level. To compare, a candle emits around 12 lumens and a hurricane lantern emits around 32 lumens (O'Sullivan & Barnes 2006). Quality lighting may influence the time distribution in the household, for example the moment of doing domestic chores or children doing their homework. The survey results do not indicate any change in the number of hours that household members are awake or whether they get up earlier or go to bed later. In half of the households with children, children did not study at home. If they did, 40% studied during daytime. In only 16% of the households with children was the pico-PV used to provide light for studying, mainly replacing a wick lamp (Grimm, Peters & Sievert 2013, p. 32). Children of school age in households with a pico-PV lamp did study 15 minutes longer after nightfall than children in the control group, but the total dedicated to

study time did not change: these children reallocated the time for study from daytime to after nightfall.[62]

The proportion of 12% of households with a pico-PV kit said that since acquiring it the radio had become more important as a source of information. The survey data do not provide evidence that the improved access to information translates into being more informed about topics such as family planning (use of contraceptives) or preventive health care (use of mosquito nets, for example). But as behavioural change takes time to materialise and may not yet have happened, the fact that the survey does not reveal significant effects does not mean that they will not appear in the future.

Kerosene lamps are a threat to health, not only because of the risk of fire or the danger of skin burns or of children drinking kerosene, but mostly because of respiratory diseases caused by the black carbon (soot) they emit. The immediate and close exposure of persons sitting next to a wick lamp during cooking, eating or reading makes kerosene a threat. Sitting next to a wick lamp is equivalent to smoking 170 cigarettes per year (Solar Aid 2013, p. 4). In 10% of the control group households, children use wick lamps when studying; this proportion is significantly less in the group with a pico-PV lamp (2%). Since no specific health tests were conducted, the impacts on health indicators can only be taken as probabilities and are not conclusive.

Impact on the environment

The effects on the environment are threefold, being on small particle emission (mainly soot), on CO_2 emission and from inappropriate disposal of batteries. Though not a Kyoto Protocol substance, black carbon is highly climate active. The contribution of kerosene lamps to the total air pollution in the household is low compared to that of firewood and charcoal.

Each household that uses a pico-PV lamp saves on average 1.02 candles and 0.44 litres of kerosene per month. Applying a CO_2 emission factor of 2.52 kg CO_2/l for kerosene and 2.95 kg CO_2/kg for paraffin waxes[63], the total savings amount to 1.26 kg CO_2 per household monthly.[64] Since approximately 8,000 ToughStuff kits were sold, this is equivalent to 10,000 kg CO_2 monthly. By comparison, a regular car emits about 24 kg of CO_2 per 100 km.

The ToughStuff kit also replaces small dry-cell batteries for lighting that do not emit CO_2 during operation. For mobile phone charging there is no reliable information on the precise source of electricity used. However, given that only a few households were using the ToughStuff kit for charging mobiles, emission savings can be assumed to be negligible.

[62] This result is in contrast to an evaluation of the impact of Philips solar portable lighting products in Rwanda, which concluded that there had been an increase in time spent on educational activities (Kesreliglu, 2012).

[63] Emission factors have been adopted from the Intergovernmental Panel on Climate Change (IPCC), available at http://www.carbonmetrics.com/ipcc.html.

[64] Assuming a candle weighs on average 50g.

The current practice of disposing of used batteries is harmful to the environment. About 5% of all the households gave away used batteries, mostly ones that were too run down to power a radio but could still be used to power homemade LED lamps. Most (92%) households threw used batteries into the open pit latrine, to prevent children from playing with them. Others disposed of the batteries with their garbage (2%) or threw them away somewhere outdoors (3%). The toxic metals end up in the groundwater and surface water. The solar kit also contains a battery, which if not recycled has harmful effects on the environment.

5.8 Sustainability

The Lighting Africa certificate[65] did not prevent an insufficiently mature product like the ToughStuff kit from entering the market. In 2013 these deficiencies were addressed (a new mobile phone charger and a battery package were included and the panel size was increased), but these modifications came late, after reputational damage had already occurred. In addition, the modifications came with a price increase to EUR 20-27 (depending on the composition of the kit). With the low sales volume and revenues, the company could not cover its operational costs.

The ToughStuff experience does not imply that there would be no market for pico-PV systems: there is a niche market, as evidenced by the EUR 1.2 million turnover for pico-PV gear in Rwanda, with approximately 40,000 lamps sold (Great Lakes Energy figures for 2013). However, reaching the energy-poor rural population through a market mechanism, as aimed at by donors, requires special support mechanisms. To arrive at a commercially viable enterprise, any company needs customers with sufficient purchasing power. For solar devices, these customers are usually urban or rural middle to high class, who use the solar lamp as back up, not as the prime device for light. The energy-poor in rural areas cannot afford such a device in the absence of a credit system or subsidy. In Rwanda, the solar companies with an active outreach to rural areas were all established with grant money or are protected by guarantees (some of which are external). Sales of high quality pico-PV systems can be successful in Africa, as shown by ToughStuff in Kenya and by SolarAid[66] in Tanzania, Malawi, Kenya and Zambia, but in those countries there are facilities such as credit schemes or business protection guarantees.

Based on the survey data, there is no indication that ToughStuff users are motivated by the solar experience and are more inclined to buy other solar devices: among those that obtained a PV kit in 2012, none had bought any other solar device at the time of the follow-up survey.

[65] The certificate (November 2011) concerned the lamp and the solar panel only.
[66] SolarAid is a London-based international charity organisation that provides affordable solar lights.

5.9 Findings

It was the Ministry of Foreign Affairs' strategy to support and influence the multi-actor energy sector through different channels, including the private sector. The Daey Ouwens Fund responded to a Parliamentary amendment for allocating budget for the promotion of small-scale projects in the area of sustainable and job-creating energy supply in developing countries. The Ministry had placed the management of DOF 'at arm's length' by delegating it to RVO.nl and had indicated that RVO.nl should apply a 'light assessment procedure', giving attention to the legitimacy of the subsidy provision, while abstaining from direct involvement in the contents of the proposals. In practice, this implied that the appraisal focused on legitimacy and institutional setting[67] while the technical appraisal was indeed 'light'.

ToughStuff Rwanda aimed at selling pico-PV kits through grassroot networks of women. The project is illustrative for the flaws in appraisal: the far from realistic sales targets were no impediment to approval of the subsidy. It should have been obvious that the envisaged targets could never be achieved, since they implied achieving a penetration rate of over 9% in a two-year period. On top of this, the kit's technical specifications were not adapted to Rwandan conditions. The marketing strategy was indeed innovative but, while relying solely on female sales agents, lacked any specific indication on how to benefit from this in the marketing. Furthermore, this aspect was not assessed during appraisal. Apart from being given the opportunity to comment on the intended subsidy allocation, the embassy was deliberately assigned no role in terms of monitoring or control.

Owners of pico-PV kits use these mainly for lighting (85%) inside the house and for listening to the radio (68%). The lighting provided by a solar lamp is brighter and cleaner than that of a kerosene wick lamp or candles. To families that obtained a pico-PV kit it brings savings in expenditure on energy, but more importantly it improves living conditions (for example, health benefits and more freedom in time use). The lamps do not replace all traditional lighting sources simultaneously, but usually one particular source (kerosene wick, candle). The impact of a solar kit on the household economy is only minor, notwithstanding that savings on energy sources for lighting are over 40%, but rural families simply spend very little on energy for lighting. People feel safer at home, but do not change their behaviour in terms of going out after nightfall. The pico-PV kit influences above all the time spent listening to the radio (which is an important source of information) and the moment for doing domestic chores. The effect on CO_2 emission is substantial in relative terms, but used batteries are disposed of in ways that are harmful to the environment.

There has been international debate about whether pico-PV systems can be considered as an alternative to grid-supplied electricity. According to the Sustainable Energy for All

[67] RVO.nl applied the instrument of the Ministry of Foreign Affairs to assess the organisational strength and weakness of the applicant, the so-called COCA list. To amounts up to EUR 1 million a light procedure is applied.

initiative, it can. Advocates of pico-PV systems argue that pico-PV systems can satisfy the demand for basic electricity use at lower costs than grid-supplied electricity. While grid-based electrification costs EUR 800 per household, the pico-PV system costs only between EUR 15 and 75. In Rwanda, however, this is not a subject of policy debate, since solar lamps are left to market forces and are not a component of Government's electrification strategy. It is questionable whether market forces are strong enough for the pico-PV lamps to reach the energy-poor households. In remote areas, in which pico-PV lamps could meet the basic demand for electricity, purchasing power is low. In contrast, in areas where purchasing power is higher, the pico-PV can no longer satisfy the demand for electricity (television, fridge). Pico-PV could be a bridging technology or pre-electrification technology in which it is justified to provide certain forms of subsidy and guarantee credit facilities to the enterprises (social or otherwise) that sell these devices.

6

Sustainable Energy Development project

6.1 Introduction

One of the four PREP objectives was to influence the policy of partners responsible for investment in renewable energy. The strategy was to influence the policies of multilateral organisations that were managing ongoing energy programmes, such as the World Bank. The Ministry of Foreign Affairs had noticed that within the World Bank the attention for renewable energy was more developed for Asia than for Africa. In 2009, the Africa Energy Unit (AFTEG) of the World Bank grouped seven separate activities into one single portfolio to support the access to energy services in Sub-Saharan countries in an environmentally-aware manner. The Africa Renewable Energy Access programme (AFREA) was established and started its activities with a EUR 24 million contribution from the Netherlands to the Clean Energy Investment Framework Multi-Donor Trust Fund (CEIF-MDTF) of the Energy Sector Management Assistance Programme (ESMAP). AFREA funds support AFTEG and its clients by focusing on: (i) energy access, in particular the scaling-up of innovations in lighting and cooking; (ii) green growth (low carbon development, energy-efficiency and climate change adaptation; and (iii) capacity building of ministries, power utilities, regulators and power operators.

AFREA enables AFTEG to engage in small-scale renewable energy activities, such as: pilot projects on woody biomass, through the Biomass Energy Initiative for Africa (BEIA); market development and consumer behaviour on solar energy, through Lighting Africa; a gender-sensitive approach, through the Gender and Energy programme; and a multi-country platform on energy regulation and research, through the Africa Electrification Initiative. Each of these programmes and initiatives was funded not only by Dutch means but also by different groups of co-financiers. AFREA also provided support and grants to governments for conducting activities that complement existing World Bank operations.

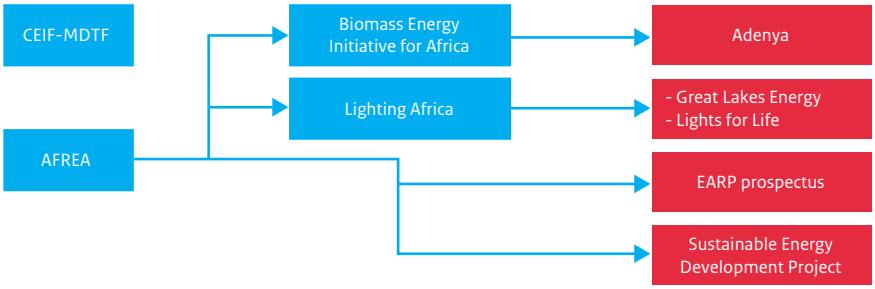
In Rwanda, four activities were funded by AFREA resources: (see figure 8):

1) The Biomass Energy Initiative for Africa provided funding to the Rwandan NGO Adenya[68] for its programme to enhance sustainable charcoal production.
2) The Lighting Africa Development Marketplace awarded financial incentives to two businesses active in solar energy: Great Lakes Energy and Lights for Life. Lighting Africa also certifies solar equipment imported in Rwanda.
3) Direct support was given to the development of the Energy Investment Prospectus that provided the basis for the multi-donor support to the Electricity Access Roll-out Programme.
4) Direct funding was provided to the Sustainable Energy Development Project (SEDP), co-funded by the Global Environment Fund (GEF).

[68] Adenya also participates in ENNY, a private joint venture of the German company CARERA, Adenya and six private investors for the Mazimeru micro-hydro project. Mazimeru started in 2009 within the EnDev programme and has a capacity of 500 kW; it is the second hydropower plant developed and operated by a private company in Rwanda.

This chapter deals with one of these four activities only, the Sustainable Energy Development Project (SEDP).

Figure 8 *AFREA-funded activities in Rwanda*



6.2 Evaluation methodology

The qualitative evaluation method comprised a desk study applying a funnel approach, starting with the five main PREP-funded programmes implemented through the World Bank[69], through a focus on the programme for Sub-Sahara AFREA, zooming in on Rwanda and subsequently selecting one programme: the Sustainable Energy Development Project (SEDP). SEDP in itself is again a container project, encompassing 25 different activities, each of which is contracted out to different implementing actors (companies, research institutes, consultants and development organisations). After completion of the desk study, a verification field visit was made in spring 2013 in which a selection of the 25 activities was visited. Semi-structured interviews were held with activity implementers and SEDP management.

6.3 Organisation and activities

The Sustainable Energy Development Project was established in 2009 with two main objectives: (i) to improve the policy and institutional framework of the Rwandan government in the area of renewable energy; and (ii) to increase private sector participation in the renewable energy sector. A third – indirect – objective was the reduction of greenhouse gas emissions through the use of renewable energy technologies. A grant of a total of USD 8.3 million was approved, USD 3.8 million of which was provided by AFREA, while the remaining USD 4.5 million came from Global Environmental Facility (GEF). The

[69] Asia Sustainable and Alternative Energy Program (ASTAE), Energy Sector Management Assistance Programme (ESMAP), International Finance Corporation (IFC), Scaling up Renewable Energy Programme (SREP), and Africa Renewable Energy Access programme (AFREA).

Nordic Development Fund allocated an earmarked USD 5.6 million for a specific project on solar heaters. The three financial sources were not pooled and remained administratively separate. Neither the Dutch Ministry of Foreign Affairs nor its embassy in Kigali is directly involved in either the selection of activities or the management of SEDP.

SEDP is implemented by, and functionally integrated within the electricity and water utility company EWSA (see chapter 3) under a World Bank Technical Team Leader (World Bank 2009, Annex 6). The daily management is assigned to a 'focal person' or coordinator, two accountants and a procurement specialist (none of these is permanent staff of EWSA). For each activity Terms of Reference have been elaborated, checked by the World Bank and subsequently contracted out. For contracts up to USD 150,000, EWSA and the project coordinator take autonomous decisions, while for contracts over that amount, each step in the procurement process has to be endorsed by the World Bank Technical Team Leader. The amounts allocated to the different activities range from USD 5,000 to USD 956,000. By mid-2013, a total of 25 activities had received funding from SEDP.

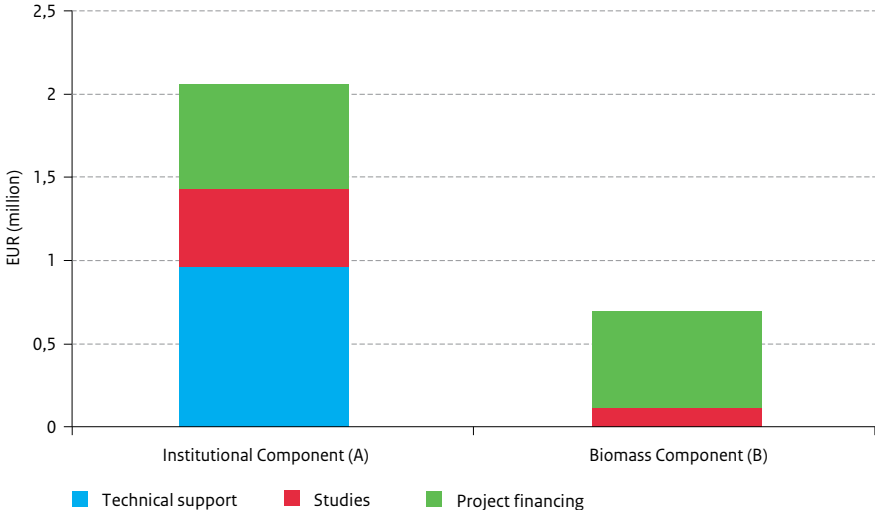
They can be classified into five groups (World Bank 2010):

A) strengthening of renewable energy policy, strategy and management (8 activities);
B) efficient utilisation of biomass resources (6 activities);
C) sustainable development of micro-hydro resources (3 activities);
D) solar energy (6 activities); and
E) energy efficiency (2 activities).

The AFREA funds were mainly destined for activities in categories A and B. Within these two categories, activities are grouped (see figure 9) into: (i) project financing, which includes funding for the implementation of promotional activities, training and workshops; (ii) studies, either administrative in nature (for example, control of contracts) or technical (for example, studies that result in maintenance manuals); and (iii) technical support. This last group encompasses the largest activity of the AFREA portfolio: the USD 1 million technical support to the monitoring unit established at Lake Kivu regarding the extraction of methane gas (see box 7).[70]

[70] In July 2013, KivuWatt was the single large private sector contract that EWSA had in place for additional energy generation. Since the extraction of methane gas is not without hazards, a special monitoring unit has been established. Initially, the monitoring of Lake Kivu was a separate activity under AFREA, but later it was integrated within the SEDP portfolio. The support entails the provision of a boat, a vehicle, laboratory equipment and technical expertise.

Figure 9 *Distribution of funds within SEDP components A and B*



Source: SEDP Activity Status Report, 29 May 2013.

Institutional component A contains activities such as the Technical Business Incubation Facility for starting entrepreneurs in the field of renewable energy, implemented by the Kigali Institute of Science and Technology (KIST); and the elaboration of the National Renewable Energy Strategy study, as input to the Energy Sector Strategy Plan.

Box 7 *Environmental monitoring of methane gas extraction in Lake Kivu*

The Netherlands has supported the environmental monitoring unit in Lake Kivu through SEDP with some USD 176,000, and since 2013 the unit has been supported by the Dutch Great Lakes programme. The methane gas exploitation in Lake Kivu is risky. Some 2 million people around Lake Kivu could face consequences if trapped volcanic gases rise to the surface. Gas extraction could trigger tectonic movement that would destabilise the holding layers in the lake and this could release a deadly cloud of CO_2. The methane extraction could also alter the lake's chemistry, turning it more acidic and promoting algal blooms that could be catastrophic for fish life. In addition, under certain circumstances, pressured methane could explode when it meets the air.

In the biomass component B, the activities funded include the training of charcoal producers and the promotion of improved cooking stoves (ICS) in rural and urban areas. The training of charcoal producers was an extension of a project previously funded by the European Commission and implemented by CARE International. In Rwanda, ICS are all

commercially marketed, since MININFRA has prohibited NGOs from distributing improved stoves for free. In the context of the Global Alliance for Clean Cookstoves, Rwanda has a Country Action Plan for ICS.[71] In 2013, the government – with support from SNV – started pilots in support of the development of the improved stove market, building on the market for the same type of improved stoves that Practical Action Consulting (PAC) had initiated. This biomass component has several links with other Dutch-funded organisations and programmes, such the NGO Adenya, the PAREF woody biomass programme, the biomass programme of IFDC and the ICS support by SNV. CARE has been contracted to train charcoal producers to use improved charcoal-producing techniques. Adenya is funded through the Biomass Energy Initiative for Africa for the organisation and transformation of the charcoal production sector. IFDC and PAREF received direct Dutch support from EKN through the delegated programme. The Embassy was active in stressing the need for coordination between IFDC and PAREF, but did not include CARE and Adenya in that coordination effort. CARE and PAREF promote different stoves, different methods and techniques concerning charcoal stoves, kilns and burning techniques.

Technical support activities funded by AFREA comprise consultancy studies mainly, such as a study of the market for LPG and the study that resulted in a maintenance manual for hydroelectric installations. To monitor these 25 activities, the World Bank applies its standard Monitoring and Evaluation system as used for all lending and grant activities. This comprises a bi-annual implementation status report and a project completion report at the end of the funding period. The monitoring is restricted to measurable indicators related to inputs and outputs. Since all activities are contracted out, the information is reported by the implementing agency. Responsibility for the SEDP monitoring rests with the same officer responsible for monitoring the nationwide EARP programme. If quarterly progress reports require extensive data collection, consultants are contracted, for example on the emission of greenhouse gases. The World Bank does not envisage conducting any effectiveness or impact evaluation after completion of the project. There is no specific public reporting on SEDP, or separate reporting to the Ministry of Foreign Affairs. In Rwanda there is no institutionalised sharing of information between the World Bank and the Dutch embassy about the content or progress of SEDP.

6.4 Efficiency

Although the name 'project' suggests a set of related activities, SEDP is a fund encompassing 25 unrelated activities. The efficiency of SEDP was assessed at two levels, from a managerial and operational perspective.

From a managerial perspective it is efficient for both the World Bank and EWSA to have at their disposal a financing source that addresses immediate needs for: (i) funding of project

[71] See: Country Action Plan. The Government of Rwanda indicated that the Global Alliance Action Plan should adhere to the national standards.

implementation; (ii) studies; and (iii) technical assistance. In general, the studies were not budgeted for in the EWSA annual budget planning. Using a single mechanism and operational procedure for both projects and studies keeps transaction costs low. Use can be made of standard procurement systems, for example. From that perspective, SEDP can be compared to a technical assistance facility. The activities to be funded are not selected on the basis of results-oriented eligibility criteria or competition (there is no competition among proposals), but are appraised individually.

Once selected, each activity is contracted out. The strict application of procurement through tenders may suggest operational efficiency in terms of the best price-quality relation for implementation. While this is a valid argument for studies, it is not the case for activities pertaining to broader programmes. An example of that is the contracting out of promotion campaigns of improved cooking stoves without any involvement in either their production or marketing.

6.5 Effectiveness

The effectiveness of tangible activities, such as those in the areas of improved cooking stoves and training in charcoal production, is modest. The strict separation between promotion (seen as a MININFRA task) and production and marketing (considered a task of the private sector) did not lead to a higher uptake of improved cooking stoves. Comparable observations can be made regarding charcoal production: the organisation and technical efficiency of charcoal production were separated from the marketing: the output of the intervention was substantial (about forty cooperatives established and 1,008 charcoal producers trained) but the outcome is less impressive because only a few persons are full-time producers and the remaining vast majority are incidental or part-time producers who make charcoal to meet their immediate need for cash.

The second objective was to increase private sector involvement in the renewable energy sector. At the moment of evaluation, KIST was training 120 entrepreneurs in the field of renewable energy (none of these entrepreneurs had graduated by mid-2013). Although they were being trained to become independent entrepreneurs, all trainees interviewed indicated that their business aim was to be contracted by EWSA (the most important contracting agency in the area of energy in the country) and to focus on hydro-energy. Since these trainees had not yet established their firms, it was too early to assess the effectiveness of SEDP in this aspect.

Another product was the elaboration of the Renewable Energy and Energy Efficiency study by MININFRA; the single indicator that refers directly to activities implemented with AFREA funds. This study provides an overview of the current renewable energy sector, and also of a

strategy and investment plan. MININFRA endorsed this study, which was pivotal to incorporate a 'renewable energy' focus in the Energy Sector Strategy Plan.[72]

A major activity is the technical assistance to the Lake Kivu methane gas monitoring unit. This monitoring has been effective in the sense that gas exploitation is permanently monitored on its environmental impacts and exploitation has remained at a pilot level.

The Implementation Status and Results reports (World Bank 2013) document progress on indicators for intermediate outcomes, outcomes and impacts. They do so on the basis of quarterly information submitted by the SEDP monitoring expert. Although information on progress is documented, there are shortcomings: (i) information is self-reported by the contracted company, organisation or individual professional for each of the 25 activities. Only in exceptional cases is this information scrutinised; (ii) the choice of indicators is unmethodical; (iii) the information submitted does not always respond to the indicator; and (iv) there is no evidence that effects can be attributed to the intervention.

6.6 Impact

Although most SEDP activities support either EWSA or MININFRA responsibilities, EWSA lacked both a plan for its future organisational structure and one for an integral approach for a capacity-building plan for its staff. In addition to the World Bank, development partners such as the Japanese International Cooperation Agency (JICA) and Belgian Technical Cooperation (BTC) focus actively on capacity building of EWSA, since EWSA itself has noted flaws in its organisational capacity (and human capabilities), both at technical level in the districts and at a theoretical level at headquarters. The impact of SEDP at institutional level cannot be observed.

6.7 Sustainability

At the moment of the field study in July 2013, various activities were still ongoing and not all financial resources of SEDP had been committed. Regarding sustainability, only a few remarks can be made. EWSA feels that it owns SEDP since the latter responds to immediate EWSA organisational needs. Since the activities funded are a regular EWSA responsibility, EWSA will continue these activities in the absence of SEDP finance. In a few cases EWSA actively searches for follow-up funding: for example, for the technical support to the monitoring unit at Lake Kivu that will be continued with support from the Embassy of the Kingdom of the Netherlands. The Nordic Development Fund and the Russian Development Fund will continue to support the hydro and solar markets (USD 3.5 million for the Energy Small and Medium Enterprise Grant).

[72] Source: interviews EWSA and MININFRA, June 2013.

6.8 Findings

The Dutch Ministry of Foreign Affairs channels PREP resources through the World Bank in order to:

(i) Exercise influence on World Bank institutional policies on energy by promoting *renewable* energy. This PREP objective applies to both the global and national (representative offices) levels.
(ii) Exercise influence policies on national governments in scaling up the access to renewable energy.
(iii) Control project management's workload and the transaction costs of project management.

At programme level SEDP responds to these higher level goals. AFREA has appealed to the World Bank office in Kigali to embark upon renewable energy activities, which were previously considered as the domain of the civil society.[73] The SEDP supports the technical and management capacity of EWSA in order to 'help the Government in mainstreaming renewable energy development within the national Energy SWAp, complementing the efforts made on grid extension [...] to reach rural growth centres where grid connection is not economically viable' (World Bank 2009, p. 6). The World Bank has used the Rwanda SWAp as best practice and is mainstreaming the approach in the SE4ALL country programming.

On the ground, SEDP responds less to PREP goals and more to the daily needs of EWSA and priorities of the World Bank team. First, access to energy was not a specific objective of SEDP, except in the case of the biomass component. Second, SEDP hardly provides structural capacity building to EWSA, but instead fills immediate institutional needs. The relation to capacity building is rather indirect.[74] Third, the World Bank applies a project modality, an approach that differs from the fully aligned approach for the electricity subsector as advocated for the Energy SWAp by the Dutch embassy.

SEDP is coherent with other MININFRA-managed activities in the energy sector, such as EARP and NDBP. Some SEDP components (mainly in biomass) have similarities with other Dutch-funded programmes (the improvement of the charcoal value chain, the promotion of improved cooking stoves) but are implemented differently. SEDP is implemented autonomously and takes no account of other activities funded from PREP.

[73] Interview with World Bank, June 2013.
[74] The World Bank in Kigali considers SEDP more than a technical assistance facility, since it fills in capacity needs in the absence of an integral capacity-building programme. Interview July 2013.

Annexes

Annex 1 About IOB

Objectives

The remit of the Policy and Operations Evaluation Department (IOB) is to increase insight into the implementation and effects of Dutch foreign policy. IOB meets the need for the independent evaluation of policy and operations in all the policy fields of the Homogenous Budget for International Cooperation (HGIS). IOB also advises on the planning and implementation of evaluations that are the responsibility of policy departments of the Ministry of Foreign Affairs and embassies of the Kingdom of the Netherlands.

Its evaluations enable the Minister of Foreign Affairs and the Minister for Development Cooperation to account to parliament for policy and the allocation of resources. In addition, the evaluations aim to derive lessons for the future. To this end, efforts are made to incorporate the findings of evaluations of the Ministry of Foreign Affairs' policy cycle. Evaluation reports are used to provide targeted feedback, with a view to improving the formulation and implementation of policy. Insight into the outcomes of implemented policies allows policymakers to devise measures that are more effective and focused.

Organisation and quality assurance

IOB has a staff of experienced evaluators and its own budget. When carrying out evaluations it calls in assistance from external experts with specialised knowledge of the topic under investigation. To monitor the quality of its evaluations IOB sets up a reference group for each evaluation, which includes not only external experts but also interested parties from within the ministry and other stakeholders. In addition, an Advisory Panel of four independent experts provides feedback and advice on the usefulness and use made of evaluations. The panel's reports are made publicly available and also address topics requested by the ministry or selected by the panel.

Programming of evaluations

IOB consults with the policy departments to draw up a ministry-wide evaluation programme. This rolling multi-annual programme is adjusted annually and included in the Explanatory Memorandum to the ministry's budget. IOB bears final responsibility for the programming of evaluations in development cooperation and advises on the programming of foreign policy evaluations. The themes for evaluation are arrived at in response to requests from parliament and from the ministry, or are selected because they are issues of societal concern. IOB actively coordinates its evaluation programming with that of other donors and development organisations.

Approach and methodology

Initially IOB's activities took the form of separate project evaluations for the Minister for Development Cooperation. Since 1985, evaluations have become more comprehensive, covering sectors, themes and countries. Moreover, since then, IOB's reports have been submitted to parliament, thus entering the public domain. The review of foreign policy and a reorganisation of the Ministry of Foreign Affairs in 1996 resulted in IOB's remit being

extended to cover the entire foreign policy of the Dutch government. In recent years it has extended its partnerships with similar departments in other countries, for instance through joint evaluations and evaluative activities undertaken under the auspices of the OECD-DAC Network on Development Evaluation.

IOB has continuously expanded its methodological repertoire. More emphasis is now given to robust impact evaluations implemented through an approach in which both quantitative and qualitative methods are applied. IOB also undertakes policy reviews as a type of evaluation. Finally, it conducts systematic reviews of available evaluative and research material relating to priority policy areas.

Annex 2 Energy sources and targets in Rwanda

Annex 2a Energy sources in Rwanda		
Energy source	**Demand**	**Supply**
Biomass	Expanding due to population growth (2.9%) and urbanisation (4.4%). Urban consumers use charcoal mainly, requiring 1.9 times the quantity of firewood.	Eucalyptus trees provide 80% of firewood. An active reforestation programme, planting on both public and private land. Strict tree-cutting laws. Remaining natural forests are successfully protected under law.
Fossil fuels	Oil and derivatives for diesel generators and vehicle fuel.	5.5 thousand barrels of fuel imported per day. In 2008, a reserve of oil at 3 km depth under Lake Kivu was detected (MININFRA 2009c).
Methane gas	Gas for power (electricity generation).	39 billion m^3 of methane is potentially extractable[75]; sufficient to generate 700 MW of electricity for 55 years (Rwanda's share 350 MW). Small quantities are extracted from under Lake Kivu and piped to the KivuWatt power plant.[76]
Peat	Peat for power (electricity generation). Piloting of peat as cooking fuel.	Reserves of 155 million tonnes of dry peat spread over an area of about 50,000 hectares. Fuel sufficient to generate 450 MW of electricity for 25 years.
Biogas	Institutional demand (introduced as pilot in prisons in 2001) and demand at household level.	In 2008 GoR started to the National Domestic Biogas Programme (NDBP) that actively promotes use at household level.
Solar photovoltaic	Solar field feeds into the grid; demand for solar home systems from households and rural public facilities. Pico PV-systems for households without access to electricity.	The solar radiation (5.2 Wh/m^2/day) is adequate. The 250 KW Kigali Solair installation (2008) (GTZ 2009) feeds into the grid.[77] PV installations in public institutions are mainly donor-funded. A small market for solar home systems and pico-PV systems.
Geothermal energy	Heat for power (electricity generation).	Potential of 170-340 MW[78]. Government has designated USD 30 million for exploration, but no private investment has been made.

75 At Standard Temperature and Pressure.

76 FMO and EAIF are co-lead arrangers for KivuWatt (subsidiary of ContourGlobal SA) with a combined senior debt of USD 50 million, along with an AfDB investment of up to USD 20 million. See: www.afdb.org.

77 In 2014, a start was made with the installation of an 8.5 MW photovoltaic park 60 km outside Kigali, developed by GigaWatt Global, with USD 23 million investment by Scatec Solar and Norfund and loans from FMO, the Emerging Africa Infrastructure Fund and Norfund. Source: FMO News Archive, 14 February 2014. *FMO invests in first utility scale solar project in Rwanda*.

78 Geothermal Energy Association 2011.

Energy source	Demand	Supply
LPG and Kerosene	Cooking fuel for higher-income strata. Kerosene use is declining.	LPG and kerosene are imported.
Electricity	An additional 60,000 households are connected each year.	Focus on both large- and small-scale hydro generation (333 sites with a combined capacity of 96 MW). Regional hydropower plants (235 MW) are developing slowly.

Source: elaboration IOB.

Annex 2b Energy targets, baseline (2008) and results (2012)

	Baseline 2008	Targets for 2012	Realised Dec. 2012	Realised in % 2012
Electricity generation capacity	55 MW (72.4 MW installed)	110 MW; later adjusted to 130 MW; of which 25 MW from methane gas	120 MW	92%
Percentage of households owning an improved stove	50	100%; later adjusted to 80%	Not available	
Number of biogas digesters at household level	500	15,000; later adjusted to 3,000, in 2013 set at 10,000	3,000	20%
Electrogaz / RECO / EWSA customers	97,510	320,000	332,000	104%
Percentage of households connected to the electricity grid	6	16	15	94%
Grid extension lines (LV) in km		5,000	9,030	181%
New Electrogaz / RECO / EWSA customers per month	400	4,600	5,000	109%
Number of health centres connected to the electricity grid	30	442 (100%); later 90%	286	65%
Number of Administrative Centres connected to the electricity grid	50	416 (100%); later 90%	245	59%
Number of schools connected to the electricity grid	100	1,704 (50%)	1,226	72%
Technical and commercial losses of electricity supply	25%	15%	Not available	

Source: IOB, based on: National Energy Policy and National Energy Strategy 2008-2012 (targets); NEPAD Secretariat Rwanda, June 2013; World Bank 2013 (realisation).

Annex 3 Overview of stakeholders in Rwanda's energy sector

Annex 3a Overview of stakeholders' roles in the energy sector in Rwanda						
	MININFRA	Other ministries and government institutions	RURA, REMA and other regulators	EWSA	Private sector, commercial	Private sector, NGOs
Policy and regulatory framework						
Policy making	√					
Energy planning	√	√		√		
Energy pricing	√	√	√			
Energy efficiency and conservation	√	√		√	√	
Energy and environment		√	√			√
Subsector investment						
Woodlots, charcoal, stoves	√	√	√	√		√
Petroleum	√	√	√		√	
Electricity (grid)	√	√	√	√	√	√
Micro-hydro electricity	√	√	√		√	√
Methane	√		√	√	√	√
Peat	√	√		√		
Geothermal	√	√	√		√	
Solar feed-in (Kigali Solaire, GigaWatt Global)	√		√	√	√	
Domestic solar PV or pico-PV		√			√	√
Biogas (NDBP)	√			√	√	√

Source: IOB, amended from MININFRA National Energy Policy and Strategy 2011, p. 30.

Annex 3b Role of public entities in the energy sector in Rwanda	
Public entity	**Function in energy sector**
Ministry of Finance and Economic Planning	In charge of funding investments and providing subsidies. Represents Government as owner of the Energy, Water and Sanitation Authority. Responsible for taxation of fuels and energy.
Ministry of Foreign Affairs and Cooperation	Attracts and administers official external aid to the energy sector.
Energy, Water and Sanitation Authority (EWSA)	In charge of the execution of the electricity policy through programmes and projects. Responsible for the transmission and distribution of electricity.
Rwanda Utility Regulatory Agency (RURA)	Responsible for the technical regulation of the electricity sector and related energy sub-sectors and contracts.
Ministry of Natural Resources (MINIRENA)	In charge of supervision and follow-up of forestry policy. Policy related to biomass as source for energy. Methane gas exploitation.
Department of Forest and National Conservation	Responsible for the regulation and management of natural forests and biomass plantations.
Ministry of Agriculture and Animal Resources	Promotes agro-forestry, also as a source of biomass. Involved in biogas activities.
Ministry of Local Government	Responsible (through the district and sector authorities) for the implementation of forestry laws, the issuance of tree-cutting and charcoal production permits, and protection of the environment. Also involved in the promotion of improved cooking stoves.
Rwanda Environment Management Authority (REMA)	Appraises and judges the environmental suitability of projects, including the ones on electricity generation and distribution. The Designated National Authority (DNA) for registering Carbon Credits (Certified Emission Reductions) derived from renewable energy projects under the UN Framework Convention on Climate Change.

Annex 3c Development partners in the energy sector in Rwanda	
Development partner	**Programmes and projects in the energy sector**
World Bank	Rwanda Electricity Access Scale-up and Sector Wide Approach (SWAp) Development Project (USD 70 million); the Urgent Electricity Rehabilitation Project; the Rwandan Tunisian Power utility; Rusumo Renewable energy feasibility study; ESME: support to market development for sustainable energy products (hydro-power, pico solar, and institutional capacity building).
World Bank Global Environment Facility (GEF) and AFREA	Entrepreneurship development through an incubation approach; support to the private sector in the micro-hydro area; promotion of PV and stand-alone renewable energy systems; support to the biomass sector through promotion of improved stoves and charcoal kilns; SEDP facility to EWSA.

Development partner	Programmes and projects in the energy sector
African Development Bank	Support to EARP; financing of electricity sector Master Plan and regional interconnections for transmission of electricity. Studies for regional hydro projects and methane to power consortium.
Belgian Government (BTC)	Renewable energy projects (solar and micro-hydro); financing of studies (micro-hydro atlas, wind atlas). Construction of 5 Small Hydro Power Plants (completed) and two additional ones in collaboration with EC (2012). Sector support to EARP; Geothermal energy development (Gisenyi, Kinigi, Karisimbi). Reforestation (PAREF Support Programme to the Development of the Forestry Sector in Rwanda) with additional funding by the Netherlands (MINAGRI/IFDC).
European Commission	Micro-hydro development and solar electrification to 200 schools; capacity building; studies for regional hydro projects (Rusizi III and IV).
Japan International Cooperation Agency	Support to EARP. Rehabilitation of substations; rehabilitation and extension of district networks; capacity building for distribution network engineers and technicians.
OPEC Fund for International Development (OFID)	Support to EARP.
Saudi Fund for Development	Support to EARP; capacity building and transaction advice.
French Development Agency	Debt swap (debt relief programme) in support of EARP.
UNIDO	Through Investment Climate Facility for Africa: co-financing of four micro-hydropower plants: Nyamyotsi I, Nyamyotsi II, Mutobo and Agatobwe.
GIZ and DfiD (UK)	Market development in the solar PV, micro-hydro and institutional biogas sectors.
European Commission	Energy solutions for off-grid public institutions: target is to equip 350 schools, hospitals, and district offices with PV systems. Micro-hydro plants of about 3 MW capacity in 3 to 15 sites serving up to 70 villages. Two of these sites have been established in cooperation with BTC (Rukarara II and Ntaruka A). Investment in Ruzisi III hydro plant.
USAID	PEPFAR programme for health sector, in which energy supply to health centres is one component.
Other actors	Practical Action (biomass, charcoal); World Vision and Care International (improved cooking stoves in rural areas); ICAP/ Colombia; Stadtwerke Mainz.

Sources: IOB inventory based on World Bank 2013; http://mininfra.gov.rw; Energypedia 2013; Indicative cooperation programme (ICP) Belgium-Rwanda 2011-2014 (2011, pp. 9-12); www.eeas.europa.eu.

Annex 4 Main baseline characteristics of sampled households

Annex 4 Main baseline characteristics of sampled households				
	Households in non-electrified communities	Households in electrified communities		
		all	connected	non-connected
	(1)	(2)	(3)	(4)
Number of households	686	288	180	108
Average household size	4.98*	5.24	5.70	4.47***
Household structure, in %				
female-headed households	17	18	18	17
proportion of household members under 15	39	39	41	36*
proportion of household members over 65	2	3	2	6***
Highest education level of household heads, in %				
no formal education	23**	16	14	20
adult literacy	2	4	4	4
primary school	56	58	56	61
higher education	18	22	26	15**
Annual household expenditure (in RWF thousand)	778	784	1016	456***
Household assets, in % of households				
farmland	79*	73	75	66
livestock	67	63	64	57
bicycle	26*	21	26	15**
motorcycle	3	4	2	6*
Main source of income in community, in %				
agricultural activities	72	67	-	
non-agricultural activities	14	13	-	
animal husbandry	14	33	-	

	Households in non-electrified communities	Households in electrified communities		
		all	connected	non-connected
	(1)	(2)	(3)	(4)
Availability of main infrastructure in community, in %				
schools	72	80	-	
health infrastructure	45	33	-	
market	31	53	-	

*Note: baseline values. The asterisks *, ** and *** indicate significance levels at p < 10%, 5% and 1%, respectively.*
Source: IOB baseline dataset EARP 2011.

Columns (1) and (2) compare non-electrified and electrified communities in terms of socio-economic indicators of households. The few statistically significant differences are indicated by asterisks. Columns (3) and (4) disaggregate within communities with electricity those households that were connected to the electricity grid and those that were not connected.

Annex 5 Brief note on techniques applied

This study made use of 'mixed methods' to assess the impact of energy interventions. Mixed methods imply the integrated and mutually reinforcing application of both qualitative and quantitative techniques. In order to identify effects or impact, the challenge is to attribute observed results to the intervention. That is not simple, because an array of other (unobserved) factors that have nothing to do with the intervention may also have contributed to the results. The comparison with a counterfactual situation is therefore of utmost importance: it is not sufficient to have measured results before and after the intervention, but also to know what would have happened in its absence. Therefore, an unbiased assessment takes into account the influence of specific characteristics of the users, in order to determine the effects of the intervention itself. In the case of access to electricity, in this study the researchers observed that in communities with electricity, households send their children more frequently to school than households that lack electricity. But it is unwarranted to conclude that obtaining access to electricity will cause someone to send their children to school. More information is needed before a conclusion can be drawn. That is why researchers prefer to compare the results in the intervention group (called the 'treatment group': in this case, the households with electricity) with a 'control group' (the group that does not have access to electricity). But if this control group has characteristics that differ from those of the intervention group, results may still be biased: for instance the households that connect to the electricity grid can afford to do so because they are more middle or high class, and they would have sent their children to school anyhow. Ignoring any selection effects may lead to biased estimates of effects (and therefore to wrong conclusions).

Ideally, researchers select the treatment group and control group randomly. This is the best way to ensure that both groups have the same characteristics and that differences in results between the two groups can be attributed to the intervention. This is common practice when trialling drugs, for example. The generic term applied for these random assignments is 'randomised controlled trial – RCT'. In socio-economic studies, however, random assignment is difficult or impossible. Since a solar lamp is a small portable device, an RCT could be applied in the case of the ToughStuff programme. The specific methodological problems of conducting a RCT will be discussed later in this Annex.

Sometimes the control group can be constructed after the intervention, instead of identified prior to it. Then, for each person (or household) in the treatment group the researcher tries to find one or more persons with the same characteristics (such as household characteristics, age, income, urban/rural, etc.) in order to create a control group. A high degree of similarity between the intervention group and control group reduces the risk of potential selection bias attributable to differences in observable and unobservable characteristics. Forming pairs of persons (or households or enterprises for example) is complicated and time-consuming, but statistical theory is helpful in this regard. The method of *propensity score matching* (PSM) forms pairs by matching on the probability of treatment: for example, of being the owner of a biogas digester (chapter 4). In other words,

it determines the likelihood (propensity) that someone with the same characteristics will acquire a biogas digester. The method uses all information available (such as household characteristics) to construct a control group. These variables are ones that can be reasonably assumed to be unlikely to be affected by the intervention (e.g. educational attainment, ownership of certain assets). The PSM is particularly useful when it is not possible (or feasible) to conduct surveys at different moments in time (i.e. cross-sectional analysis). The matching procedure is based on regression techniques.

Regression analysis is a statistical technique for studying how a variable of interest (e.g. the use of electricity) is related to one or more other variables (for example, household characteristics such as income or educational level). The analysis uses mathematical function relations between variables: $Y = a + bX + cZ$, where Y is the variable of interest, X may be the intervention and Z a control variable. The estimated *coefficients* a, b and c indicate how in the sample the variable of interest responds to changes in the other variables: for example, the use of radio with a solar kit (X), controlling for specific household characteristics (Z). Regression analysis is therefore also a technique for obtaining unbiased estimates of the effect of an intervention as long as selection is based on observable characteristics (Z).

In general, statistical analysis is based on samples and not on the entire population. There is thus a risk that the data in the sample suggest a relationship that in practice does not exist or does not occur (or that is larger or smaller). Several statistical measures have been developed to assess that probability, such as t-values and z-scores. These are based on *standard errors* that describe the error margin of a specific estimate. High t-values (or low standard errors) are a sign that the estimated coefficients reflect a true relationship and are not just the coincidental outcome of a particular sample. The normal benchmark for t-values and z-scores in the analysis of social data is an absolute value of about 2 or higher. With t-values so high one would only rarely (one case out of every 20 observations or measurements) be mistaken in concluding that a true relationship exists.

The most common regression technique is Ordinary Least Squares (OLS).[79] However, OLS cannot solve the problem of *selection on unobservables*: unknown differences between control group and intervention group that lead to different results. Providing these unobserved variables do not change over time (such as education, rural/urban divide) this problem may be solved by using a difference-in-differences approach (Diff-in-Diff). This approach is applied if change in both the intervention group and the control group can be measured at two moments in time (a baseline and a follow-up survey, as was done in the case of the EARP chapter 3). The Diff-in-Diff technique analyses changes over time (before and after the intervention): $(Y_1-Y_0) = a + b(X_1-X_0) + c(Z_1-Z_0)$. Now, if Z does not change over time, $Z_1=Z_0$ and therefore $(Z_1-Z_0)=0$. This means that the variable can have no impact on the change in the dependent variable (Y_1-Y_0). In the case of the electricity roll-out for example, the assumption of Diff-in-Diff is that – in the absence of EARP – both the project and control communities

79 The term OLS refers to the specific technique that is used for the computation of the coefficients.

would have developed similarly over time. This assumption is called the parallel trend assumption. Diff-in-Diff allows the researcher to control for all confounding factors that may have an impact on the outcomes of interest and that are constant over time: it is a way to eliminate or filter out *time-invariant* unobservable variables. With this basic 2x2 design (before-after & control-treatment), programme impacts are estimated by calculating the difference in outcomes between treatment and control groups after programme implementation minus the difference in outcomes between the two groups prior to the implementation.

In this study another regression technique was also used: the *probit analysis* (probit estimation). OLS assumes a continuous variable (such as time, or wood usage). Sometimes, however, the variable of interest is a *binary variable*, which has only two values: for instance, a household does or does not own a biogas digester. With a *probit* analysis it is possible to estimate the *probability* that an observation with particular characteristics will fall into one of the two categories. And as probability is a continuous variable, it may be estimated using standard regression techniques. Propensity score matching, for instance, may use probit models for estimating the probability of pertaining to a specific category.

Coming back to the RCT as applied for the solar lamps, one of the major problems is whether the participants know that they were participating in an experiment and so changed their attitude or normal behaviour – for example, to please the researcher. The *Hawthorne Effect* and *John Henry Effect* describe this phenomenon. Since participants in an RCT have given informed consent, in most cases they know to some extent that they are under scrutiny in an experiment and therefore these effects cannot be totally eliminated. But they can be kept as small as possible. For example, in the ToughStuff RCT, the surveys used for the study were presented as a component of a general survey on energy use in Rwanda and some families received a solar lamp as appreciation for their participation, while others received other rewards for participating in the survey. This also addresses the potential concern that randomly assigned treatment to one group may induce uncomfortable feelings in the other group.

The randomised controlled trial on personal solar lamps is the first RCT ever conducted on personal solar lamps.

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In 2008 the Promoting Renewable Energy Programme was launched in order to promote access to of renewable energy in developing countries and to mitigate the negative effects of the use of energy on the climate.

Between 2010 and 2014, the impact was evaluated of the roll-out of the electricity grid, the national biogas programme, the marketing of personal solar lighting, and a project aimed at strengthening the energy authority in Rwanda. To that end, both quantitative and qualitative research methods were applied.

The renewable energy interventions were relevant to the objectives of both the Government of Rwanda and the Promoting Renewable Energy Programme. The electricity roll-out programme has been efficient; other activities were less efficient. The electricity roll-out programme has also been effective in providing access to energy. Impacts on household income and expenditure are modest, while welfare impact is most pronounced in the case of grid-supplied electricity. A strict application of the market approach for small energy interventions is at odds with aspiring to a significant reduction of CO_2 emissions.

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