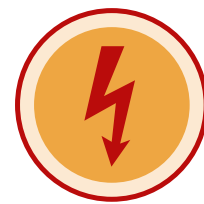




ACCESS TO ELECTRICITY

Technological options for
community-based solutions



www.wisions.net

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BACKGROUND

The current debate on the future prospects of the energy system, energy security, climate change and the reduction of energy poverty is clearly linked to the urgent need for sustainable energy technologies (SET) to be more widely implemented. A global transition to a sustainable energy system is crucial in order to satisfy the worldwide energy demand for the future.

The development and deployment of climate friendly technologies constitute a core element of this future system and are key to achieving effective global climate change mitigation. However, if the usual path of the gradual diffusion of technologies is followed, change will not happen fast enough to meet the demanding challenges ahead. One of the most important barriers is the lack of knowledge about existing and appropriate options, especially in the developing world.

WISIONS INITIATIVE

WISIONS of sustainability is an initiative by the Wuppertal Institute supported by the Swiss-based foundation Pro-Evolution. The name WISIONS is a combination of the initials of the Wuppertal Institute (WI) and our visions for sustainable development.

The initiative was launched in 2004 to promote practical and sustainable energy projects. Since then, WISIONS has not only become well established, it has also learned a lot about the barriers that still hinder the widespread dissemination of sustainable energy solutions and successful implementation models, especially in developing countries and emerging economies.

In addition to the new Technology Radar, which serves as an information tool, practical financial support for the implementation of innovative and feasible energy projects and models is provided via SEPS – Sustainable Energy Project Support. Since 2004, more than 50 projects around the world have been selected. Some successful examples of these projects are described in this publication as case studies to illustrate the technologies and also feature on our website.

WISIONS TECHNOLOGY RADAR

The aim of the newly developed Technology Radar is to give a comprehensive and transparent overview of the existing renewable energy technologies and their possible contribution to meeting basic energy needs, today and in the future. It will serve as a scientifically founded source of information for individuals who come from different backgrounds but share a common interest in identifying (and applying) solutions to address the global challenges related to the need for energy.

On our website, www.wisions.net, the basic energy related needs are defined as water issues, lighting, electricity, food issues and heating/cooling and these energy needs guide you through the Technology Radar.

The first phase of the Technology Radar examines the options for providing access to electricity using renewable energy sources. The focus of both this brochure and the internet platform is on those technological options that have demonstrated significant potential for community-based solutions.

KEY QUESTIONS ADDRESSED FOR EACH TECHNOLOGY

- What is the technology's potential contribution to global sustainable development?
- How great is its CO₂ reduction potential?
- Can the technology help to achieve the Millennium Development Goals?
- Does the technology have negative or positive environmental impacts?
- What social and regional impacts are linked to its implementation?
- How will the technology be developed in the future?
- What type of set up is needed to ensure the technology is economically viable?

TECHNOLOGIES ADDRESSED

In this brochure we examine wind electric power, micro-hydro power, biomass electric power, including biogas and vegetable oil-based solutions, as well solar photovoltaic electric power. You will find, for each technology, a short, clear description of the techni-

cal aspects, an evaluation of the technology's global potential, statistics on environmental and economic issues, and an explanation of the links to social issues. The socio-economic aspects are crucial and similarities are seen in the small-scale solutions. These are summarised before the technology descriptions.

SEPS CASE STUDIES

For each technology that is considered, a case study, supported by WISIONS under its "Sustainable Energy Project Support – SEPS", illustrates the practical implementation of the technology and lessons learned in the field. To ensure that the projects it chooses to support are sustainable, WISIONS has developed key criteria, which are used to assess and describe each case study. In addition to examining the technical and economic viability of the projects, environmental and social aspects are highlighted. And, even more importantly, the results and lessons learned for future replication are presented.

We particularly support community-based solutions, where the residents in the community are beneficiaries as well as agents of change. Essential success factors, such as social acceptance, motivation, feelings of affiliation and ownership, can be better developed when the local population is actively involved right from the conception of the technological solution through to the point where it is put into operation.

Community-based approaches are difficult to achieve. However, by means of social empowerment and a more integrative approach to development, they are more likely to bring long-lasting benefits to people and to lead to paths of sustainable development.

NEXT RADAR TOPICS...

In the next phase of the Technology Radar we will look at the technologies that can be used to meet lighting needs, for better education, security or to enable people to benefit from more of the day. Following that, the focus will be on solutions for the preparation of food in healthy ways using local resources. Thereafter, the need for heating and cooling, as well as the need for energy to supply clean water for drinking, cooking, washing or land irrigation, will be analysed and related technologies illustrated.

ACCESS TO ELECTRICITY

ACCESS TO ELECTRICITY - ACCESS TO DEVELOPMENT OPPORTUNITIES

Electricity is possibly the most versatile form of energy in modern life. It serves many purposes, from recharging the battery of a mobile phone and running a refrigerator at home to providing the power to run an energy-intensive production plant.

Although the provision of electricity does not produce any direct benefit for human well-being on its own, securing access to electricity is today regarded as a crucial human need and a key factor in human development. It offers people many options for shaping their lives.

However, according to the International Energy Agency (IEA), about 1.5 billion people still lacked access to electricity in 2008 [1], see Figure 1. Securing access to electricity is, therefore, regarded as a key factor in meeting the Millennium Development Goals adopted by the international community in 2000 [2].

ELECTRICITY FROM RENEWABLE SOURCES - TECHNOLOGICAL OPTIONS

Securing universal access to electricity by using renewable energy sources is technically feasible. A broad range of technological options, which can meet almost any requirements, are available. Solutions can comprise the connection of users to large distribution networks (on-grid solutions) or the application of power supply systems that can operate autonomously (off-grid and mini-grid solutions). This brochure concentrates on the latter solutions; technologies for large-scale distribution are not covered.

OFF-GRID AND MINI-GRID SOLUTIONS

Off-grid solutions consist of low capacity power generation equipment (tens or hundreds of watts) that can provide electricity to satisfy basic household demand or meet the power needs of small businesses. Very small hydro turbines (pico-hydro), small wind turbines or solar home systems (SHS) are some examples of off-grid technological options.

Mini-grids refer to relatively small electric networks that are used to distribute alternate electric current within a village or neighbourhood. The local and decentralised character of mini-grids often facilitates the use of renewable energy resources, which also have a decentralised nature. Mini-grids are usually supplied from a single power generation station (e.g. micro-

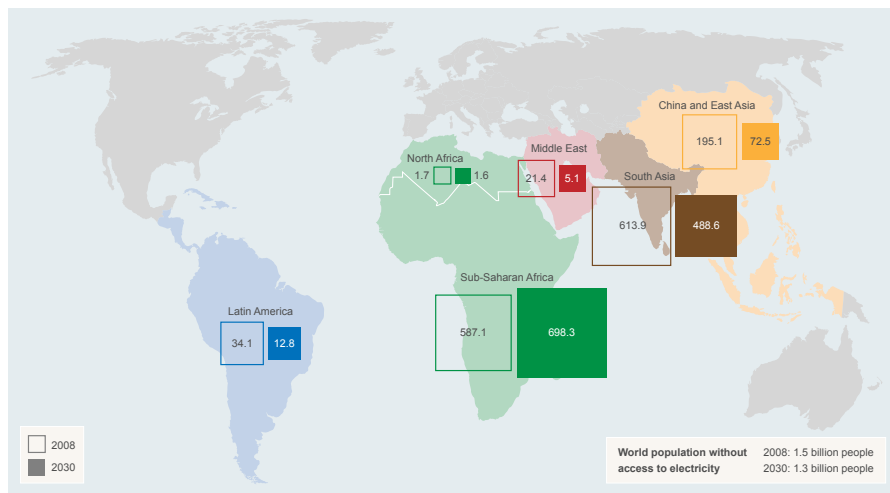


Figure 1. Number of people without access to electricity in the Reference Scenario (millions)
Source: IEA World Energy Outlook 2009

hydro power plant, wind turbine, combustion engine running on biogas or a photovoltaic array). However, the combination of two or more generation technologies (hybrid power systems) attracts greater interest, as this provides the potential to improve the reliability of the electricity supply.

The main role of off-grid and mini-grid options in global energy supply is to enable areas that are not covered by central networks, and will not have the option to be connected to a grid in the near future, to access electricity.

THE SOCIO-ECONOMIC CONTEXT

The development of off-grid and mini-grid solutions may result in a significant improvement in the ability of individuals and communities to ensure the livelihood of the population (positive impacts). On the other hand, a community-based approach often encounters additional (non-technical) challenges, which are clearly linked to the socio-economic structure of the target community.

IMPACTS

Among the potential positive impacts of assuring access to electricity, the following areas of improvement should be highlighted:

- Better education and health conditions

Electricity services enable the use of lighting, information systems and electronic teaching resources in schools, which may significantly improve educational opportunities. The reli-

able provision of electricity allows health centres to run cooling devices for vaccines and to use and sterilise electrical medical equipment. Electricity can also provide lighting for operations to be carried out at night. Access to electricity also helps attract health professionals, social workers and teachers to work in poor rural areas.

- **Improving communications**

One of the most immediate effects of having access to electricity is the associated access to communication technologies: the ability to use a radio or recharge a mobile phone is one of the most basic uses of electricity.

- **Business options**

The establishment of small craft enterprises (e.g. hairdressers, tailors), skilled workshops (e.g. carpenters, metal welding) and agricultural processing facilities (e.g. drying, milling, pressing) may be supported by the ability to use electrical equipment.

- **Gender issues**

Better education, improved health conditions and small business opportunities can improve the living conditions of women in particular. In urban settlements or unsafe areas, street lighting can also improve the safety of women and allow them to go out or work after sunset with less fear of being attacked.

CHALLENGES

To ensure the long-term provision of electricity services, and the associated positive impacts, the active involvement of the local population and many other participants may be necessary. Issues that commonly arise can be divided into three categories:

- **Community participation and organisation**

Involving people at the point of conception of the project may reduce the risks of failure during and after the implementation stage. A fundamental starting point is the identification of the actual needs that can be addressed by providing or enhancing access to electricity. This information is essential even for the technical design of the project.

Clear and transparent information about the technological options that are applicable should be provided at the early stages of the project. Unrealistically high expectations, together with low awareness about the work involved in operating the system (e.g. daily charging of manure in the case of biogas digesters), may lead to users becoming disillusioned at a later stage and choosing not to continue adopting the technology.

Community participation at the planning stage can also help to reduce costs. Local labour can be used for the construction and installation of the technology. Local availability of some special skills (e.g. experienced masons, carpenters, etc) may help the process.

- **Financial issues**

The capital costs of off-grid or mini-grid systems in most cases exceed the investment capacity of those communities that do not have access to electricity. This problem is often reinforced by a lack of access to commercial loans and also by the fact that there may not be a direct financial benefit to the users in implementing the technology.

The most common scheme adopted to overcome this difficulty is the provision of subsidies to cover either part of, or the full amount of, the initial costs of the project or technology implementation. Financial mechanisms may include price discounts, grants and loans at favourable rates to allow potential users to purchase off-grid equipment, or assistance for local entrepreneurs in establishing (or improving) energy businesses to supply power or power-related services.

Securing the finance for the running costs - and consequently the long-lasting operation of the solution - is a crucial component of each strategy. The most common approach is to establish a tariff scheme that allows the entrepreneur or the responsible organisation to cover operation and maintenance costs, repay any loans and make a profit. Communication and consultation is necessary in order to establish the proper tariff or repayment scheme, one that is suited to the ability to pay and to the consumption patterns of the end users.

- **Building local capabilities**

Technical and managerial skills are a prerequisite for ensuring the continued operation of the system. Local technicians should be trained to be able to tackle failures of the installed systems. Training in bookkeeping and some managerial skills will also be needed to run newly established energy businesses and/or community funds.

Electrification measures can include components that promote the productive use of electricity in order to improve the income generation potential of the population and also the overall financial sustainability of the activities. Some examples are components supporting irrigation, mechanical processing in agriculture or the establishment of local businesses providing services such as battery recharging or communications. The promotion of the productive use of electricity may include aspects such as training in entrepreneurship and support in accessing new markets.

WIND ELECTRIC POWER

Wind power systems transform wind energy into mechanical or electrical energy. Wind turbines are the main component of wind power plants. Modern wind turbines use the aerodynamic lift principle, i.e. the same principle applied to generate the lift forces on the wings of aircrafts. The wind flow passes over the rotor blades of the wind turbine generating a lifting force that makes the rotor rotate.

Equipment and strategies to regulate power generation are important components of modern wind power systems. These perform functions such as the optimisation of wind resources utilisation, the protection of the system in the case of extreme winds and the monitoring of the system in order to assess the need for maintenance or repairs. Additionally, wind power systems for off-grid applications commonly include storage capacities, as shown in Figure 2.

GLOBAL POTENTIAL

Wind power can make a significant contribution to a sustainable energy system. Wind resources are relatively evenly distributed around the globe. More than 20% of the global electricity demand could be met by wind power by the year

2050 [3]. Exploiting offshore wind power potential, along with the rapid growth in onshore wind power, and integrating wind power properly into electricity networks will be the key issues for developing the global potential for wind energy.

ENVIRONMENTAL ISSUES

Wind power generates no CO₂ emissions other than small amounts in the production and installation of turbines. The technology has no water needs. However, wind power has an environmental impact at a local and regional level. This is mainly due to the visual impact, which can include shadows from the rotating turbine blades, noise from the turbines and the risk of bird collisions and disruption to wildlife. These potential disadvantages may be alleviated by careful selection, design and operation of the site.

DEVELOPMENT STATUS AND PROSPECTS

Globally, installed wind capacity has grown by 20-30% every year since 2001. There are wind farms in more than 40 countries worldwide, 13 of which have more than 1,000 MW of installed

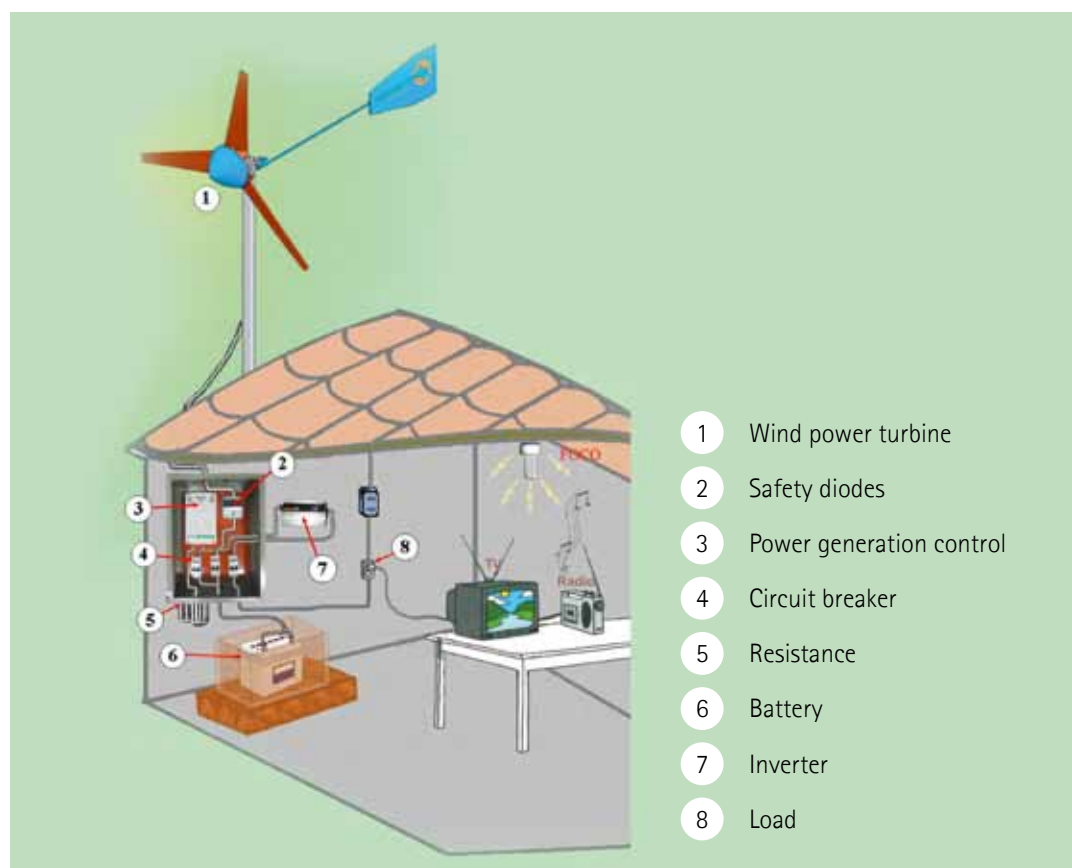


Figure 2. Schematic view of a wind power system for off-grid applications. Source: Soluciones Prácticas, technical handbook prepared during the project in “El Alumbre”.

capacity. In both the short and long term, it is expected that this impressive level of growth will be maintained, or even increased.

Although market deployment is underway, there is still some research, development and demonstration to be done if wind is to contribute a significant share of the power supply in a low-carbon society. The technological advances needed include the optimisation of the design and construction of equipment components, higher production volumes and advanced materials.

Modern wind plants are already able to operate during network failures. The biggest challenge for the future will be to develop strategies to integrate considerable shares of the fluctuating power from wind plants into the electricity network.

Significant efforts have been made to adapt small wind technologies for the technical and market requirements of developing countries. Because of this, the ability to locally manufacture small wind solutions adapted to suit particular local situations is already emerging. This may well contribute to the diffusion of the technology in the near future.

SOCIAL ISSUES

Lessons learned from community-based wind projects stress the need for developing local technical skills and for the involvement of the local population in the development of the system. Training local technicians may guarantee the smooth operation of the systems. A well functioning wind system becomes an object of pride for the community, especially when individuals' efforts have contributed to the construction. When local plants for the manufacture of equipment are established, an increase in the regional employment potential can be expected.

ECONOMIC ISSUES

Three major trends have dominated the cost of onshore wind turbines in recent years:

1. Turbines have become larger and taller.
2. The efficiency of turbine electricity production has increased steadily.
3. The investment costs per kW of installed power decreased up to 2004.

The capital costs of wind power systems connected to a central grid vary between US\$ 1,450 and US\$ 2,200 per kilowatt [4]. This figure is dominated by the costs of wind turbines, which constitute 74-82% of the total investment.

The capital costs of small systems that are not connected to a central grid and include storage capacity (bank of batteries) may reach levels of between US\$ 4,160 and US\$ 5,430 per kilowatt [5].



WIND ELECTRIC POWER CASE STUDY

SMALL WIND POWER GENERATION SYSTEMS TO PROVIDE CLEAN ENERGY IN POOR RURAL AREAS – A PERUVIAN EXAMPLE

AIMS

- To show that small wind power generation systems are a suitable technology for rural electrification in Peru
- To improve the living conditions in the rural community through better lighting and the access to modern communication and information technologies

PROJECT DESCRIPTION

The project was designed to electrify an entire rural community including a school and a medical centre in a village in Peru, a country where wind power has not yet received much attention. The selection of the village El Alumbre was based on the favourable wind potential and the willingness of the authorities and the population to contribute to the project. The project, which was carried out by Soluciones Prácticas, started with a detailed socio-economic survey to establish the levels of demand for energy within the community and the current spend on energy by the population. Another important step for the success of the project was the training of users and technicians. The trained

local technician has the responsibility of managing the system and collecting the payments for the electricity. Based on the results of the survey, it was decided to install 22 wind power generation systems in 2007 – this included the provision of electricity for the school – and then to install an additional 13 wind power systems in 2008, which resulted in the medical centre also gaining access to electricity. The entire project to implement the wind power systems was based on the active and effective participation of the whole community in every aspect. The District Municipality took over the legal ownership of the electrical systems once the project was finished. To ensure the future sustainability of the project, a local management model that takes into account the social relationships has been incorporated.

TECHNOLOGY, OPERATIONS AND MAINTENANCE

The wind power systems used in El Alumbre are small installations each providing electricity for one unit i.e. household, school or medical centre. The small 100W wind power generators are 10m tall and the 500W ones are 12m tall. Both systems consist of different components that ensure their operation; in the project a 100W/500W micro wind power generator, a 35 Amp wind power controller, a 130 AH battery, a 12 VDC/220 VAC inverter and a control panel were used for the construction.

The system works independently, so the user does not have to operate or regulate the power generator. The structure of the windmills was specially designed so that the technicians could easily climb to the top. Most of the components were purchased in Lima because the costs there were lower compared to regional prices due to the larger market in the capital. Users and potential local technicians/administrators were trained to operate and maintain the system. The community and local authorities then chose one of

the potential technicians to be responsible for managing the system as a one-person micro enterprise.

FINANCIAL ISSUES AND MANAGEMENT ISSUES

The estimated cost for the individual wind turbines was as high as US\$600/€400 (for the 100W turbines) and US\$ 1800/€1200 (for the two 500W turbines at the school and the medical centre). The families now spend less on average on energy than they did prior to the project. They used to spend more than US\$5/€4 a month



Location:

El Alumbre, Peru

Costs:

Total: € 63,700

WISIONS financial support: €24,500

CO₂ Reduction:

38,32 kg CO₂/year

Partners Involved:

Soluciones Prácticas

Website: www.solucionespracticas.org.pe

E-mail: info@solucionespracticas.org.pe

Duration:

2007 - 2009

for energy from kerosene or candles etc.; now, each family pays US\$3/€2 a month for a better quality service and for greater periods of light. With a family income of between US\$28/€18 and US\$148/€100 per month, this represents a significant saving. Since the end of the project implementation period, the District Municipality has legally owned the system and the trained technician has been in charge of the technical and administrative operations. Together with the Community Electrification Committee, the users and the Control Unit, the technician and the District Municipality also belong to the group of five stakeholders. This local management model ensures the sustainability of the project, as it takes into account the social relationships that exist within the community.



ENVIRONMENTAL ISSUES

The use of the wind power generating systems has replaced the former use of conventional energy such as kerosene, candles and batteries. In order to save energy, efficient light bulbs have been installed in most houses and in the school. The total volume of power used in the village now amounts to 2737 kW/year, which is a reduction of 38.32 kg CO₂/year. The consumption is 43% less than estimated upfront, as the families consume less electricity than the predicted amount of 400W/day/family. In future, the energy consumption is expected to increase – but only to a limited extent.

SOCIAL ISSUES

As a result of the access to electricity, several small businesses such as two radio broadcasting stations, a sweater-making business and a cheese factory have been established. Furthermore, access to electricity has enabled the local population to use modern information and communication technologies. As an example, the

percentage of the local population using mobile phones has increased from 5% to 95%, due to the access to electricity.

RESULTS AND IMPACTS

In total, 35 small wind generators were installed. Now the family homes are provided with electricity for lighting, radios, TVs, DVDs and for charging batteries and, in addition, school children are able to study and do their homework at night. In the school the energy is also used to operate 4 computers and in the health care centre to operate a refrigerator to store vaccines. There is no doubt that the project has helped the families to improve their standard of living in many ways. So far the project has gained attention from the national media as well as from local and provincial authorities and university students. The local authorities have already expressed their interest in further projects.

POTENTIAL FOR REPLICATION

Wind power is not very widespread in Peru; the project was the first to electrify a whole community with the use of wind power and so the success of the project can serve as an example for further wind energy projects. The critical points to be aware of when considering replication are the funding and the purchase of technical equipment, which is not available in rural



areas and which has to be transported from bigger cities to the construction site.

LESSONS LEARNED

Instead of small wind power systems for each house it would be better to install centralised generation for small housing complexes within the community and connect those with micro grids. That way more powerful equipment could be installed. Furthermore, the implementation should take place during the summer to avoid delays due to winter rainfall, and future projects should plan an additional budget to purchase basic equipment for the electrified public buildings so that the energy available can be used to benefit the community immediately.

Source: Final Report Submitted to WISIONS by José Chiroque from Soluciones Prácticas, Peru

MICRO-HYDROELECTRIC POWER

Micro-hydroelectric plants are appropriate for the provision of electricity where the demand for power is relatively low (e.g. below 100 kW) and where a constant flow of running water is available. This is often the case in villages or industries located in rural regions. Micro-hydro projects are commonly designed in "run-of-river" schemes, i.e. configurations where only part of the water flow of a stream or river is deviated to drive the hydroelectric units, as shown in Figure 3.

As in other hydroelectric options, in micro-hydroelectric plants the flow of water turns a water turbine. The turbine drives an electric generator, which transforms the rotary movement of the turbine into electricity. The total power delivered to the turbine is proportional to two factors:

1. the rate of water flow, and
2. the hydraulic head of the plant, i.e. the difference in elevations between the water level of the water source and the turbine outflow.

GLOBAL POTENTIAL

In regions where water flow is readily available, micro-hydro can be used to improve the provision of electricity or even to meet the electric power needs of local populations and/or industries. The technology is suitable for feeding both off-grid

configurations and grids in distributed schemes. Micro-hydro can, therefore, be an important component of the energy development plans in many countries.

ENVIRONMENTAL ISSUES

Greenhouse gas emissions associated with the operation of micro-hydroelectric plants are considered to be marginal. However, the operation of micro-hydro plants involves modifications to the natural water flow. In the case of "run-of-river" schemes, only a section of the stream will be used (i.e. between the intake weir and the outflow of the turbine).

In the case of schemes that use reservoirs, the operation of the plant affects the water flow downstream of the dam. Changes in the water flow can have a critical impact on the habitats of local species (e.g. fish, birds and mammals).

In order to guarantee the minimum supply of water needed to conserve local ecosystems, water management strategies should be developed in situations where water flows are modified.

SOCIAL ISSUES

The development of a micro-hydro project can lead to synergies or conflicts with other issues. For example, a micro-hydro

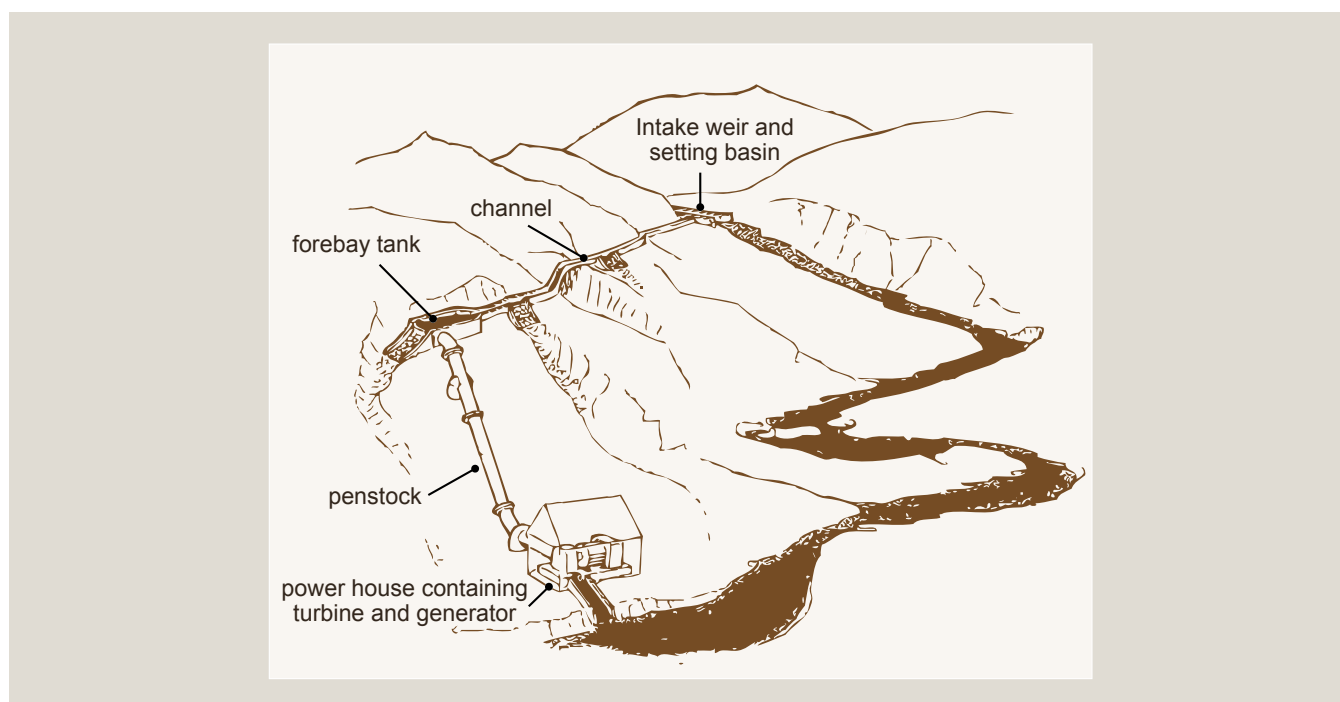


Figure 3. Typical configuration of Micro-hydro plants. Source: Practical Action, technical brief on micro-hydro power

project can be integrated into programmes addressing other local needs such as irrigation, flood prevention, flow regulation for navigation or the fostering of tourism activities. On the other hand, the operation of a micro-hydro plant can also result in conflict: competition with other programmes for the use of water flow or negative effects such as floods or an insufficient water flow downstream of the plant.

Measures to avoid conflict and harness synergies, as well as other aspects of local development, should be included in the project strategy from the outset.

DEVELOPMENT STATUS AND PROSPECTS

A set of terms – from pico-hydro to large-hydro – is commonly used to differentiate technological options depending on the size of the plants, as shown in the table 1. The power capacity values are indications only and do not claim to be exact limits.

Most of the water turbines and generators used in micro-hydro plants are commercially available. The technologies are already mature and no significant cost changes are expected. However, in some developing countries with excellent resource availability, access to the technology can be improved by developing local hardware and software supply capacities (e.g. local production and engineering skills).

The development of in-stream turbines is gaining increased interest. They are designed to better use the kinetic energy of water flow. The installation of such turbines does not require complex civil works to divert the water, as they are submerged in the river and commonly fixed to a floating platform. In terms of development, some concepts in this field appear to be reaching commercial maturity.

ECONOMIC ISSUES

Capital costs of hydroelectric systems greatly depend on the particular features of the site (e.g. accessibility, need for special civil works etc.). Investment in simple systems at household level (pico-hydro) may be around US\$ 1,500 per kilowatt. Capital costs of micro-hydro systems for the supply of mini-grids can reach levels of between US\$ 2,000 and 2,800 per kilowatt [5].

Table 1. Usual classification of hydroelectric schemes
Adapted from: Practical Action, technical brief on micro-hydro power

Usual term	Capacity	Main applications
Pico-hydro	few tens of Watts - 5 kW	single household
Micro-hydro	5 kW - 100 kW	mini-grids, small communities, rural industries
Mini-hydro	100 kW - 1 MW	mini-grids, villages, industries, or grid connected
Small-hydro	1 MW - 15 MW	usually grid connected
Medium-hydro	15 MW - 100 MW	grid connected
Large-hydro	> 100 MW	grid connected



MICRO-HYDRO POWER CASE STUDY I

COMBINED PICO-HYDRO AND PV SYSTEM FOR THE ELECTRIFICATION OF 10 COMMUNITIES IN THE ANDES

Location:

Chirinos district, Cajamarca region,
North-eastern Peru

Costs:

Total: € 78,931
WISIONS financial support: € 40,400

CO₂ Reduction:

32,070 kg CO₂/year

Partners Involved:

Practical Action
Website: www.solucionespracticas.org.pe
Green Empowerment
Website: www.greenempowerment.org
E-mail: palvarez@solucionespracticas.org.pe
and anna@greenempowerment.org

Duration:

April 2006 – September 2007

In this rural electrification project, both solar PV and pico-hydro systems were implemented in a total of 10 communities in the Cajamarca Region of Peru. The aim of the project was to improve both the standard of living of more than 400 families and also the health care and education in the area through the electrification of schools and health outpost.

Prior to the technical implementation of the project, surveys were carried out amongst the communities and residents were consulted about their priorities for electricity use. As a result of this research, combined with data on the availability of streams and budget considerations, the decision was taken to install one pico-hydro scheme in the community of Balcones, to provide energy for domestic use in 31 homes, as well as for 2 schools, a health outpost and a community building. Additionally, 15 Photovoltaic Systems (PVS) would be installed in schools, health outpost and community centres in nine other communities.

One of the major activities during the implementation stage of the project was to develop technical and managerial skills within the communities, in order that each community would be able to own and operate the project on an economically sustainable model. In each village a committee was chosen to manage the finances and collect payments. The project team focused heavily on non-technical aspects, as experience shows that these are the most likely reasons for a project to fail. A few months after the project was complete, and again after three years, the technical and social aspects and, in particular, all matters relating to the management of the service were evaluated in order to learn lessons for future projects.

TECHNOLOGY, OPERATIONS AND MAINTENANCE

In order to reduce dependence on external factors and to lower costs – and to make the project more feasible for implementation in poor areas – the pico-hydro system was primarily constructed from locally manufactured components. The hydro-power system has a gross head of 98 meters and a design volume of 18 lts/seg. It generates 9kW and, therefore, provides electricity for all of the 31 households, small businesses, schools and a health outpost in the community of Balcones. The houses are connected to a mini-grid installed with self-supporting cables. In addition, every home in the settlement has been supplied with an energy control system, to prevent the excessive use of power. One or two people in each community have been trained to operate and maintain the systems.

The solar PV systems installed included 60-85W panels, controllers, inverters, and deep-cycle batteries. The energy use includes 11W and 15W compact fluorescent lights, cell phones, radios and, in the case of schools, a TV/DVD system. The project included the provision of a range

of educational DVD programs, such as "The Human Body", multiplication, and folklore from the various cultures of Peru. Several school systems also light up the housing areas for teachers from other areas who come to work and live in these rural communities.

FINANCIAL ISSUES AND MANAGEMENT

The average project cost for each solar community is estimated at €6546 and the micro-hydro with home electrification at €26,556. The costs include all equipment, installation, training, community work and administration. The Municipality of Chirinos and its communities contributed a quarter of the total project costs. After the project was completed, the Municipality became the legal owner of the systems but signed a contract of concession to the community for management. The community in turn elects an Operation and Management Unit (OMU) to provide the service, do maintenance and collect the monthly fee (10 soles a month = ~\$3 per household). There is also a supervising committee of users to oversee of the OMU.

In some communities, the solar school systems are now managed by the Association of Parents and the teachers of the school, while in other communities there is an independent "Light Committee". After 4 years of operation, there is an average



of 255 soles (~€70) in each community's solar maintenance account. The funds have been raised by charging a small fee for community members to charge cell phones off the system, showing movies at the school house, organising events, selling snacks at the school, and in one community, providing micro-loans (with interest) from the maintenance fund.

ENVIRONMENTAL ISSUES

The replacement of oil lanterns for lighting and batteries for radios and other applications with electricity from solar and hydro power has led to the reduction of 32,070 kg CO₂ emissions per year.

SOCIAL ISSUES

The project focused on using existing local skills and local organisations to implement, operate and manage the systems. The participation of the population throughout the implementation process was encouraged to ensure the sustainability of the project after the departure of the project team. The electrification of households, schools and health outposts provides the possibility for the population to read and learn after nightfall, improves mobile phone communication, broadens educational opportunities and also facilitates better medical care.

RESULTS & IMPACT

421 families – an estimated 2100 people – have gained access to electricity (31 of these from the pico-hydro scheme), which has significantly improved the quality of life in the communities. The bottom-up implementation approach has promoted local leadership and community decision-making. The project can serve as an example of an appropriate development model that could be replicated in village-scale renewable energy projects. In addition, the

project was also the first joint solar installation undertaken by these two partners, so it also served as an opportunity to build technical skills and lay the groundwork for a partnership that has since flourished.

POTENTIAL FOR REPLICATION

This development model could be replicated in other rural communities both in Peru and other developing countries. In Peru's northern Andes, for example, approximately 800,000 inhabitants have no access to electricity or other modern energy services. The modular design technology, the short timeframe that is required for the implementation, and links to poverty alleviation and rural economic development are also positive reasons to replicate this project in other parts of the world.

LESSONS LEARNED

An evaluation after four years of operation showed that the efficiency of the management organisation varied greatly between the nine communities. Where the organisation was solid (e.g. made up of the Parents' Association, teachers or a committee), the system continued to function and the maintenance costs were low. However, in some of the communities with weaker management, raising the funds for the operation and maintenance of the system has been a problem. In fact, where there was weak management, two of the panels were stolen. Although the financial responsibilities were agreed and certified in each community, many people have made no monthly contributions. Because of this, future projects should identify fund-raising mechanisms and, if necessary, involve the municipality.

Another lesson learned is that awareness raising amongst the users with regards to the advantages of renewable energy, as well as its limitations, is very important. The pico-hydro project provides electric-

ity for each household; the solar projects were designed to generate power solely for communal uses. Whilst providing electricity for communal purposes – such as for schools – can bring benefits, communities seem to prefer home electrification and are more willing to pay for this service. Inevitably, supplying electricity to every household would multiply the scale of the project and budget requirements. For future projects an in-depth evaluation of the pros and cons of providing domestic energy vs energy for communal uses should be made.

Long term monitoring showed that the electricity at the rural health outpost is infrequently used because medical staff only visit these rural communities once a month – and only in the daytime. There are community-based health promoters, with access to the health outpost, but their homes are at quite a walking distance from the health outpost, so they rarely walk to the health outpost at night to get supplies to treat a sick person. In future projects, supplying health outposts with electricity will only make sense if there are permanent staff, resources such as vaccine refrigerators or sterilisation equipment and a regional health system that will supply the vaccines. The greatest use for electricity turned out to be for charging mobile phones for many people in the community, and for operating DVDs for education and training.

Finally, it is worth noting that the grid may arrive in the next few years but, when the community embarked on the project, their representatives signed a contract allowing the solar systems to be used by more distant villages should the grid arrive. With regards to the micro-hydro scheme, the community is considering connecting it to the grid, or using it independently for coffee processing.

Source: Final Report submitted to WISIONS by Practical Action (2007). Updated information from Practical Action and Green Empowerment 2010.

MICRO-HYDRO POWER CASE STUDY II

MICRO-HYDRO POWER FOR COMMUNITY CORN MILL AND LIGHTING IN SOUTHERN MINDANASO, THE PHILIPPINES

This project combines the installation of a community-based micro-hydro power (MHP) system for household lighting with the establishment of a multifunctional mill in the communities of Datalnay and Dlumay in Southern Mindanao, the Philippines. It is being jointly implemented by SIBAT and its local partner CLANS (Centre for Lumad Advocacy and Services).

The project beneficiaries are subsistence upland farmers, belonging to the B'laan tribe of the Lumad Ethnolinguistic Group. The MHP system is expected to produce around 11kW, and will provide off-grid electricity for lighting in around 60 households. Over 300 households are also targeted to benefit from the mill enterprise, which will provide energy for the post harvest processing of rice and corn. The intention is that the mill will also provide energy in the future for processing coffee. In addition, the tailrace water of the MHP will be used for irrigation to expand the agricultural production areas.

The energy project is part of an integrated area approach to develop climate-resilient and village-level sustainable development initiatives. In addition to the provision of

energy, it addresses the community's food security concerns through the improvement of traditional rice and corn varieties and the expansion and diversification of food production areas, as well as promoting the rehabilitation of critical watershed areas for environmental management and the sustainable use of hydro power.

TECHNOLOGY, OPERATION AND MAINTENANCE

The water source for the hydro project is the Bangat Spring, which has the potential to operate the mill for 8 hours per day with an estimated milling capacity of 150kg per hour for 8-10 months per year. The 11 kW of energy produced will be enough to power the 5-7 kW multifunctional agrimill and provide electricity to the surrounding households.

Local community members assisted in the construction phase of the project, predominantly by helping to build the main components of the installation i.e. the power house and the agrimill, by undertaking tasks such as digging canals, hauling materials and equipment and by carrying out carpentry and masonry work. The MHP powerhouse site was deliberately designed to accommodate the directly coupled multi-functional agrimill, which was custom-built for this purpose. The next steps during the implementation



process were the construction, installation, testing and commissioning of the powerhouse and post harvest technology.

The upcoming phase of the project, which covers the period from April to June 2010, mainly comprises the completion of the electromechanical components.

FINANCIAL ISSUES AND MANAGEMENT

Alongside the installation of the corn and rice mill, capability-building courses have

Location:

The Philippines

Costs:

Total: € 63,800

WISONS financial support: € 29,300

CO₂ Reduction:

28,670 kg CO₂/year

Partners Involved:

Sibol ng Agham at Teknolohiya Inc. (SIBAT)

Website: www.sibat.org

Center for Lumad Advocacy and Services (CLANS)

Duration:

2008-2010





been carried out to equip the community with entrepreneurial skills and technical and financial managerial competencies. The MHP system is supported and sustained by tariff payments from household consumers and corn mill users. A community project management committee has been formed for the mill enterprise to formulate and enforce the maintenance, operation and management policies.

The project is supported by WISIONS/SEPS, Green Empowerment and the German Embassy in the Philippines. Electro-mechanical devices were donated by Canyon Hydro and the Canada Fund for Local Initiatives supports the water and irrigation system.

ENVIRONMENTAL ISSUES

The project addressed the community's food security concerns by delivering agricultural improvements and by making seed banking of traditional rice and corn varieties possible, and simultaneously achieved its stated objective of rehabilitating watershed areas for environmental management and micro-hydro power generation. The project helped to raise environmental awareness among the local population about the need to preserve the watershed.

SOCIAL ISSUES

The first phase of the project included making preparations on a social level in order to ensure that the community was ready for the implementation phase to follow. This involved making the community aware about the concept behind the project and its objectives, as well as setting the work schedules for the civil works, which involved members of the local community.

RESULTS & IMPACT

This project serves as an illustration of the productive use of renewable energy in combination with improvements in agricultural cultivation and processing. The positive outcomes are better food security and an improvement in the health and nutrition of the community.

REPLICABILITY

There is good potential for this project to be replicated nationally, as it fits in with a broader vision to bring water, watershed protection, electricity and sustainable agriculture to 100 villages in the Philippines that are not connected to the electricity grid. The aim is to provide

approximately 10,000 households with electricity through the so-called "100 Villages Campaign". Similar projects have already been successfully implemented in the region.

LESSONS LEARNED

The MHP project started in May 2008 and ends in autumn 2010. It was originally scheduled for implementation within one year, but several external circumstances hindered the project's progress. The Philippines in general, and this region in particular, have been experiencing unusually severe storms and heavy rainfall due to climate change, which negatively influenced the technical work and hauling of material. There were also crop failures resulting from an erratic season, which made it difficult for the locals to provide sufficient food for themselves and the project site.

At the outset of the project, military activities in the region were also a threat to the project team as there was the risk of being caught in the conflict. This situation has been improved during the project by protection given by the local government unit.

Source: Progress Report submitted by SIBAT (June 2010)

SOLAR PHOTOVOLTAIC

Photovoltaic (PV) technologies convert solar radiation directly into electricity. The traditional building block for PV systems is the photovoltaic cell, a thin square plate or film of semiconductor material that measures around 10cm x 10cm. Solar radiation "falling" on the cell induces an electric voltage as a result of the photovoltaic effect. Several cells are interconnected and assembled in PV modules. These modules can be arranged in mounting structures in order to generate more power.

In addition to the PV modules, a PV system also requires other devices that are commonly called the Balance of System (BoS). The BoS comprises different electrical components, such as wires, a DC-AC inverter, a controller and switchboards (in the case of on-grid systems), batteries and a charge controller (for off-grid systems), and structural elements, such as mounting structures or sun-tracking systems. A schematic view of an off-grid system is shown in Figure 4.

GLOBAL POTENTIAL

Photovoltaic technologies have the potential to make a significant contribution to electricity generation in the future. Photovoltaic systems are expected to meet between 6% and 12% of the global electric power demand in low carbon scenarios by 2050 [4] [3]. On-grid distributed applications that are already available, as well as future grid-connected technologies (such as systems integrated into buildings), are set to play the major role in these scenarios.

ENVIRONMENTAL ISSUES

The operation of photovoltaic technologies can be considered as emission free. The technology's main environmental impact relates to the production and later the recycling and disposal of the photovoltaic devices.

The overall level of emissions of greenhouse gases from PV Systems is somewhat marginal. A lifecycle assessment of on-grid silicon photovoltaic systems (without bank of batteries) currently operating in Europe has estimated the total impact on climate change to be between 35g and 92g CO₂ (equivalent) per kilowatt hour generated [11].

Although the current flow of photovoltaic waste is rather insignificant (e.g. around 4 tons per year in Europe in 2008), the recycling and disposal of photovoltaic components is expected to become a crucial issue over the next ten years. The sector seems to be aware of this challenge and some technologies to deal with these disposal issues have already been developed and tested [12]. Recycling policies and regulations are expected to lead to the establishment of proper take-back systems in the biggest PV markets around the world.

SOCIAL ISSUES

Several experiences in the dissemination of PV have illustrated the importance of establishing appropriate local technical

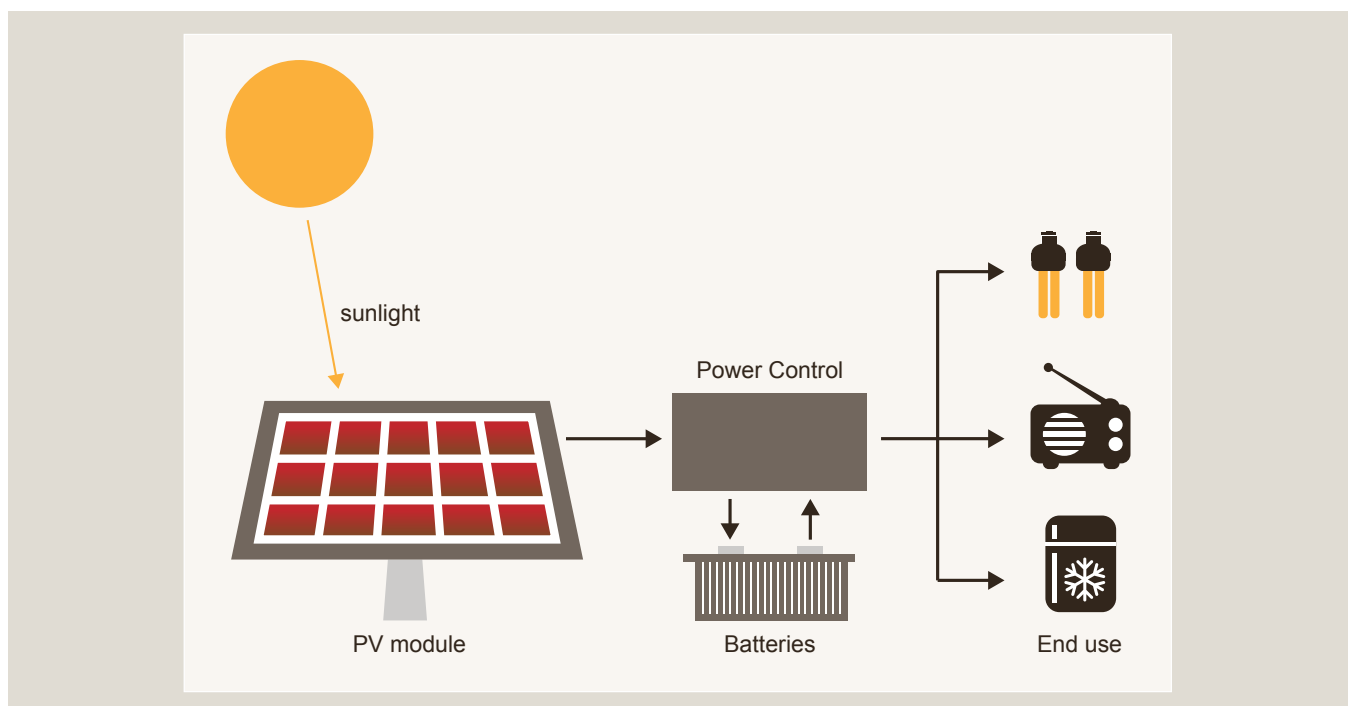


Figure 4. Schematic view of a PV-System for off-grid applications

capacities and regional after-sale systems that can reach all users. Access to technical advice, maintenance and reparation services, availability of spare parts or the means of enforcing warranty agreements can all help to guarantee the long lasting adoption of the solutions.

Proper information and awareness campaigns are also crucial. Often the expectations about the capabilities of the systems are too high and users become disappointed when they see the limitations.

Only well-off people can afford expensive solar home systems without the need to resort to third party funding. This may lead to envy and increased social disparity.



DEVELOPMENT STATUS AND PROSPECTS

The photovoltaic market has been experiencing impressive annual growth rates. Starting from a modest 1,500 MW in 2000, the global, cumulative installed capacity reached 13 GW in 2008 [9]. The PV market accounted for around 5.4 gigawatts (GW) in 2008 and some projections anticipate market levels of 10 GW per year by 2010 [4].

Investment costs for photovoltaic applications remain high. The rapid growth of the PV market has been driven by decisive political support. Several countries have introduced programmes and legislation in recent years in a bid to make the PV market more attractive.

The photovoltaic industry is very dynamic. Optimisation and new developments are expected in a variety of different areas.

Some of the most relevant challenges of PV technologies are:

- the need to increase the conversion efficiencies of commercial systems (currently around 10% for thin films and 16% for crystalline silicon cells)
- the need to improve resource and energy efficiency in the production process, as well as to reduce or avoid the use of rare metals

ECONOMIC ISSUES

Photovoltaic technologies have shown relatively high learning rates over recent decades. PV modules account for around 60% of the total investment costs required for a PV system. The average price of crystalline silicon modules on the spot market was between US\$ 2,500 and US\$ 3,000 per Kilowatt at the end of 2009 [13]. Assuming sustained learning rates, continued support for market development programmes and continued technological development, the average cost of PV modules could be below US\$ 2,000 per kilowatt in the near future [4].

Capital costs of systems that are not connected to the grid may vary between US\$ 5,000 and US\$ 7,000 per kilowatt. This figure mainly derives from the PV modules, the power regulation equipment (e.g. inverter, charge controller) and the bank of batteries [5].

SOLAR PHOTOVOLTAIC CASE STUDY

ENERGY SHOPS – USING SOLAR PV ENERGY TO PROVIDE BUSINESS OPPORTUNITIES, TO ENCOURAGE ENTREPRENEURSHIP AND ENHANCE ACCESS TO MODERN ENERGY SERVICES IN THE OFF-GRID RURAL AND INFORMAL SETTLEMENTS OF NAMIBIA

Location:

Namibia, rural and informal settlements across Namibia

Costs:

Total: € 53,000
WISIONS financial support: € 53,000

CO₂ Reduction:

1,500 kg CO₂/year

Partners Involved:

Desert Research Foundation of Namibia
(www.drfn.org.na)
E-mail: drfn@drfn.org.na

Duration:

April 2009 – May 2010

supply electricity for mobile phone charging, hair cutting, electric lantern charging and lighting. In addition, the businesses were provided with solar and wood-saving stoves for baking and catering. The organisation in charge of implementing this project, Desert Research Foundation of Namibia (DRFN), monitored the technical and economic performance of the systems and social implications of the shops over a six-month period. They concluded that the concept is viable and developed several recommendations for a larger scale implementation to ensure the financial feasibility and sustainability of small Energy Shops in the future. The lessons learned will provide feedback for the government's "Off-Grid Energisation Master Plan" (OGEMP) of Namibia, which had already proposed the establishment of solar powered Energy Shops.

fore, need another solar panel or battery to run properly all year round. The improper use of the system resulted in damage to a converter and fast draining of the battery. These experiences highlighted the need for improving the training and knowledge about the capability of the system and battery, as well as further developing the options for system expansion.

FINANCIAL ISSUES AND MANAGEMENT

Each solar system costs around 12,000N\$ (≈1300€). In this demonstration project, the selected entrepreneurs received the solar system for free, after they had submitted an energy profile of their region and attended a business management course. They were also required to submit monthly financial records to DRFN for monitoring purposes.

The shop owners were permitted to set prices at their own discretion, which var-

AIM

The objective of the project was to encourage entrepreneurship and enhance access to modern energy services in the off-grid rural and informal settlements of Namibia.

PROJECT DESCRIPTION

In Namibia, over 60% of the population does not have access to grid electricity, which is hindering the country's economic and societal growth. For off-grid regions, the establishment of "Energy Shops" can provide basic energy services, foster renewable energy technologies and enhance small-scale business opportunities.

In a thorough selection process, ten suitable entrepreneurs were identified in rural or informal settlements in six regions across Namibia with different local conditions. After undergoing training in technical operations and business management, the entrepreneurs were equipped with solar business systems that can

TECHNOLOGY, OPERATIONS AND MAINTENANCE

Two types of solar systems from Namibian solar companies were provided. Each consisted of an 80W solar panel, a 12V battery and a 200W inverter. They have an AC and a DC power strip and ten assorted DC mobile phone chargers. The system has the capacity to charge ten mobile phones at once. In addition, the shops were equipped with a hair clipper, which can run for two hours a day, two wired lights, each with an operation time of three hours per day, and two portable LED lanterns. The systems were designed to be plug-and-play and, therefore, were easily installed in the shops. The participants were technically trained in the operation of the system.

On cloudy days some of the systems did not generate sufficient electricity for phone charging and would, there-





ied from around 3-5N\$ for mobile phone charging and 10 – 20N\$ for hair cutting. Based on the data of the 10 systems, the detailed profits gained through the use of the PV systems could be assessed to analyse performance and viability. They varied from 50N\$ to over 3000N\$ for mobile phone charging per month in the first half year. The income is clearly dependent on local conditions (e.g. distance from grid, range of products offered in the shop, business experience of the owner, publicity & advertising, shop design).

With a 5% fixed yearly interest rate, the entrepreneurs would be able to repay the system after five years or less, assuming that they could afford to repay 250N\$ per month. However, not all shops generated this amount on PV services. The shops with lower income were given advice on how to improve their business.

ENVIRONMENTAL ISSUES

By using solar energy for charging mobile phones and other devices, less fossil fuel based electricity is used, with the result that the CO₂ emissions are reduced by around 1,500 kg per year. The reduction in the use of kerosene lamps should also mean that

there is a positive impact on health. The only negative environmental impacts are related to the production and later disposal of the solar cells and batteries.

SOCIAL ISSUES

The Energy Shops offer business opportunities for the entrepreneurs and improve access to energy services for people with no grid connection. As the systems were purchased from local suppliers, the project also gave a boost to the local market for PV systems. However, in some communities, the Energy Shops had local business competitors, which resulted in envy.

The access to charging services also influenced other services provided by the entrepreneurs. For example, a small bar run by one entrepreneur was able to extend its opening hours thanks to improved lighting, which both influenced the social life of the community and, simultaneously, improved the entrepreneur's profits from the solar charging.

RESULTS & LESSONS LEARNED

The results are greatly dependent on the different conditions of each location. The

shop that is farthest away from the grid and offers several non-energy products in addition to the charging services was the most successful in the first six months. The separation of an owner's shop and home is also significant in influencing the success of the business, and advertising and business know-how are also important factors. Marketing was not always sufficient which was, in part, due to the fear of theft of the systems. However, the shops that are not yet economically viable do have the potential to improve their business in the future.

RECOMMENDATIONS FOR REPLICATION

Based on the monitoring data and an on-site interview, the following recommendations were developed for the implementation of a large-scale Energy Shops programme in Namibia:

- market assessment survey of the community prior to implementation in order to understand the local energy service demand
- preference should be given to shops located far away from the grid
- system operation should be separate from the entrepreneur's home
- entrepreneurs should have business training
- the attendance of a training course to understand the system should be mandatory and haircutting training should be an integral part of this course
- a broad portfolio of services or non-energy products is recommended in addition to charging services
- signage advertisement and word-of-mouth advertisement is a requirement

Source: Progress and Final Report Submitted to VISIONS by DRFN, Namibia (June 2010).

BIOMASS FOR ELECTRIC POWER

Biomass is human civilisation's most ancient source of energy. It can be produced in forestry (woody biomass), in agriculture (energy crops) or form part of the waste derived from different kinds of processes (biomass residues). Biomass resources can be found or produced in almost any part of the world.

There are several technological ways to transform the energy content of biomass into electricity. The transformation process consists of at least four main stages:

1. Biomass supply includes traditional activities of the agriculture and forestry sector, e.g. land preparation, cultivation and harvesting, or the collection of the useful organic fraction from different waste flows, e.g. municipal or industrial wastes.
2. Biomass conditioning, i.e. the processing of the resources to make them suitable for use by energy conversion technologies. It may include processes like size reduction, cleaning and drying.
3. Energy conversion of the biomass's energy content into electric power, e.g. through an engine-generator set or a fuel cell.
4. Transport and storage may be necessary between the stages outlined above.

Figure 5 shows a schematic view of four of the most applied transformation paths to supply electric power from biomass.

GLOBAL POTENTIAL

Biomass already accounts for 10% of global primary energy consumption, a proportion that is expected to remain constant or even to increase. However, traditional inefficient burning still constitutes the major part of this figure and the contribution of biomass to electricity supply is marginal, about 1% of global electricity generation in 2007 [1].

Technologies that use biomass in a more efficient way must be given priority in the sustainable energy system of the future. Modern biomass electric power technologies offer several advantages that are crucial for the sustainable supply of energy: providing base load, balancing out supply fluctuations from other renewable sources and generating heat and power on a decentralised basis. Electricity from biomass could account for as much as 5% or 10% of global electricity generation by 2050 according to the IEA [4] and Greenpeace [3] respectively.

ENVIRONMENTAL ISSUES

Biomass supply activities (i.e. production, collection and transportation activities), which depend on resources and the supply system, form a key part of the impact of biomass use on the environment [7].

Biomass residues can be collected as a by-product or waste from agricultural, forestry and industrial activities, as well as a fraction of municipal solid waste. The use of this source

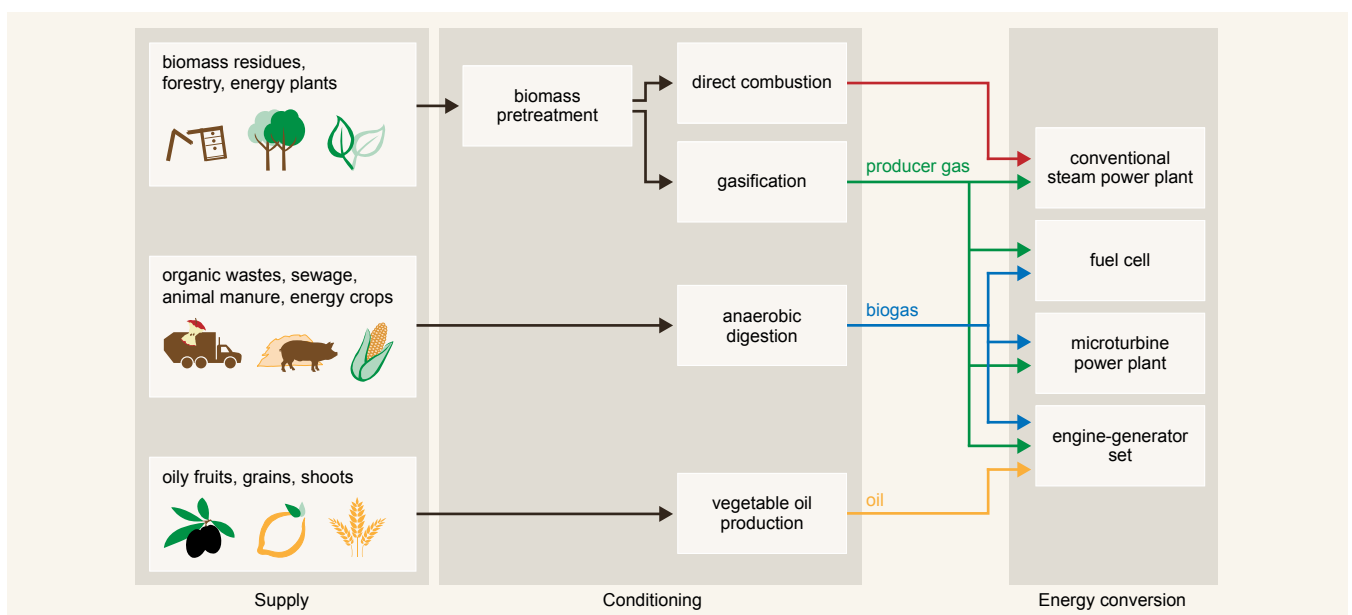


Figure 5. Schematic view of some transformation paths to generate electric power from biomass

of biomass does not usually imply any significant additional environmental threat. Rather, in some cases, it represents a useful alternative to waste that can otherwise become a source of contamination unless it is disposed of properly.

However, special attention should be given to harvest residues that are traditionally used to condition soil, as diverting these residues for energy purposes could lead to soil degradation and/or increased application of chemical additives.

The potential environmental impact of the production of woody biomass and crops for energy purposes depends on several factors, such as:

- the production system: monoculture, diverse cropping, agroforestry, etc.
- the intensity of the use of chemical fertiliser, additives and pesticides
- site-specific characteristics (e.g. soil, climate, slope)
- distances between production areas, storage points and final processing and transport requirements

Examples of potential negative effects resulting from increased biomass production are:

- the emission of nitrogen dioxide and eutrophication due to fertiliser use
- the transport of nutrients into water bodies, which can lead to eutrophication of water sources
- soil degradation, for example due to less humus in the soil

Additionally, changes in land use patterns can result in both positive and negative effects. The production of biomass for energy purposes can form part of programmes addressing both the recuperation of depleted lands and the improvement of access to energy.

In this context, the increase of biomass production for energy would lead to positive environmental effects, such as reforestation of wastelands and the enhancement of the soil's ecological functions.

On the other hand, the clearing of pristine forests for energy crops or plantations is one of the most destructive options for increasing the production of biomass for energy. Such a measure represents a threat to the local ecosystem and biodiversity and can even lead to a net increase in greenhouse gases.

Therefore, the environmental impact of the supply of biomass for power generation is very case specific. Strategies to establish

sustainable biomass production systems should be assessed as early as during the formulation stage of any particular measure that seeks to encourage the use of biomass for energy.

SOCIAL ISSUES

Biomass resources play a key role in economic and social development. Critical issues are directly related to technical know-how and the management of biomass resources, including food security, land use, ownership and agricultural and forestry development. Therefore, the introduction of new energy technologies that use biomass has a direct impact on social development at local, regional or national level [8].

In best-case scenarios, the increasing demand for biomass for energy use may add value to the products of local farmers and translate into additional income. On the other hand, the rising demand for biomass may also result in a concentration of land ownership, competing land uses (energy vs. food crops), higher food prices and greater poverty for the poor.

Although the social impacts of using biomass for the provision of electric power are diverse and case specific, the implementation should always take the social realities of the target region into account, for example by:

- identifying interested parties and the populations and organisations that could be affected
- adopting transparent and participative communication and decision-making processes
- establishing adequate regulations and institutions to ensure that the application of modern biomass technologies becomes a driver of social development
- considering possible prejudices against the use of organic waste from humans or animals

Technologies such as biodigesters, engine-generator sets, oil expellers or biomass gasifiers (which are some of ways in which power can be generated from biomass) are often available in developing countries. Therefore, regional supply chains can benefit from the diffusion of biomass power systems for community-based approaches.

A number of schemes using biomass-based energy technologies have been put into practice, which provide us with lessons to learn for the future. The different outcomes of biomass schemes offer contrasting conclusions: the most striking case may be that of household biogas solutions, where in some areas high acceptance and diffusion rates are reported, yet in others the users have become deeply frustrated and have discredited the technology.

It seems that the complex nature of operating the system is common to most biomass-based technologies. Because of this, training the end users (who are often also the operators of the equipment) as well as establishing local technical skills that are able to provide after sale services (e.g maintenance, repair, further training of users) are seen to be crucial for the long-term acceptance and use of the technology.

BIOGAS-BASED POWER GENERATION

Biogas is the product of breaking down organic matter in the absence of oxygen (anaerobic digestion). It can be used in several ways, including for the generation of electricity. Figure 6 shows some options for the generation of electric power from biogas. The most common option is using biogas to fuel conventional engine-generator sets. These consist of an internal combustion engine coupled with an electrical generator, the rotary motion of the engine being transformed into electricity. Biogas can also be used to run other conversion technologies such as gas turbines, Stirling engines and certain types of fuel cells.

DEVELOPMENT STATUS AND PROSPECTS

Generating electric power from biogas is already a commercial standard. Using cogeneration units to utilise biogas from sewage plants and landfills is common practice in many countries.

Improvements in the technology are possible in various areas: cleaning and upgrading the biogas, using different types of substrates, integrated plant management (heat management) and improving conversion technologies (e.g. gas engines, micro turbines or fuel cells) to suit the properties of the biogas.

ECONOMIC ISSUES

The biodigester and the engine-generator set constitute the main investment outlay. The capital costs of a small 60 kW electric power system are between US\$ 2,260 and US\$ 2,720 per kilowatt [5]. These figures are not expected to vary significantly in the future.

The resulting power generation costs depend heavily on the source of substrates. Biomass from waste flow often has no market price. Therefore, in such cases, only the cost of collection and transportation need to be taken into account.

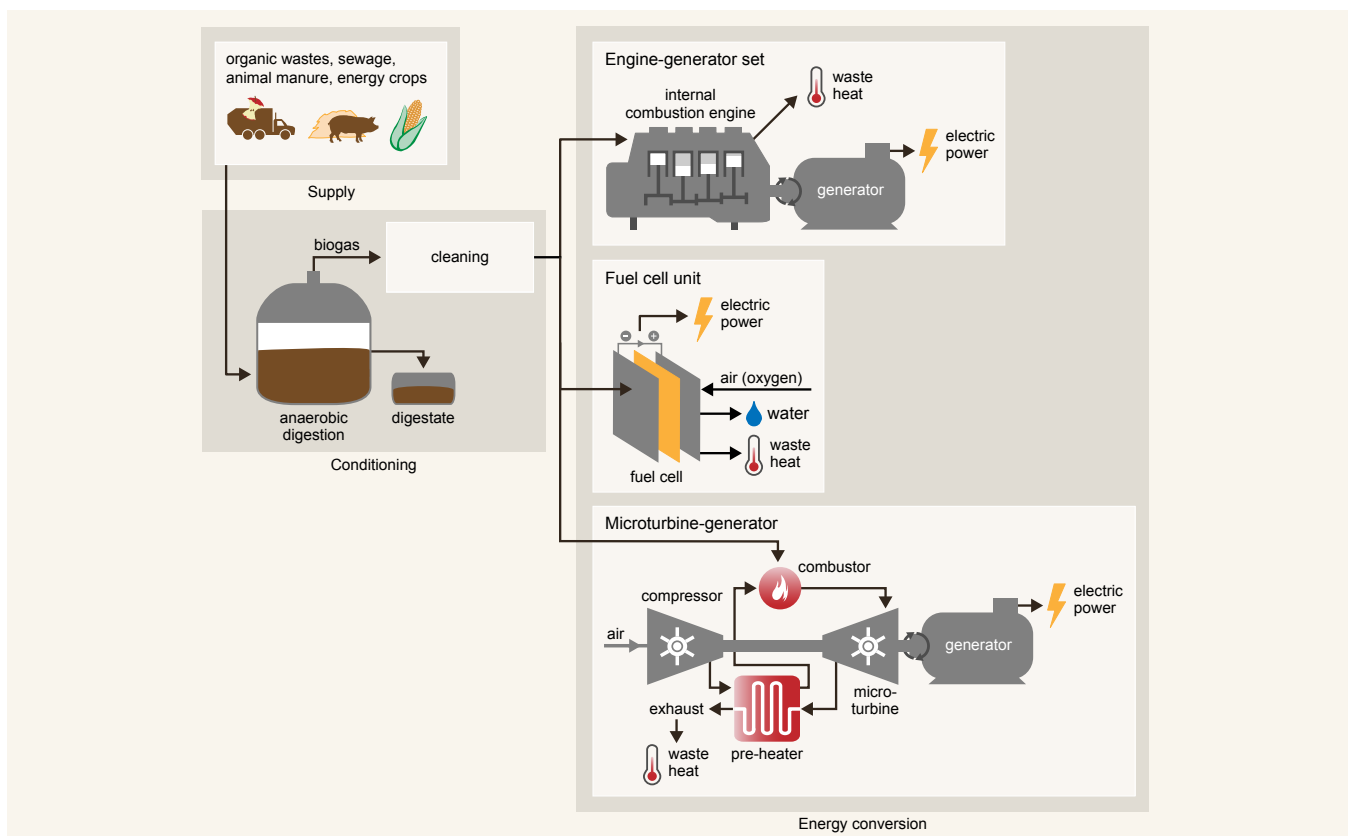


Figure 6. Schematic view of some transformation paths to generate electric power from biogas

VEGETABLE OIL-BASED POWER GENERATION

Vegetable oils can be extracted from the fruits, grains or shoots of different kind of plants (e.g. castor, jatropha, rapeseed, sunflower, etc). These oils can be used to fuel conventional diesel engine-generator sets. In this context there are two main variants:

1. The use of vegetable oils in "pure" condition, i.e. without further treatment other than filtering fibres or particles
2. The upgrading of the oils through thermo chemical processes, i.e. the production of biodiesel

The use of pure vegetable oil may have detrimental effects on the performance of diesel engines. Measures to mitigate harmful impacts are: making adaptations to the engine (e.g. changes in the fuel distribution and combustion system) and preventive operation strategies (e.g. using fossil diesel during the starting and stopping phase of the engine).

The use of biodiesel does not have any major effects on conventional diesel engines. However, producing the biodiesel entails additional operation and maintenance, the need for additional inputs (like methanol, water or even electric power) and the further treatment of sub products (like glycerine and waste water).

DEVELOPMENT STATUS AND PROSPECTS

The main hardware components for the use of pure vegetable oil (the oil pressing unit and the engine-generator set) are commercial technologies. However, power systems optimised for running on vegetable oils are still not broadly available. Some producers (especially in Europe) are already offering small

cogeneration systems, adapted to run on one particular pure vegetable oil (e.g. rapeseed oil).

Suppliers of small biodiesel plants (with production capacities of several hundreds of litres per day) can be found in a number of countries. The market for this technology seems to have a strong regional character and standardisation seems to be very low.

ECONOMIC ISSUES

The major components in a system for power generation from vegetables are:

1. The supply of oily plants
2. The oil production unit
3. The engine-generator set

The level of investment for the supply of feedstock is very case specific. It can be marginal when oily plants already make up part of the local vegetation, and are not used for any other purpose. In some areas the use of oily plants (e.g. castor or jatropha) as biological fence is promoted, which means that the initial costs and, most importantly, the risks for farmers are relatively low. The most costly and risky approach consists of establishing plantations of oily plants [10]. The suitability of plantations for community-based power projects must be carefully evaluated.

Technologies for vegetable oil extraction range from manual expellers to the use of fully automated equipment. Availability and prices vary widely from region to region. The same seems to be the case for small biodiesel plants.

The capital costs of small commercial diesel generators may range between US\$ 200 and US\$ 500 per kilowatt. Unlike the capital costs (which are low relative to other technologies) the running costs for maintenance and servicing are high. This includes periodic activities such as the replacement of engine oil, filters and coolant, and regular preventive maintenance and major overhauls such as, among others, the reconstruction of the cylinder head and piston replacement.

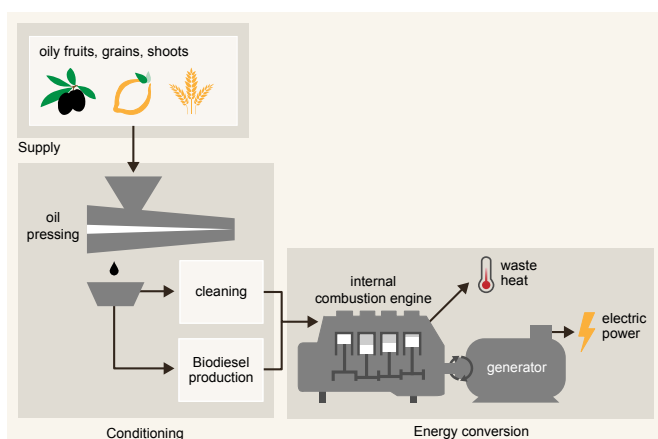


Figure 7. Schematic example of electric power generation based on vegetable oil

BIOMASS CASE STUDY I

BIOGAS ELECTRIC POWER FOR RURAL COMMUNITIES IN SRI LANKA

Today 1.2 million households and about 4.5 million people in Sri Lanka are still not connected to the electricity grid. To demonstrate that the decentralised electrification of these communities is possible with electrical energy generated from biogas, Energy Forum implemented this project. One of the main objectives was to promote biogas as a mainstream off-grid energy technology in Sri Lanka. Steps were taken to establish 12 pilot projects, which consisted of eleven Chinese type biogas units and one Small Batch Type biogas plant. The electricity that is generated is distributed to the individual households over several mini-grids. To manage and operate the biogas power plants in the future, a community-based organisation (CBO) was established in each village. Based on the experience gained during the implementation stage of the 12 pilot projects, Energy Forum formulated a training manual for biogas power production and a 3-day training programme was run to train selected potential biogas power developers. Parallel sessions were conducted for developing financing schemes with officials from Provincial Councils and Regional Banks under the RERED (Renewable Energy for Rural Economic Develop-

ment) project. Energy Forum will monitor the future performance of the pilot projects with the assistance of the Federation of Electricity Consumer Societies for a further 3 years after the project's completion. In addition, steps have been taken to draft biogas power standards for Sri Lanka.

TECHNOLOGY, OPERATIONS AND MAINTENANCE

Biogas is a fuel generated from organic waste materials, under anaerobic conditions. The two types of biogas technologies that have been installed need material to be fed daily into the digester. The main feedstock for the Chinese type biogas plants is pig and cow dung, and for the small batch system only straw is used. Both resources are widely available in the dry zone areas of Sri Lanka. For the establishment of the batch type digester a separate gasholder to store the generated biogas is needed. As well as the biogas plant, a powerhouse for electricity generation was constructed in each community. The generated electricity is distributed among the members of the CBO using a stand-alone mini-grid. Operators were trained in

the necessary skills to operate and maintain the power plants, and another training programme was established to train project developers and biogas unit constructors in order to encourage the replication of the project.

FINANCIAL ISSUES AND MANAGEMENT

Each community collectively contributed €2,000 to the capital cost of the project. In addition, the communities provided unskilled labour for the construction work. It was compulsory for the end users to provide unskilled labour worth €50 and to pay a registration fee of €50 per family to become a member of the Electricity Consumer Society which will own the power plant. The monthly operation and maintenance costs per household are estimated at €1.75–€2.00. To manage the power plant in the future, training modules were developed to train local community leaders in responsibilities, technical capabilities, staff and financial management, record keeping, accounting and leadership qualities.

ENVIRONMENTAL ISSUES

The main environmental benefit of the biogas power plants is their low level of carbon emissions. It is tentatively estimated that the biogas power potential in Sri Lanka is around 300 MW. Assuming that 300 MW of fossil-based power plants are replaced with biogas-based energy, the net saving in terms of CO₂ emissions would be about 1.7 million tons per year. In this particular project the reduction was around 12,800 kg CO₂ for the first year. Additional environmental benefits come from the by-products of the biogas production as these can be used as fertiliser to aid crop growing, which reduces the use of chemical fertilisers. Furthermore, the biogas slurry is pest repellent and hence can replace pesticides in agricultural use.

Location:

Moneragala, Sri Lanka

Costs:

Total: € 34,647

WISIONS financial support: € 32,300

CO₂ Reduction:

12,800 kg CO₂/year

Partners Involved:

Energy Forum (Guarantee) Limited

Email: eforum@slt.net.lk

Duration:

2007 – 2008 (12 months)





SOCIAL ISSUES

The original concept of the project was to test the establishment of community biogas power systems with community-owned common animal sheds. However, this idea was not acceptable to the community as they were not willing to share a common shed for their animals as that was against their culture. To overcome this issue, the Energy Forum tested possible options with individually-owned animal sheds, which have proved to be successful.

RESULTS & IMPACT

During the project 12 schemes were established and these are providing elec-

tricity to 56 households and water supply to 80 households. The energy systems satisfy all the energy requirements of the households: energy for cooking, electricity and water supply. The access to modern energy services and clean water has significantly improved living conditions in rural communities.

POTENTIAL FOR REPLICATION

The biogas scheme that has been tested in the project can be replicated, both within Sri Lanka and in other countries, particularly those in Africa. Within Sri Lanka the scheme can be used in rural dry areas with biomass supply produced from livestock and agricultural plantations. Once suc-

cessfully implemented in the dry zone, the schemes can be adapted to address waste management issues within peri-urban areas. Well-established financing schemes exist within Sri Lanka for other off-grid energy technologies such as Solar Photovoltaic, Micro-Hydro, Wind, and Dendro power. Following the completion of this project, biogas will also qualify for these finances and will be eligible for Technical Assistance Grants. The lessons learned from this project in Sri Lanka have already been used in parts of Africa and will further help to increase the use of biogas for community applications.

LESSONS LEARNED

The duration of the project was one year but future projects should include more time for observations and tests prior to the outset of the project so that the long-term sustainability of the schemes can be better assured.

Source: Final Report submitted to WISIONS by Energy Forum (Guarantee) Limited (2008)



BIOMASS CASE STUDY II

MULTI-FUNCTIONAL PLATFORMS RUN WITH BIODIESEL – IMPROVING ACCESS TO MODERN ENERGY SERVICES IN RURAL UGANDA

The majority of the population in Uganda lives in rural communities that currently have little or no access to modern energy services for agro-processing or domestic use. This project, implemented by Energy & Development Group, was designed to improve access to modern energy services in the Masindi District of Western Uganda. The installed Multi Functional Platforms (MFPs) provide both mechanical and electrical energy to meet the local needs. Two of the MFPs operate on biodiesel, produced from locally-grown sunflower seed, and have been funded



under SEPS. The other two operate on conventional diesel fuel and are supported by the UNDP. The selection of the communities was based on socio-economic surveys conducted prior to the implementation of the project. In order to qualify, a community had to be able and willing to contribute financially to the project.

Four different types of operation were put into practice to allow for the assessment of different implementation models:

1. an Energy Service Company (ESCO) approach where the biodiesel production is outsourced,
2. an approach where the ESCO also grows/processes the bio-diesel,
3. a model where the MFP is operated by a local women's/community group and
4. a system where the MFP is operated by a local institution such as a local government centre, school or health outpost.

TECHNOLOGY

Each MFP consists of a small diesel engine of 50-60 kW mounted on a chassis, to which a variety of end use equipment can be attached (grinding mills, battery chargers, vegetable or nut oil presses, welding machines and carpentry tools). It can also support a mini-grid for lighting and electric pumps for a small water distribution network. Typically an MFP runs for around 4 hours a day and can attract up to 200-300 regular clients, with the greatest demand being for processing agricultural products. The modules are designed and built locally using easily available skills, materials and parts; only the two biodiesel plants were imported from South Africa. The configuration of equipment modules is flexible and can be adapted to the needs of each village. Considering that

land access is a serious issue in Uganda, the decision was taken to use high-yield sunflower seeds (yielding up to 800 kg/acre with a possible 40% oil content) to keep the land requirements as low as possible. A total of 75 acres (37.5 acres/site) of sunflower was planted for the first season by contracted-out growers close to the biodiesel sites.

FINANCIAL ISSUES AND MANAGEMENT

The cost for each MFP was around €15,000 (€60,000 in total), of which €15,900 was funded by the communities. WISIONS contributed €47,000, a quarter of the overall project costs, specifically for the implementation of the biodiesel MFPs; the main source of funding for the rest of the project was the UNDP.

All MFP managers were trained to acquire skills in book-keeping and basic finance. The operators were given practical training in the installation, operation and maintenance of the MFP and are also responsible for the collection of fees from the users. The running costs of the platform and engine can be recovered through fees from the services provided by the platform. Taking into account the fact that studies have been carried out.



Location:

Masindi District of Western Uganda

Costs:

Total: € 60,000

WISIONS financial support: € 47,000

CO₂ Reduction:

48,400 kg CO₂/year (compared to grid extension)

Partners Involved:

Energy & Development Group (EDG)

Website: www.edg.co.za

Duration:

May 2007 – June 2008



ENVIRONMENTAL ISSUES

The use of the two biofuel MFPs results in approximately 80% less CO₂ emissions, and almost 100% less SO₂, compared to the use of conventional diesel fuel. Biodiesel is also safe to handle and transport. The annual CO₂ emissions and the associated use of fossil fuel are reduced with the implementation of MFPs. The CO₂ reduction potential is 48,400 kg CO₂/year when compared to grid extension.

RESULTS & IMPACT

The implementation of the MFPs provides modern energy services to the four rural communities. The positive impact is significant in the water, health and education sectors, with positive effects especially notable in the improved living conditions



of women. In addition to providing access to energy, income-generating opportunities have also been established. It is also now possible to carry out agro-processing within the community itself, meaning that the community is more financially self-sufficient.

LESSONS LEARNED

The knowledge that had been gained from the projects has been collated and distributed widely to both national and regional stakeholders as well as to future potential financial backers. There have been some technical problems on one site with the biodiesel plant but the sharing of expertise and experience between the different operators could help remedy future problems. Another key problem has been procurement of the seed from the farmers as up-front cash payment is required, which creates an issue for the operators who only make their money once the biodiesel is sold. To mitigate this problem, future projects need to consider that short-term loans should be available to the operators in order that they can purchase the seed required for the biodiesel production.

Source: Final Report submitted to WISIONS by the Energy & Development Group (2008) (www.edg.co.za)

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