# Expanding Energy Access in Developing Countries

The Role of Mechanical Power

## Praise for the book...

*'It is an excellent report... The case studies have been chosen well to represent the geographic areas as well as range of applications of mechanical energy, and range of models used for implementing the projects. The case studies have also been documented very well. The glossary of mechanical energy devices also appears to be exhaustive and it will be a useful tool for subsequent work in this area.'*

**Priyadarshini Karve**, Appropriate Rural Technology Institute, India

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The United Nations Development Programme (UNDP) is the UN's global development network, advocating for change and connecting countries to knowledge, experience and resources to help people build a better life. UNDP is on the ground in 166 countries, working with the countries on their own solutions to global and national development challenges. As they develop local capacity, they draw on the people of UNDP and its wide range of partners.

World leaders have pledged to achieve the Millennium Development Goals, including the overarching goal of cutting poverty in half by 2015. UNDP's network links and coordinates global and national efforts to reach these Goals. Our focus is helping countries build and share solutions to the challenges of: democratic governance, poverty reduction, crisis prevention and recovery, and environment and sustainable development. UNDP helps developing countries attract and use aid effectively. In all our activities, we encourage the protection of human rights, the empowerment of women and capacity development.

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Cover Photos: *Main Image*

- Men loading goods at upper station of gravity ropeway in the remote Mustang area of Nepal. The scheme, implemented by Practical Action and ICIMOD, has dramatically reduced transport time and drudgery associated with moving food and goods between producers and village markets in the region. (Photo: Upendra Shrestha, Practical Action)

Cover Photos: *Inserts from top*

- A farmer irrigating his land with a treadle pump through the ILLISCON project at Joshipur village, Nepal (Photo: Matrika Sharma, Practical Action)
- Local technicians maintaining a Kijito Wind Pump in Kenya (Photo: BHEL)
- A woman using a Multifunctional Platform in Mali (Photo: UNDP)

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# Acknowledgements

This publication represents the findings of the first phase of a study and mapping exercise commissioned by the Sustainable Energy Programme of UNDP in New York. Its aim is to document and highlight the role of mechanical power in expanding energy access for the poor in developing countries. The study was managed by Steven Hunt of Practical Action Consulting (PAC) based in Rugby, UK. The report was written by a team comprising Liz Bates, Steven Hunt, Smail Khennas and Nararya Sastrawinata at PAC-UK.

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**Steven Hunt**
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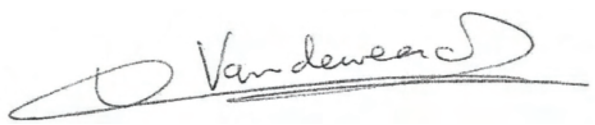
*Rugby, 2009*

# Foreword

Access to energy services is a fundamental prerequisite for poverty reduction and sustainable human development. Of the over 6.5 billion people in the world today, 2.5 billion depend on traditional biomass for cooking and heating, around 2.6 billion live on less than US$2 a day, a billion lack clean water and 1.6 billion lack access to electricity. These are some of the stark numbers that define poverty in the world today. Notable in the day-to-day livelihood activities of the poor is the significant role that mechanical power plays in enhancing the productivity of labour in many ways – including in agriculture and food processing, running small enterprises, water-pumping and irrigation – which form the core of poor people's daily activities. In spite of the importance of mechanical power in meeting energy needs, there exists little data on mechanical power in developing countries. There is often also limited technological enhancement applied to what mechanical power equipment is available, and the poor often continue to depend on unimproved versions of mechanical power equipment, inefficiently using human or animal power to meet their most basic energy needs.

This publication documents the contribution of mechanical power to expanding energy access for the poor. It is based on a mapping exercise of international experience and literature, including case studies from various countries in sub-Saharan Africa and South Asia. The mapping exercise is the first phase of a continuing process to study the contribution of mechanical power to expanding energy services for the poor. In the second phase, the study will look more closely at barriers, and strategies to overcome them.

The work is based on the recognition that access to mechanical power contributes to the development of the human, social, financial, natural and physical capitals essential for the poor to increase their resilience to environmental shocks and other pressures on livelihoods. The contribution of this publication is to highlight the importance of mechanical power as a crucial component of the improved energy access that is required to accelerate human development and reduce poverty in developing countries.



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# Summary

Mechanical power has been used for centuries for agro/food processing, water pumping and other productive uses, providing some of the most fundamental services required for poverty reduction and human development. Indeed, over the past century, technological advances have helped reduce the drudgery and increase the productivity of human labour through the widespread use of mechanical power. Mechanical power is critical to enhancing the productive use of labour in many ways, directly supporting core day-to-day activities such as transporting and lifting water, irrigating fields, processing crops into edible forms and many more. Mechanical power is often viewed however as being only a derivative of other forms of energy such as electricity, and it is assumed that users will convert in appliances as needed on the "other side of the meter". However this assumption is unsafe and ignores the special contribution of mechanical power itself to rural production and physical processes.

***In spite of the importance of mechanical power in meeting every day energy needs at local levels, it is generally under-appreciated and under-considered to the point that data and documentation of the role of mechanical power are almost completely lacking.*** In an attempt to address this gap, this publication seeks to highlight the contribution of mechanical power to energy access in developing countries based on an initial mapping study conducted between February and May 2009, through literature review, interviews, a consultation workshop, case study investigations and analysis.

***The contribution of mechanical power is to increase the efficiency and effectiveness of productive activities supporting development, as well as physical processes fundamental to meeting basic human needs.*** Mechanical power has been found to provide a range of energy services which may be grouped under the heading of productive uses and basic processing, including a wide range of specific applications in the following sectors: water supply, agriculture, agro-processing, natural resource extraction, small-scale manufacturing and lifting/crossing. Experiences show that mechanical power helps alleviate drudgery, increase work rate and substantially reduce the level of human strength needed to achieve an outcome, thus increasing efficiency and output productivity, producing a wider range of improved products, and saving time and production costs.

***Mechanical power generally has relatively low investment costs, and is an effective way to directly benefit poor people who stand to gain most from the services mechanical power technologies provide.*** In this regard, financing of mechanical power is often one of the most cost effective ways to support poor people. Mechanical power is particularly suitable for generating local investment and a fees-for-service approach; a vital local and private source of revenue enabling the sustainable operation and growth of energy services.

***Countries should consider mechanical power alongside electricity, transport, and cooking, in energy and development strategy formulation.*** Specifically they should:

- Develop methodologies to enable the integration of mechanical power into development strategies and policies, including setting targets and tracking of progress against these.
- Strengthen linkages between mechanical power and agricultural development, to maximise mechanical power's agricultural and agro-processing contributions in support of the productivity of small farmers and food production.
- Conduct and support awareness raising and capacity development initiatives aimed at scaling-up mechanical power initiatives.
- Advocate for the incorporation of mechanical power into international energy programmes, strategies and declarations, including the Commission on Sustainable Development (CSD) review of the energy and climate change agenda.
- Implement financing initiatives to scale-up mechanical power alongside other energy options in new and existing financing windows.

# 1

# Introduction

There has been increasing recognition in recent years of the importance of energy access in developing countries for meeting the Millennium Development Goals (MDGs). Crucial linkages between the two have been documented (DFID, 2002; Modi et al, 2006) and highlighted at global forums such as the Commission on Sustainable Development (CSD). Internationally, multilateral agencies have committed to partner with developing country governments to address energy access issues in the context of sustainable development, as defined in the Johannesburg Plan of Implementation (JPOI), adopted at the World Summit on Sustainable Development in 2002.

At the same time energy has climbed the international policy agenda, driven by concerns about oil and gas prices, energy security, and links to climate change. However, even progressive agendas that promote low-carbon, alternative energy and energy efficiency in developed countries have so far not clearly meshed with the requirements of energy access for development in developing countries. These requirements are for a drastic increase in the quality and quantity of energy access by the poor. On current trends however, the existing grim energy access statistics of 1.6 billion people in developing countries without access to electricity and 2.5 billion still using traditional biomass fuel for cooking look unlikely to change by 2030 (PAC, 2008).

While these figures are justifiably often quoted and act as drivers for energy access advocacy and policy, they fail to reflect the full extent of the energy access gap. In particular they do not fully reflect the need for energy in productive uses and basic processing in many different rural livelihood activities, undertaken everywhere in enterprises, farms, mines, workshops, forests, wells and river crossings to name a few. These energy services are fundamental to rural livelihoods, and to the efficient transformation of natural resources into vital products and services including food. This access to energy results in wealth creation for producers and more affordable prices for consumers. For poor people, such energy needs are often met with simple hand tools or with physical strength – often leading to exhaustion, extra costs in time and money, and reduced human and natural resource productivity. In rich countries, these services are provided by the diesel and electrically-driven machinery which economic wealth can obtain. The crucial point however is that the energy end-use vector in all these cases is mechanical power, derived from whatever energy source is available. With this recognition, the contribution of mechanical power becomes apparent, and examples of its role in many applications can start to be mapped, along with their impacts, development outcomes and associated interventions.

This publication sets out to do just that, and mechanical power is seen through this study to be critical to enhancing the productive use of labour in many ways, directly supporting the core of rural people's daily activities. Mechanical power is defined here as 'the effective outcome of transforming different forms of energy sources (e.g. wind, hydro, fossil fuels etc) to kinetic energy (to cause motion)'. Mechanical power can further be broken down from an energy source perspective into that created by electrical and non-electrical power; the latter sources include human power (e.g. treadle pumps, rope pumps etc), animal power (e.g. oxen, donkey), renewable/natural power (e.g. wind pumps, hydro turbines, biogas engines) or fossil energy (e.g. gas/diesel engines/pumps etc) without intermediate conversion to electricity. These can be roughly ranked in terms of their technical complexity, cost and flexibility as shown in Figure 1, although the suitability and fit of a given energy source to a mechanical power application is strongly dependent on context. The local and global environmental impacts of mechanical power installations are linked mainly to the use impacts of the energy and the type of energy source being converted, with renewable sources clearly being less carbon intensive than fossil fuels for example.

Of great concern is that, even though mechanical power is one of the oldest and most widespread

> ***"National energy policy should have defined the contribution of each type of energy within the national energy mix. At the present moment, no national energy policy has been put into place. A policy on the development of mechanical power should be integrated into the framework of an overall energy plan established at the national level."***
>
> Albert Sambu
> Ministry of Rural Development,
> Democratic Republic of Congo

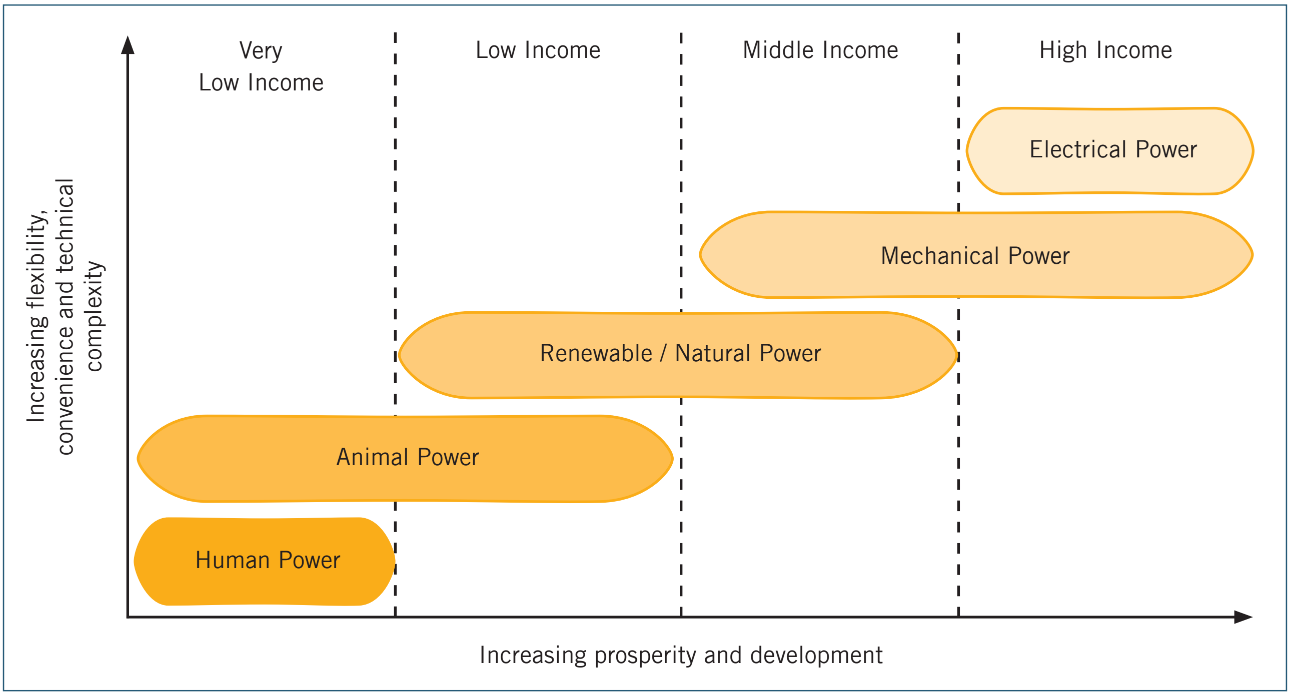


**Figure 1** Mechanical power ladder (Derived and adapted from WHO 2006 and UNDP 2009 respectively)

forms of energy, there is often limited improvement in relation to technology or form of use apparent in impoverished regions of the world today. Since the industrial revolution, access to advanced forms of mechanical power have defined the pace of human development and advancement, and has shaped development in various ways in different parts of the world. However, the gap between technology used for mechanical power in developed countries and developing countries is increasing.

Mechanical power is today obtained from motorised equipment such as steam, diesel and gas engines/ turbines, electrical and hydraulic motors. In spite of these technological improvements, the 2.5 billion people without access to modern energy services still depend on unimproved versions of mechanical power equipment that inefficiently use human or animal power to meet their energy needs. However, in spite of these technical challenges, motive power has remained an important driver of livelihood activities in impoverished regions of the world.

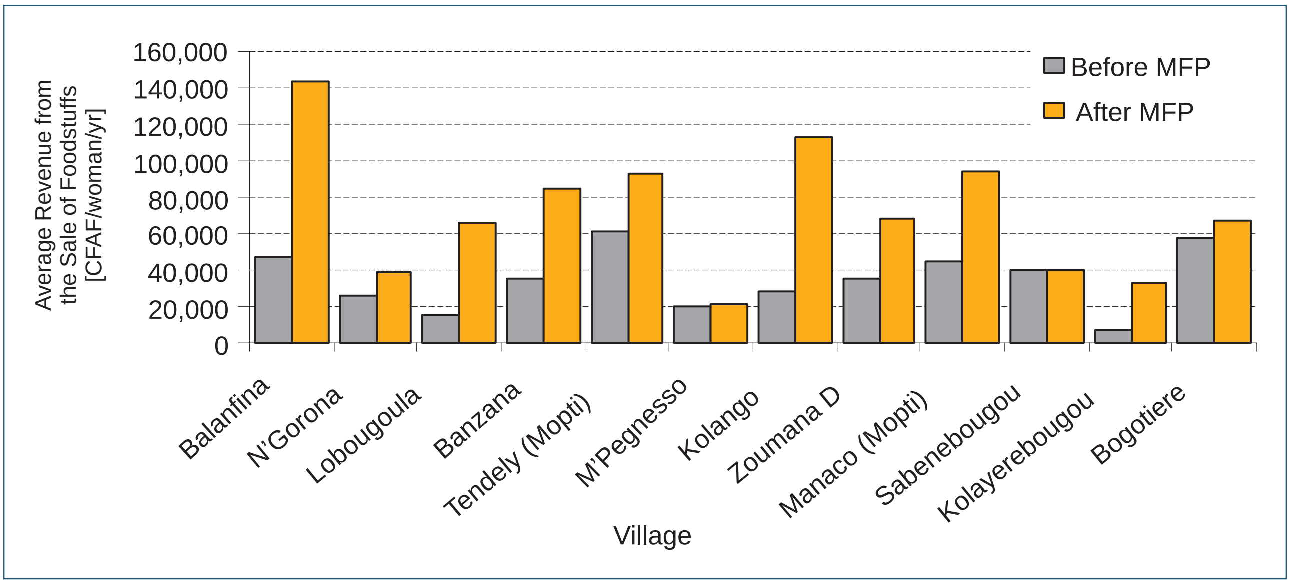


**Table 1** Revenue generation by village before and after the introduction of Multifunctional Platforms

**Table 2** Mechanical power is least documented by LDC countries that provide data on access to modern energy (baseline and target)*

| | | National | Rural | Urban |
|---|---|---|---|---|
| Fuels for cooking/ heating | Baseline | 48 (96%) | 17 (34%) | 15 (30%) |
| | Target | 5 (10%) | 2 (4%) | 2 (4%) |
| Mechanical Power | Baseline | 0 (0%) | 2 (4%) | 0 (0%) |
| | Target | 0 (0%) | 2 (4%) | 3 (6%) |
| Electricity | Baseline | 48 (96%) | 38 (76%) | 35 (70%) |
| | Target | 22 (44%) | 16 (32%) | 9 (18%) |

* The 50 Least Developed Countries are used in the calculation. (%) indicates the percentage of LDC countries that provides data on access to modern energy. *Source*: UNDP 2009

The basic energy services provided by mechanical power include agricultural operations such as irrigation, water pumping, food and agricultural processing, and basic value-addition activities at the household level. Others include, running of micro-enterprises including timber industry, small-scale mining, food and agriculture, and village cottage/micro-enterprises. Examples of common mechanical power equipment include: wind pumps, water wheels, hydrams, stationery engines, manually operated pumps such as treadle pumps, manually operated lathes, home and farm equipment sharpeners, corn threshers, rice dehuskers, oil presses and machines for producing building materials (brick presses).

As an example of the role that mechanical power can play in improving human development, UNDP supported the Government of Mali to initiate a pilot program in 1997, called the "multifunctional platform (MFP)" programme.[1] The programme has expanded to over 5 per cent of the rural population in Mali and, with support from the Bill and Melinda Gates Foundation; the programme is spreading to Burkina Faso and Senegal. The programme has contributed to a significant increase in the productive capacity of people in isolated villages in Mali. For instance, a survey carried out in 2005[2] by UNDP in the villages of Sikasso and Mopti showed that women earn additional revenue, averaging US$68 per year, through access to mechanical power from the "platform's" services, as shown in Table 1. Taking into account their expenses, this translates into an average $0.32 PPP1993 per day or $44 per year of additional income. In a country where the average gap between the dollar-a-day international poverty line and the mean income of the poor is $0.37, the additional income is a significant step towards poverty reduction.

In spite of the importance of mechanical power in meeting local energy needs, recognition of its role as an important factor in energy for development, is not widespread. While baseline data for electricity access and fuels for cooking and heating are documented in almost all of the 50 least developed countries, very few countries provide similar data for mechanical power, and this is only available for rural areas. In terms of targets for access, national plans are lacking in all areas of energy access with cooking fuels much more poorly represented than electricity, and mechanical power not even registering. For example, Table 2 shows that although 5 out of the 50 Least Developed Countries (LDCs) have a national target on access to modern fuels and 22 on access to electricity, none of them have a specific national target on access to mechanical power.

This publication was commissioned by UNDP in the context of an ongoing process to address this gap in data, targets and reporting on mechanical power and its contribution to energy and development. It seeks to document the contribution of mechanical power in expanding energy access in developing countries, in particular those in sub-Saharan Africa and South Asia. Section 2 of this publication seeks to define the boundaries in the application of mechanical power, in terms of its scope of use, by mapping it to different energy services and the livelihood activities that these services provide. Section 3 relates the services provided to the

> ***"The little importance given to mechanical power is due to poor knowledge of benefits that mechanical power services can offer, competitiveness if compared with conventional energy sources and high costs involved in its conception or design."***
>
> Pedro Sabino Feliciano Caixote,
> National Directorate of Renewable Energy,
> Ministry of Energy, Mozambique

MDGs, highlighting the development outcomes deriving from mechanical power. Section 4 describes interventions which expand access to mechanical power, and Section 5 discusses financing options. The final section of this report contains conclusions and recommendations on how mechanical power may be more effectively harnessed in the fight against poverty.

This publication was written in consultation with the Sustainable Energy Programme of UNDP's Environment and Energy Group. Information on mechanical power applications has been compiled from various resources, including publications, secondary literature and consultations; and the assistance of the various contributors and reviewers is gratefully acknowledged at the beginning of this report. A general framework of mechanical power has been derived from literature and data, and case studies have been selected to provide concrete examples of technologies and practices illustrating the various contributions made by mechanical power. The cases were chosen for their geographical spread, with a focus on Africa and South Asia, and for the range of sectors served and applications of mechanical power. Cases were identified from development partners, organizations and awards programmes, and were conducted by consultants and Practical Action Consulting regional office specialists, acknowledged at the beginning of this report. Cases are provided in full in after Section 6, while key case insights are included as boxes within the report, where relevant, and references to the cases are made throughout. A glossary of mechanical power technologies follows the case studies, with brief descriptions for each technology and pictures where available.

## Endnote

1 The MFP consists of a small diesel engine mounted on a chassis, to which a variety of food-processing equipment is attached, including grinding mills, vegetable or nut oil presses and dehuskers, as well as other equipment such as battery chargers, welders and carpentry equipment; according to business demand. It can also generate electricity for lighting and pumping water.

2 Porcaro, J. and Takada, M. (2005). "Achieving the Millennium Development Goals: The Role of Energy Services", UNDP, New York, USA.

# 2

# Mechanical power, energy services and livelihoods

The indicative range of energy services people need can be mapped onto the major energy vectors at point of use, as shown in Table 3 below. This shows that mechanical power is most suitable for processing and production, and in assisting mobility. Only static applications of mechanical power are within the scope of this report, so applications to assist mobility are limited to lifting and crossing.

**Table 3** Applicability of energy vectors at point of use

| | Solid | Liquid | Gas | Electricity | Mechanical Power |
|---|---|---|---|---|---|
| Cooking/Heating | ■■ | ■■ | ■■■ | ■■ | |
| Lighting | ■■ | ■■ | ■■ | ■■■ | |
| Communications | | | | ■■■ | |
| Refrigeration | ■ | ■■ | ■■ | ■■■ | |
| Mobility | ■ | ■■■ | ■ | ■ | ■■ |
| Processing/Production* | ■■ | ■■ | ■■ | ■■■ | ■■■ |

***Key***
■ – Possible but not usually preferable, ■■ – Applicable but limited, ■■■ – Suitable.
*Including natural resources, water, agriculture goods, minerals, timber, etc.

For the mechanical power applications in Table 1, a further division can be made for the major sub-sector uses of mechanical power: **water supply**, **agriculture**, **agro-processing**, **natural resource extraction**, **small-scale manufacturing**, and **lifting and crossing**. Each of these will be addressed in the following sections, illustrating the range of services and the impacts that mechanical power technologies can provide, referring also to a selection of the provided **case studies**. Table 4 to Table 9 give examples of these specific services, typical technologies in use in low-income communities, and relevant mechanical power alternatives. For a description of each technology, refer to the **glossary of technologies**.

## Water supply

**Table 4** Water supply technologies

| Service | Typical technology | Mechanical power alternative |
|---|---|---|
| Drinking | Container (bucket) for lifting / carrying water | Diesel pump, treadle pump, rope pump, ram pump, Persian wheel, hand pump, river turbine, wind pump |
| Irrigation | | |
| Livestock watering | | |

*Note*: all technologies are generally suitable for both drinking and irrigation.

Having a clean and reliable source of drinking water is essential in improving the health of a community. In rural areas, water collection often makes up a large part of a woman's day, so a nearby water source allows her to focus more on other activities, such as spending time with her children and taking care of her own health. Some technologies have even been altered to change the chore of water collection to a more enjoyable activity via mechanical power, such as the Play Pump. The applicability of technologies is context-specific, with factors including demand levels and local resources.

For some technologies, such as wind pumps, options are available in different sizes – ranging from household (e.g. wind/rope pump) to village scale (e.g. the Kijito wind pump, Case Study 3), where wind speeds are sufficient for economic operation. The treadle pump, a human powered technology, can be advantageous because it can accommodate a wide range of weather conditions and is only used when needed. A simple irrigation system, like a drip system, can also reduce water consumption for a crop by 50%, compared with conventional irrigation practices, and increase the yield by 30–40% (IDE-I). It should be used in tandem with a water pumping device in dry areas.


Photo: Practical Action

**Case 1 – Water-current turbines – Sudan**

The river turbine uses the kinetic energy in a flowing river or canal as the power source for a water pump and is available 24 hours a day. It floats in the free stream of the river and pumps water onto the bank up to a maximum of 25m above the river level, and flow rate of 47m$^3$/hr. The fact that it is placed away from the riverbanks usually also means that they draw a cleaner supply of water.

## Agriculture

**Table 5** Agricultural technologies

| Service | Typical technology | Mechanical power alternative |
|---|---|---|
| Tillage, ploughing | Animal drawn tiller, hand hoe | Power tiller/two-wheel tractor |
| Harvesting | Scythe, animal drawn mower, manual practices | Harvester[1,2] |
| Seeding | Hand planting | Bed planter[1], row planter, seed drill |

[1] Can be attached to a power tiller/tractor. [2] Often has a thresher attached to it.

*Note*: Irrigation is included under water supply because of the commonality of the technologies used. Mobile tillers are included here even though not strictly static due to their limited range and power take-off capacity.

Agriculture in developing countries relies heavily on the physical capability of the farmers. The introduction of mechanical power machinery can greatly improve their productivity and hence their livelihoods. In Bangladesh, power tillers (12–15hp) are used for about 70% of farm work because of their versatility; they can be used for tilling, irrigation pumping, threshing, husking and transporting. Locally made attachments to the tiller, such as a bed planter with a seeder, allow bed formation and seeding to be done in one pass. A study has shown that the yield of wheat, maize and mungbean on beds was around 19–23% higher than on beds using conventional systems. In one year, the total cost of planting in a bed system can be reduced by 59% compared to that of conventional methods (Hossain et al, 2003). Research has found that by using this system, the irrigation method can be changed, and this can lead to a reduction of the demand for water by 30% (Sayre and Hobbs, 2003).

## Agro-processing

**Table 6** Agro-processing technologies

| Service | Typical technology | Mechanical power alternative |
|---|---|---|
| Milling, pressing | Hand ground, flail | Powered mill, oil expellers |
| Cutting, shredding | Knife | Saw mills, powered shredder |
| Winnowing, decorticating | Winnowing basket | Powered shaker, grinder |
| Spinning | Manual spin | Powered spinner |
| Drying | Hand-held fan, sun drying | Powered fan |

*Note*: Powered alternatives in this case are attachments to hand/fuel/water derived shaft power.

Post-harvest activity is arguably the main factor in helping farmers increase their income. Substantial time and resources are spent transporting crops to neighbouring mills if the services are not available in


Photo: Practical Action

**Case 6 – Multipurpose watermills – Himalayas**

Improved water mills can have an 80–90% increase in power use and efficiency compared to a traditional water mill. They can also have multiple uses such as for both agro-processing and power generation, which increase the load of the mill and make such installations more sustainable.

farmers' own villages. Most processes can utilise energy derived from shaft power, with many alternatives for technologies powered by human, animal, water or a stationary engine. Diesel powered mills, for example, can easily be adapted to power other machines such as oil presses. This opens up the possibility of self-sustaining community systems, where machine fuel will be obtained from the crops processed, and maintenance costs will be paid for through a charge for the services. This framework has been successfully used, for example, by the Multifunctional Platform (MFP) project in Mali (Case Study 2).

## Natural resource extraction

**Table 7** Natural resource extraction technologies

| Service | | Typical technology | Mechanical power alternative |
|---|---|---|---|
| Minerals | Drilling, crushing, hole enlarging | Shovel, chisel, hammer, pick axe | Manual percussion drill, petrol powered drill, expandable tube with hydraulic pump |
| | Washing | Hand washed | Hand/fuel/water powered water jet |
| | Grading | Hand screen | Hand/fuel/water powered shaker |
| Timber | Sawing | Hand saw | Powered saw (sawmill, chainsaw) |

**Medium-scale sawmill**
Medium scale sawmills in rural areas, using mechanical power to create planks from felled trees, can increase productivity of timber processing for construction and income generation without increasing pressure on forests to unsustainable levels. In the case in Sri Lanka shown, the sawdust is also used in kilns for firing bricks, another important shelter material and livelihoods activity in rural areas.

Photo: Practical Action

Small-scale mining is a labour intensive industry that often poses serious health hazards due to poor working conditions and lack of safety precautions. Artisanal and small-scale mining (ASM) may be the only livelihood opportunity for some people, or may be their source of income during the agricultural off-season. In recent years, the international community has increasingly recognised the link between ASM and poverty. This has materialised through initiatives such as the Community and Small-Scale Mining (CASM) network set up by the World Bank, and Mining, Minerals and Sustainable Development (MMSD). The suitability of mechanical tools for small-scale mining, and their use, has been well-documented, and there are many technologies that can reduce the effort needed for mining (McDivitt, 1990; Priester, 1993). Small-scale forest harvesting has seen increased interest in recent years due to its relatively low environmental impacts. Without access to large machines, these enterprises are limited in the size of trees that they can harvest, and this means that extracting them from the forest does not create the wide pathways that unnecessarily destroy vegetation. Improvements in the use of mining and forestry methods and technologies can help save lives by reducing human error, and can enable access to previously inaccessible resources.

Most traditional methods involve hand tools (Table 7), so there is significant room for some degree of mechanical power to increase efficiency and support related livelihoods.

## Small-scale manufacturing

The ability to generate income is often seen as the first step out of poverty. This requires people with skill levels sufficient to produce goods, at a sufficient level of quality and quantity. Mechanical power technologies allow micro-enterprises to produce goods consistently at the same quality and at a faster production rate. This, in turn, will directly affect their income for the same time spent on labour. In some cases, new products can be manufactured, for example, setting up a metal workshop, where previously people did not have the means to produce replacement engine parts. Once they can manufacture their own products, entrepreneurs can ensure that local demands are met. For example, lemongrass can be added to the mix for briquettes to drive mosquitoes away, and it can be compressed with rich nutrient materials

**Table 8** Small-scale manufacturing technologies

| Service | Typical technology | Mechanical power alternative |
|---|---|---|
| Metal working | Hammer | Sheet metal/pipe bender, hole puncher |
| Wood working, carpentry | Hand saw | Saw mill, treadle lathe |
| Briquetting/brick pressing | None | Hand/foot powered pressers |
| Textile making | Hand woven | Treadle loom |
| Papermaking | Mould and deckle | Paper press, pulp mill |
| Pottery | Hand powered potters wheel | Treadle pottery wheel |
| Packaging | Unsealed packages | Bottle cappers |

*Note*: All human powered rotary applications can potentially be replaced by a stationary engine or motor


Photo: Legacy Foundation

**Case 7 – Briquette press – Mbale, Uganda**

A simple press commercially costs US$100-175 and can be made on site without electricity or welding and will last eight years with basic maintenance. A 6-man team producing briquettes will be able to supply up to 75 households (10 people/household) per day for cooking needs. As quoted from the FAO, a person uses 1.2 kg of fuel per day for cooking and heating so this translates to a reduction of demand for fuelwood by 300 tonnes per year, while giving employment to 6 people.

for plant pots. For any new technology, there needs to be demand for the end product; mechanical alternatives are highly contextual, depending on local markets and availability of resources.

## Lifting and crossing

**Table 9** Lifting and crossing technologies

| Service | Typical technology | Mechanical power alternative |
|---|---|---|
| Lifting | Manual labour (climbing, lifting) | Chain/rope hoist |
| Crossing | Manual labour (swimming, walking) | Gravity ropeway, Tuin |

Manual lifting of goods can be very taxing physically, but is sometimes necessary. Examples include natural resource extraction (such as mining), or crossing rivers to bring goods to market centres. Vehicular access in rural areas is usually very limited, and farmers or enterprise owners may need to employ couriers to transport goods on their behalf, placing an additional burden on their own savings, whilst the work itself is both physically challenging and often dangerous. Accidents, loss of goods, and human power for lifting can be reduced with technologies such as gravity ropeways. This can help improve health and save time that can be spent on other more productive activities.

In addition to transporting goods, lifting and crossing mechanical power technologies, such as gravity ropeways, can be more flexible, and provide low cost alternatives to bridges in remote areas. These can form vital connections, enabling people as well as goods, to travel far more quickly from remote villages separated by rivers, ravines or cliffs from centres where medical or educational resources or markets may be found (Case Study 8).

## Summary of livelihood impacts

With access to the energy services mentioned in the previous sections, people are able to improve their livelihoods in a variety of ways. These changes can help shift from a subsistence existence into more productive communities where people are able to enhance their livelihoods through their own efforts. Mechanical power is crucial in enabling people in developing countries to increase both the quality and the quantity of their produce, and in contributing to increased income generation. It should be noted that such benefits must be linked to other factors such as access to markets and availability of

**Table 10** Livelihood impacts

| Livelihood impact | Mechanical power contribution |
|---|---|
| ***Human capital*** | |
| More free time | Having access to a nearby supply of water |
| | Basic processes such as irrigation or milling done more quickly and efficiently |
| | Materials processed locally without the need to travel |
| Better Health | Replacement or reduction of backbreaking manual labour |
| | Access to a clean supply of water |
| | Increased food security through better crop productivity and/or income |
| | More time to take care of the family's health |
| Capacity building | Training and education about the technologies |
| | More time to attend school |
| Loss of jobs | Through mechanisation of manual tasks (in time often leads to creation of other jobs) |
| Increased dangers | Exposure to new dangers from handling powerful machinery |
| ***Financial capital*** | |
| Higher income | Ensuring that the crops are harvested and processed at the right time |
| | Increased yield due to a reliable source of irrigation |
| | Diversification of crop production or higher yields via modern farming tools/techniques |
| | Ability to process materials locally without the need to travel or pay for transport |
| | Ability to produce goods consistently at higher quality |
| | Added value through selling processed products instead of raw materials |
| | Access to previously inaccessible resources |
| | Access to previously inaccessible markets |
| | Ability to obtain free/cheaper water and process energy |
| Entry into debt | Generally capital equipment will be tied to loan repayments and risks remain |
| ***Natural capital*** | |
| Reduce demand on natural resources | The ability to create a new fuel source for cooking and use free natural power for machinery |
| Improved environmental health | Use residues as efficient fuel instead of leaving them as waste |
| | High nutrient materials can be used as fertilizers instead of fuel |
| | Reduction of 'slash and burn' agriculture |
| | Support more drought resistant land use via drip irrigation |
| Degradation of natural resources | Increased intensity of resource extraction possible |
| | Increased agricultural intensity possible |
| ***Physical capital*** | |
| Increase in assets | Owning mechanical power technologies |
| | Producing new saleable products and increasing productivity of existing land assets |
| ***Social capital*** | |
| Increased sense of community | Increased social interactions through community projects |
| | Help promote gender equality through reducing physical exertion and time requirements in jobs typically undertaken by women |
| Decreased sense of community | Revolving funds may disfranchise some who do not receive loans |
| | Loss of some jobs displaced by mechanical power (such as porters replaced by mechanised alternatives) |
| | Helping to promote gender equality may also have negative side effects in disrupting traditional social norms |

raw materials. Access to mechanical power is thus an important, but interdependent, component of rural development. Table 10 summarises the impacts that mechanical power can achieve. The table is arranged by the five types of capital identified in the sustainable livelihoods strategy. Positive impacts are highlighted in blue while potentially negative side effects are noted in orange.

# 3

# Development outcomes

As we have seen in the previous section, mechanical power technologies can alleviate drudgery (such as pounding grain), increase work rate and substantially reduce the levels of human strength needed to achieve an outcome, thus increasing efficiency and outputs (becoming more productive), producing a wider range of products, and saving time and production costs. Unlike many other forms of power equipment, levels of investment can be quite low (see Figure 3 in Section 5) benefitting those on very low incomes. This section looks at the development outcomes in terms of their impacts on the MDGs.

## Goal 1: Eradicate extreme poverty and hunger

Growing more food and accessing sufficient water via mechanical power technologies can improve food security, moving from subsistence to improved nutrition and life quality. Cycles of poverty can be reduced with opportunities to earn income through selling additional produce. Gravity ropeways can deliver foodstuffs efficiently from high, isolated communities to market centres, making food cheaper and accessible to buyers (Case Study 8).

**Case 8 – Gravity goods ropeway – Nepal**

The delivery of people and agricultural produce to the main roads is crucial for farmers. With the availability of the gravity ropeway, they can save 85% of their transportation costs (previously employing couriers) and reduce the 3–4 hour transport time to just 5 minutes.

Photo: Practical Action

In urban East Africa, around 80% of households lack a piped (i.e. pumped) water supply (Cairncross and Valdmanis, 2006). A 10-country survey showed households spent a median of over 20% of their income buying water from vendors, whose prices were typically 10 times the normal water supply utility tariff (Cairncross and Valdmanis, 2006). A locally made treadle pump can pump water up to 130 litres per minute without fatigue, irrigating crops and extending the growing season, and reducing vulnerability to drought (Case Study 4). Wind pumps and hydrams can pump water for irrigation and drinking directly into tanks. Manufacturers can make and sell more goods using machinery. Quality is often improved, (e.g. using a pipe-bending machine, or treadle sewing machine), adding value and producer income for the same raw material cost. Packaging tools can add value by making goods more attractive. This added income can buy essentials, including more nutritious food.

## Goal 2: Achieve universal primary education

Mechanical power can help address this issue in three ways:

- Where children support the family through physical work, mechanical power can be substituted – e.g. digging, seeding, factory labour, so they can attend school. In sub-Saharan Africa, children from the richest 20% are 3–4 times more likely to attend school than those from the poorest quintile (UNESCO, 2008).
- Increasing food access (see Goal 1 above) can improve the nutritional status of children. According to the UNDP, child malnutrition is a global epidemic affecting one in three children under five, and undermines their ability to learn, especially in sub-Saharan Africa and South Asia (UNESCO, 2008).
- Additional income, through productive activities using mechanical power, may allow parents to pay school fees. After fee removal in nine countries (comprising Cambodia, Malawi, Uganda, Burundi, Kenya, Zambia, Lesotho, Ethiopia, Nigeria), enrolment increased substantially, particularly among poor children. There is some evidence that after an initial surge, the rate of growth in attendance

slowed down. The Mali Multifunctional Platform, described in Case Study 2, has shown that there is an increased level of girls' attendance in primary school and an improved proportion of school children completing primary education when the MFP is available. Reasons cited are children no longer having to work at water fetching, grinding, and some meal preparation.


Photo: UNDP

**Case 2 – Multifunctional Platform (MFP) – Mali**

MFP can perform several different tasks, including water pumping, oil pressing and milling – traditionally women's tasks. The MFP can save up to 40% of the processing time. This allows girls who had to help out with the tasks to attend schools and give women a higher production capacity to increase their income and help them set up an enterprise.

## Goal 3: Promote gender equality and empower women

Women are often overburdened by household and agricultural tasks requiring physical strength. Mechanical power can help alleviate such drudgery. In Mali, production levels and incomes have quadrupled through the use of the multifunctional platform (UNDP-MFP, 2008), and in Asia, tools such as decorticators, dehuskers, and rotary dibbers have increased productivity by several orders of magnitude (NRCWA, 2004). In Nepal, sawmills driven by micro-hydro employ women (Misana, 2001). Such activities improve women's social status through economic empowerment. Where women's rights to productive assets and services are assured, there is improved sustainability and household food security (IFAD, 2003).

Wind and water mills reduce the drudgery of grain processing and the need for women to carry water long distances. Money and time saved is equivalent to additional earnings. A pedal-operated press used by women in Orissa, India to manufacture biodiesel to run a water pump, has increased secure access to water, and provided fuel-cost savings (Case Study 2). Technologies, such as briquetting machines can enable women to make fuel for cooking, freeing up time and selling fuel rather than buying it (see Case Study 7). Freeing up female children from chores enables them to attend school. Over half the countries in sub-Saharan Africa, South and West Asia have not reached the target of gender equality at primary school level (UNESCO, 2009).

## Goal 4: Reduce child mortality

Each year, almost 11 million children under five die from preventable causes. Three-quarters of all these deaths are caused by: acute lower respiratory infections (19%), diarrhoea (18%), malaria (8%), measles (4%), HIV/AIDS (3%), or neonatal conditions (37%). Half of all child deaths are underweight children. About 40% of all pneumonia and diarrhoea deaths are in the African Region (WHO, 2005).

Much ill-health is caused by poor infrastructure; mechanical power can help provide: sufficient clean water using hand pumps, reducing diarrhoeal disease; increased earning capacity, enabling clean fuel purchase, reducing respiratory ailments and low birth weight. Improved food security can reduce child deaths through malnutrition. Child safety is compromised if women have to walk miles for water, leaving tiny children in the care of their peers. The Kijito Windpumps (Case Study 3) show how mechanical power can lift water from deep boreholes, increasing local access to water resources.

Providing tools and technologies to mothers can have a profoundly positive effect on child health. The UNICEF nutrition strategy recognizes care as a key determinant of nutrition status, demonstrating that even in adverse conditions, e.g. poverty, conflict, or limited health care, enhanced care-giving can optimize existing resources to promote good health and nutrition in young children (Winkvist, 1995).

## Goal 5: Improve maternal health

During pregnancy, women find it harder to do physical work, reflected in their lack of income to buy nutritious food, and/or difficulties in harvesting nutritious crops. Poor nutrition causes anaemia, increasing the risks of maternal death, stillbirths, peri-natal deaths, and low-birth-weight babies. Mechanical tools can help pregnant women harvest and process crops, access water, expend less energy, have time to care for family, and improve nutrition (WHO, 2005). It can enable an expectant mother to perform her chores without endangering her life and that of the unborn baby. In Nepal, integrating mechanical mills into rural villages has reduced this effort for daughters-in-law, whose role includes these tasks (CRT).

## Goal 6: Combat HIV/AIDS, malaria and other diseases

Severe anaemia probably accounts for more than half of all childhood deaths from malaria in Africa (WHO, 2005). Basic mechanical technologies can enable very poor households to grow and sell more food and/or earn greater income, thereby reducing their vulnerability to death from malaria. Water pumping can lead to increased water supplies, and 'no matter how motivated and skilled health workers are, they cannot do their jobs properly in facilities that lack clean water… '(WHR, 2006). Hand-washing is a major factor in reducing hospital disease (WHO, 2009). Diarrhoeas and skin diseases are common secondary, opportunistic infections and can be reduced by access to clean and adequate water supplies. HIV/AIDS patients are also highly susceptible to other diseases related to poor water supply, sanitation and hygiene. Easy access to a safe, reliable and sufficient water supply and basic sanitation is essential. Water can increase food security and maintain nutrition levels, keeping patients healthy for longer, and resulting in household income falling less rapidly. Furthermore, access to water for crops, vegetables and fruit for home consumption and marketing are crucial (WELL, 2003).

There is a shortage of almost 4.3 million doctors, midwives, nurses and support workers worldwide, particularly in sub-Saharan Africa (WHR, 2006). Mechanical power can help to increase the wealth of communities, creating improved built environments conducive to attracting health professionals. For example, in rural Kenya, poor living and working conditions are one of the factors that drive key health workers to urban centres and abroad (Ndetei et al, 2008).

**Power tiller – Nepal**

Attachments such as a harvester and a bed planter can be used with the power tiller, to increase crop turnover and yield, as it can perform better and quicker bed preparation and allows the use of a more effective irrigation system.

Photo: Practical Action

## Goal 7: Ensure environmental sustainability

There are a number of areas where environmental gains can be achieved:

- Local power and tools can reduce transport costs, provide local employment and reduce the carbon footprint for agro-processing operations and small enterprises.
- Low-cost manually-powered briquette presses (Case Study 7) can be used to create high-quality cooking fuel, either by compressing residues (sometimes with a binder such as gum arabic) or by charring and then compressing residues. This allows cow-dung, which has high nutrient value, but low calorific value, to be kept for fertilizer.
- Water power in sawmills, and the residues converted using hand operated presses to briquettes, reduce pressure on forest resources. In the Himalayas (Case Study 6), upgraded water mills provide irrigation water, improved agro–processing and power for small enterprises such as combing cotton (Agarwal, 2006), saw milling (CRT), increasing income and food production.
- The capacity for people to grow crops more effectively and efficiently through improved tools and irrigation may over time lead to less 'slash and burn' agriculture.

## Goal 8: Develop a Global Partnership for Development

The Energy and MDGs report (Modi et al, 2006) recommends provision for "access to mechanical power (for water lifting/delivery systems and agro-processing)...in all rural communities". A good example is the use of water-current turbines in Sudan, (Case Study 1). It suggests "aggregating demand across multiple social and income-generating needs within the community, thus lowering unit costs, and locating services for small businesses and/or cooperatives at some central point…unlocking local private capital." The report proposes "immediate wider access and scalability through use of low-cost transitional technologies…substituted eventually, as affordability and energy-demand evolve, as income levels increase". Developing consensus around mechanical power alongside other energy sources is a key step in supporting the expansion of energy access via global partnerships.

# 4

# Interventions expanding access to mechanical power

The interventions required to increase access to mechanical power vary widely according to a range of factors that include: the particular technologies in question; level of awareness; existing legal frameworks; cultural/societal contexts; access to financing and organizational/institutional scenarios within regions, sub-regions, countries and local areas. Development partners with important roles include national and local government, the private sector (e.g. technology developers, manufacturers, vendors and maintenance firms), non-governmental organizations, community groups, universities and international agency actors. The case studies selected, and research conducted, highlight a number of key factors and interventions which merit consideration in all situations.

## Delivery mechanisms

Delivery mechanisms (or 'delivery models') refer to an array of measures or strategies which are contained within the design, practice or final evolution of a project or business plan. Analysis has shown that delivery mechanisms are layered, with a variety of approaches or options possible at each level. This is illustrated in the Delivery Models tool see Figure 2 (PAC/PISCES, 2008), where possible choices regarding physical delivery systems, equipment purchase and ownership models, management responsibility and financing options are highlighted. With mechanical power selected, it is apparent that the primary energy services mechanical power provides, are Process/Production (including social services like water pumping) and Mobility in some cases, as opposed to basic household services. The tool also highlights that centralised (e.g. grid based) and commodity market (e.g. fuelwood or LPG distribution) physical delivery systems are not appropriate, due to the limited transmission and transportation characteristics of mechanical power.

These characteristics make Mechanical Power an inherently local energy vector and physical Delivery Systems therefore tend to be **Stand Alone** (e.g. at small-enterprise level), or **Decentralised Systems** (at village or community level). Although this does not rule out any particular purchase, ownership, management or financing models, it does put a premium on local participation in any interventions, and requires the local presence of trained individuals and responsible institutions for management and maintenance of systems.

The suitability of mechanical power for production and processing in particular, means that use of such services generates income for users, which can in turn also pay for the service in decentralised systems. This makes Delivery Models involving **Small-Enterprise Management Models** (Sanchez, 2007) or **Energy Service Companies** (ESCOs) particularly relevant. Such models can involve technical training and assistance in business model development to one or more locally-based enterprises, which in turn manage and deliver energy services locally, on a fee-for-service basis, which pays for the maintenance, upkeep and growth of the service. The Himalayan Watermills owned by operators serving the community (Case Study 6) is an example of this type of model.

Where decentralised systems are particularly linked to basic public services like water supply, or where conditions are conducive to community or co-operative action, then there is potential for **Energy Community Co-operative** or **Energy Consumer Society** models (PAC/PISCES, 2009). Such models involve the membership of service consumers within a local institution, which includes provision for training and payment of maintenance staff, employed by the co-op or society, who in turn are paid through fees, levied by members for the services, at rates agreed within the local institution, such as in the MFP Case Study 2.

In cases where the mechanical power systems are stand alone products for individual households or families, such as in the case of a treadle pump (Case Study 4), then **Energy Equipment Retailer Models** (PAC/PISCES, 2009), often linked with **Micro-lending Facilities**, may be most suitable. Again, the productive use of pumping in irrigation, for example, provides additional farmer or household income from better and more stable yields, which can assist in repaying the loans as well as raising subsistence farmers out of poverty and vulnerability.


**Figure 2** Energy delivery models tool beta version with mechanical power selected (PAC/PISCES, 2008)

## Promotion, awareness-raising and capacity development

In order to develop, implement, maintain and grow successful mechanical power interventions, certain enabling conditions must be in place, and it is here that multilateral and bilateral agencies and governments may play an important role. Awareness of the possibilities and benefits of mechanical power is a prerequisite for uptake and expansion of technologies and services. This awareness is necessary at all levels, from that of consumers, through intermediaries such as NGOs or private enterprises and

**Case 3 – Kijito wind pump – Kenya**

This wind pump design was developed through a collaboration between Practical Action and Christian Aid. A Kenyan company, Bobs Harries Engineering Ltd (BHEL), initiated a commercial venture around the technology with all manufacturing, maintenance and training done locally. BHEL has gone on to supply wind pumps in 20 countries in Africa, Europe, N. America and the Middle East.

Photo: Legacy Foundation

technology providers, private entrepreneurs, up to local and national governments. Awareness of the particular contribution and benefits of mechanical power is necessary, at the international level, in terms of ensuring that regional and multi-national programmes, tools, strategies and financing mechanisms adequately reflect the contribution of mechanical power to energy access.

Awareness-raising is closely linked to promotion and marketing plays an important role in generating enthusiasm and demand for a product or service at a local level, while advocacy at national and international levels can be more appropriate. Education and training at various levels is a crucial and complementary intervention, in both creating awareness and developing capacity, with respect to mechanical power (see Kijito wind pump example in box above and Case Study 3). Institutional capacity development at the national government, sub-national and local levels is needed, while technical capacity-building should include: local technicians, engineering design and development in universities and companies; community organization in NGOs/CBOs; business planning and management in energy enterprises; and incorporation of mechanical power in energy strategies at national level. Strategies to promote capacity building may include establishment of centres of excellence, exchange programmes, and transfer and piloting of successful mechanical power initiatives. Increased demand, awareness and capacity, regarding the role of mechanical power and its potentially transformative contribution to the efficiency and effectiveness of human labour, should be reflected in corresponding policy and financing measures at national and international levels.

# 5

# Financing opportunities

A key feature of mechanical power with respect to other energy technologies is its relatively **low capital costs per unit installed** compared with electricity (see Figure 3). As noted in the previous sections, mechanical power schemes usually incorporate opportunities for income generating activities and therefore a good financial return on investment. In spite of this, up front capital is still a key barrier in rural areas, where investment capital is scarce and loan facilities unavailable or prohibitively expensive at small to medium levels.

**Case 5 - Biodiesel pumps (biodiesel produced using cycle power) – India**

The water supply systems were built through bilateral funding. Village communities contributed 40% of the infrastructure cost, provided unskilled labour and local materials and the rest was covered by a grant from the World Bank Development Marketplace. The community meets 100% of the operating and maintenance costs and fuel is produced locally, so no extra costs are incurred. The project reduces the time and cost of water pumping and supports rural development.

Photo: WISIONS/CTxGreEn

Financing models and mechanisms to overcome this bottleneck for mechanical power do not differ fundamentally from other stand-alone or decentralised energy schemes. Given the particular linkages of mechanical power to income generating activities (not usually the case with household solar PV installations for lighting and radios for example), financing could in principle be less difficult if financier perceptions of mechanical power were improved, and commercial or semi-commercial loans might be considered. However, where mechanical power provides basic processes providing a social service, investment and payback characteristics are different.

The financing institutional framework, including policy, should enhance both the provision of a viable mix of energy services, and support the growth of the sectors that need the services. This is especially necessary for the sustainability and scale-up of services provided by mechanical power.

For **social services**, it is likely that subsidies and grants from international donors, in collaboration with relevant government ministries and NGOs, will remain a key mechanism for funding mechanical power installations for basic services. For this category of services (e.g. water pumping for drinking water) substantial incentives (government grants, support from projects/programmes) will be necessary to reach the poorest. Indeed income generated from social services is generally extremely low and is not sufficient to pay back the up front investment. Nevertheless, tariffs in line with the beneficiaries' willingness or ability to pay should be set in order to ensure that the maintenance costs (labour force, spare parts) are covered and costs are shared between public funding, community contributions and, where possible, private finance.

For **income generating activities** (for instance grain milling or manufacturing), soft and/or commercial loans, coupled in some instances with small subsidies, are instrumental in creating thriving businesses. The success story of micro-hydro in Nepal is mainly based on an implicit strategy aimed at prioritizing micro-hydro for mechanical power and income generating activities. Figure 3, (Khennas and Barnett, 2000) based on case studies from five countries in Latin America, Africa and Asia, illustrates the relatively low financial barriers to enter the micro-hydro business, aimed at end uses supplied by mechanical power. Despite interest rates of up to 17%, hundreds of schemes were developed on a sustainable basis in Nepal by small entrepreneurs.

For **enterprise-based mechanical power initiatives** there is a range of sources of funding already in existence which are potentially appropriate, based on commercial or semi-commercial loans, including AREED (African Rural Energy Enterprise Development) in Africa. AREED offers rural energy entrepreneurs in sub-Saharan Africa a combination of enterprise development services and start-up financing. The programme allows entrepreneurs to structure their companies for growth and, by mainstreaming local financial partners, makes eventual investments possible through loans. This is an innovative approach

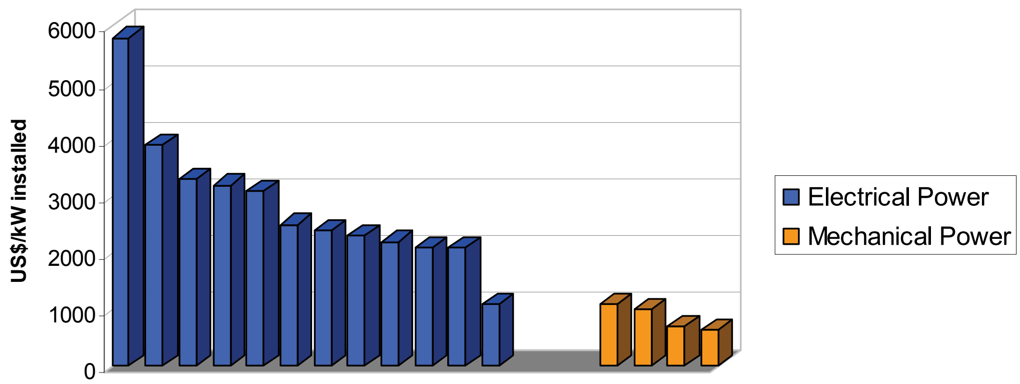


**Figure 3** Cost per kW installed for selected rural hydro schemes in Africa, Asia and Latin America

in the African context, particularly in West Africa. The government of Senegal for example has used the AREED approach to develop its national programme delivery in rural areas. However AREED remains dependent on funds from non-conventional sources of financing (UNEP).

For **stand-alone mechanical power systems** at farm or household level, financing and micro-lending models have been developed, such as that of the Grameen Bank of Bangladesh. This micro-lending agency has over 1000 branches and two million members and disseminates energy systems through a non-profit rural energy company, Grameen Shakti. Loans are made after a small down-payment and, while the model was initially developed for solar PV systems, it is extending into other sectors which could include mechanical power products such as treadle pumps (see box below and Case Study 4).

For **decentralised mechanical power systems**, such as community water supply (Case Study 3) or shared milling resources (Case Study 6), additional financing options can be considered, drawing from existing experience in revolving funds for micro-hydro – such as in Practical Action's experience with the IADB in Peru. Loans are given to institutions involving local government and the community, often with management and operation of schemes by trained local enterprises.

A number of development agencies are helping to facilitate these **micro-credit schemes** by assisting the private sector and providing the interface between poor communities, energy services and private, capital. The financial commitment of communities and entrepreneurs, together with a commercial approach, offer more guarantees for sustainability and poverty alleviation. Cost reduction, though not specific to mechanical power, is achieved mainly by:

- Addressing non-energy barriers that hinder access to financing (e.g. policies, institutions).
- Government, private sector and community partnerships and participation, enabling costs to be reduced by employing a local labour force and/or utilizing other community-owned assets such as land as a collateral to secure loans.
- Increasing the number of people involved in a scheme as shareholders/customers, reducing the costs for each contributor and increasing income generated – which is key to the sustainable development of productive processes.

Photo: KickStart

**Case 4 – Treadle pump – Zambia and Zimbabwe**

Local microfinance institutions were identified by the project initiators, International Development Enterprise (IDE), and farmers were able to secure loans in order to purchase their own pumps. Even though farmers have to bear the whole cost of the pump, they usually do not have any difficulty in securing loans since the lenders know that the pumps will increase their yield, hence income, sometimes up to 100%. The repayment rates are on average 1–2 years and in the second year, many farmers start investing in other machinery such as a radio or even a second pump.

# 6

# Conclusions and recommendations

Mechanical power has been found through this study to be something of an enigma in energy for development. It is an ancient form of energy, currently widely used in some developing countries as a foundation for livelihoods, but at the same time it is more widely under-appreciated and under-considered to the point that data and frameworks for mechanical power are almost completely lacking. The reasons for this lack of consideration may be partly because of the way mechanical power can be derived from other energy vectors such as diesel engines and electric motors. However, to assume that mechanical power is only a derivative of other energy vectors is to ignore the special contribution of mechanical power itself to rural production and physical processes. It is unsafe to make an assumption that other energy vectors are available and will indeed be turned to mechanical power in development contexts where “other side of the meter” issues are often ignored. It also ignores the many applications of mechanical power derived directly from non-fossil fuel resources including water, wind, animal and human power which can be effective, but can suffer from status perception issues.

This study has attempted to document the range of these applications and contributions in different sectors of rural economies, as well as their corresponding impacts on livelihoods and development outcomes including health. The particular role of mechanical power has been highlighted in enhancing the efficiency and effectiveness of productive and production processes (particularly those conducted most often by women), thereby assisting in breaking the cycle of subsistence production, poverty and reliance on unenhanced physical labour. Mechanical power has been shown to be a crucial component of the delivery of some basic services, including water supply and lifting/crossing, in an inherently local manner, through delivery mechanisms which reflect financial self-sustainability as well as local control, management and participation.

It is hoped that these submissions will provide evidence to policymakers of the need to **consider mechanical power on a more equal footing with electricity, transport, and cooking/heating services, in energy and development strategy formulation**. Some specific suggestions for next steps which should be taken by international agencies in particular include the following:

- Develop methodologies and a fuller informational baseline on the scope, needs, applications, gender aspects, challenges, constraints and impacts of mechanical power to enable better quantification of the sector, formulation of appropriate development strategies and targets, and tracking of progress against these.
- Consider linkages between mechanical power and emerging agricultural development agendas as outlined in the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) report, to maximise mechanical power’s agricultural and agro-processing contributions in support of the productivity of small farmers and food production.
- Conduct awareness raising and capacity development initiatives at implementation levels including more detailed case-studies, exchange programmes and pilot programmes on mechanical power technologies, practices and delivery mechanisms (including financing and business models) which can overcome barriers to scale-up for mechanical power.
- Advocate for the incorporation of mechanical power into national and international energy programmes, strategies and declarations, including the Commission on Sustainable Development (CSD) review of the energy and climate change agenda.
- Implement financing initiatives to scale-up mechanical power alongside other energy options in new and existing financing windows, such as the second round of the EU-ACP Energy Facility.

# ANNEX

## Case studies

### 1. Water current turbines for water supply

*With thanks to Barbara Sexon*

| | |
|---|---|
| **Location** | Sudan |
| **Initiation date and duration** | 1988 to 1998 |
| **Funder(s)** | Various |
| **Project initiator** | Peter Garman, Thropton Energy |
| **Overall output** | Over 30 turbines to end users; training to all parties involved in manufacture and use of turbines |
| **Beneficiaries** | Private farmers; community/village farms; refugees/internally displaced |

#### *Project description*

In Sudan, the majority of family and community farms are close to the Nile. For many, irrigation water is supplied by diesel powered pumps. Whilst stationed in Atbara, north Sudan, Peter Garman and Barbara Sexon of Thropton Energy established a local manufacturing base for the supply of water-powered pumps capable of meeting the irrigation needs of these farms. A study of the resource and the needs of the Nile region showed a potential market of 6000 turbines in north Sudan alone.

#### *Technology*

The GARMAN water current turbine uses the kinetic energy in a flowing river or canal as the power source for a water pump. It floats in the free stream of the river and pumps water onto the bank up to a maximum of 25m above the river level. Output is dependent on river speed and depth, with a maximum of $47m^3$/hr, which is available for 24 hours per day. No dam or diversion of the water flow is needed and as the turbine is tethered to one bank only, navigation of the river is not affected. This design of water current turbine is installed cheaply and quickly without the use of concrete or machinery (see www.throptonenergy.co.uk ).

#### *Delivery mechanism*

Turbines were built in a workshop in Atbara, north Sudan, under licence from Thropton Energy. The majority of beneficiaries were from family or community run farms where turbines replaced diesel-powered pumps. The funding source was dependent on the end user – the local cooperative union of farmers funded Garman turbines for farms in northern Sudan, whilst the NGO, AICF, purchased four machines for water supply to a camp for IDPs in Juba, in southern Sudan. Locally employed technicians were trained to make, install and maintain the turbines. During this period, turbines to the same design were made in the UK by Thropton Energy, for demonstration projects for the UNEP in Egypt and for FAO in Somalia.

#### *Finance*

The capital cost of the Sudan-built water-pumping turbine is four times the cost of the conventional technology (an Indian made diesel pump), and about one tenth of the cost of a solar-powered pumping system with similar daily output. When fuel and maintenance costs are taken into account, the turbine becomes cheaper than the diesel option when used for two years or more. For a Sudanese farmer, the capital cost of a turbine is equivalent to half of the farmer’s annual profit, or 120 cubic metres of water per US dollar over a 10-year life.

### *Livelihood outcomes*

Family and community farms were given access to a sustainable energy source which provided water for irrigation without the need to purchase fossil fuels. The turbines were made and maintained in workshops in the local industrial centre where the necessary training and support was given by Thropton Energy personnel. Local workshops benefited from improved skill levels and increased income.

### *Project outcomes*

The turbine technology proved itself reliable, operating for many thousands of hours in rural locations along the Nile. Apart from the import of a few components and tools, the turbines can be made from locally available materials, transported to site on a small lorry and installed using manpower and hand tools alone. The main barrier to its success is financial. The market for the turbine is small, private farmers for whom access to capital can be a problem. A system of loans or a revolving fund is needed to scale-up the technology in a rural region.

## 2. Multifunctional Platform (MFP) Project

*With thanks to Nararya Sastrawinata*

| | |
|---|---|
| **Location** | Burkina Faso, Ghana, Guinea, Mali and Senegal |
| **Initiation date and duration** | Pilot Phase: 1993–98; First phase: 1999–2004; Transition phase: 2005–07; Second phase: 2008–ongoing |
| **Funder(s)** | Pilot phase: UNIDO, IFAD; First phase: GOVERNMENT, UNDP, GEF, DANIDA, NORAD, SUISSE COOPERATION, FRENCH COOPERATION<br>Transition Phase: GOVERNMENT, UNDP, Lux-Development, AMADER, HANDICAP INTERNATIONAL, LOCAL NGOs;<br>Second phase: GOVERNMENT, UNDP, Gates Foundation, FAFPA |
| **Project initiator** | United Nations Development Programme (UNDP) |
| **Overall output** | Pilot Phase: 48 MFPs<br>First phase: ~500 MFPs installed<br>Second phase: 1500 MFPs by 2012 (Includes 600 with Burkina Faso and Senegal funded by Gates Foundation) |
| **Beneficiaries** | First phase: ~130,000 clients (mostly women) for services such as grinding, dehusking, water pumping and battery charging |

### *Project description*

The idea was first put forward in a joint project by the United Nations Industrial Development Organization (UNIDO) and the International Fund for Agricultural Development (IFAD). The project was implemented in two West African countries, Mali and Burkina Faso, and it was aimed at reducing time spent on the repetitive, non remunerated and energy-intensive domestic non-reproductive tasks allocated to women, such as grinding, de-hulling, and water fetching. Existing grinding mills in the traditional private sector were costly, and their services not adapted to women's needs. In 1996, UNDP and the Government of Mali began providing support to existing platforms and set out to install diesel-fuelled multifunctional platforms across Mali. Over the last years the replication in many other countries including Burkina Faso, Ghana, Guinea and Senegal was evident.

### *Technology*

The multifunctional platform consists of a source of mechanical and electrical energy, provided by a diesel engine of 8 to 12 horse power (hp) (with optional 7,5KW alternators), that is mounted on a chassis and to which a variety of end-use equipment can be added. The configuration of equipment modules – such as grinding mills, battery chargers, electric water pumps, vegetable or nut oil presses, welding machines, carpentry tools, and mini electricity grids for lighting – is flexible and can be adapted to the specific needs of each village when the MFP's profitability is concluded from feasibility study. The use of biomass-derived fuel (from Jatropha) has been tested in 11 MFPs and it does not show any drop in power. In Maourolo village, the MFP installed in January 1999 has been operating since then with Jatropha oil. This provides future opportunities for the MFPs to be self-sustaining.

### *Delivery mechanism*

Installation of a platform is demand-driven. A duly registered women's association has to request it, with the active support of the village community, but female ownership and management were made a requirement. Before a platform is installed, a social, economic, and technical participatory feasibility study is undertaken by local project trained partners. After initial literacy training, the association elects a women's management committee, whose members are then trained in managerial and simple entrepreneurial skills, to ensure a transparent management system, and the technical and economic viability of the platform. Male artisans in rural areas were trained in mechanical and electrical installation, maintenance and welding. Spare-parts shops are identified and connected to the women's management committee and trained artisans' network as well. In very remote areas, trained artisans are provided with spare-parts deposits.

### *Finance*

The estimated cost, depending on the number of modules, is ~US$12,000 for engine, rice de-huller, stone mill, and housing for the platform, as well as for feasibility studies, literacy training, and introductory business training for women operators, to buy, install, maintain, and replace. Between 25 percent and 30 percent of the cost is financed by the women's association, often with financial support from the rest of the community, migrants or partners. A one-time subsidy of approximately $8,400 is provided by the project (about $4,000 for the cost of studies and training and $4,400 to partially subsidise the cost of equipment and installation). The project informs beneficiaries of existing financial and management support facilities, and facilitates access to credit in order to finance the platform. Depreciation and variable costs (operations, maintenance, salaries, etc.) are borne entirely by the women's management committee.

### *Livelihood outcomes*

- Increased level of girls' attendance in primary school and improved proportion of school children completing primary education.
- Reduced seasonal liquidity problems and mitigation of adverse shocks (e.g., natural, economic, or political disasters) by improving health, generating additional non-farm income during the dry season, raising the total net income of households, and empowering women to participate in economic decision making.
- Women have been able to improve their health, as the platform project has led to a rise in the number of prenatal visits to health clinics.
- Additional employment (and new income opportunities) for women operating the multifunctional platform; local private actors.
- Reduce rural exodus of local artisans and generate business opportunities for local private sector.

### *Project outcomes*

- Over 500 MFPs installed during the first phase.
- Average saving of 2.5 hours per day of the time women spend on activities such as manual grinding and water pumping, which can be spent on other income-generating activities.
- An increase in the average annual income of $68 per woman, ~56% increase in income in rural Mali.

### *References*

UNDP

## 3. Kijito windpumps

*With thanks to Tameezan wa Gathui*

| | |
|---|---|
| **Location** | Thika, Kenya, East Africa |
| **Initiation date and duration** | Initiated in 1977, 32 years to date, and ongoing |
| **Funder(s)** | ODA; Barclays Bank; Bobs Harries Engineering Ltd |
| **Project initiator** | Practical Action; Bobs Harries Engineering Ltd |
| **Overall output** | 400 wind pumps manufactured and installed by 2008 |
| **Beneficiaries** | Rural communities in Africa; livestock ranches; private businesses in 20 countries |

### *Project description*

Bobs Harries Engineering Limited (BHEL), located near Thika Town, in Kenya, manufacture wind pumps for water pumping locally. The machines, which bear the brand name 'Kijito' come in a range of rotor diameters which are able to lift water from deep boreholes of 152m. With over 25 years experience in the manufacture and installation of wind pumps, both in Kenya and abroad, BHEL has developed a range of reliable and sturdy machines capable of withstanding storms and pumping water for years, that require only minimal maintenance and attention

### *Technology*

Kijito wind pumps are mechanical direct-drive modern wind-pumping machines, with a range of rotor diameters capable of pumping heads of 30m to 150m. BHEL has a well-equipped workshop in Thika, Kenya, with 20 skilled and experienced men and women, manufacturing and installing the entire range of wind pumps and pump cylinders. At every installation, BHEL provides intensive maintenance training which includes a comprehensive maintenance manual to all customers

### *Delivery mechanism*

Practical Action (then the Intermediate Technology Development Group – ITDG) initiated some work on wind pumps. With initial assistance from Christian Aid, they developed an improved pump design and sought to make contact with six developing countries that would be interested in trying to develop an 'appropriate' wind pump. Through BHEL, in 1998, Kenya became the first country appointed as a collaborator in the Practical Action programme. BHEL eventually took up the whole process in Kenya through to a commercial venture under the trade name 'Kijito'.

### *Finance*

The Overseas Development Administration (ODA) of the British Government provided technical design assistance, initially through Practical Action and later on through consultants. BHEL obtained financial assistance from Barclays Bank International Fund of London. During the early 1980s, a PhD student from the UK worked with BHEL for three years and made a substantial contribution to the field testing and development of the wind pumps at BHEL.

### *Livelihood outcomes*

Some of the livelihood outcomes at community level include increased water security from a constant water supply, reduced theft, increased community management capacity, and local and increased vegetation cover. The longevity and success of installed Kijito water pumps is, after many years, now attracting the interest of policy makers looking at integrating wind pumps as part of their strategic planning processes in Kenya

### *Project outcomes*

BHEL has successfully supplied Kijito wind pumps in 20 countries in Africa, Europe, North America and the Middle East. Their success has been attributed to the manufacturing process; an informal organizational and management structure; the installation capability; and provision of comprehensive maintenance training at local level.

Some of their challenges have included: lack of informed investors and financiers; lack of a favourable policy environment in Kenya; being seen as a commercial operation; being accused of trying to resurrect a 'discarded' technology; general lack of knowledge on the technology; decision-makers not wanting to go outside the accepted 'norms' of water-pumping technology; lack of reliable wind data; lack of a 'maintenance mentality' in users; corruption and unrealistic expectations by clients, sometimes due to false claims from suppliers. Recently the tide seems to have started to turn, and African Governments, aid agencies and individuals have started to see that under the prevailing conditions, wind pumps are again being considered as an appropriate way of lifting water.

## 4. Promoting market oriented smallholder agricultural production through treadle pump irrigation

*With thanks to Tameezan wa Gathui*

| | |
|---|---|
| **Location** | Zambia and Zimbabwe |
| **Initiation date and duration** | 1998–on-going |
| **Funder(s)** | USAID, CIDA |
| **Project initiator** | IDE |
| **Overall output** | • 50–80% increase in crop productivity and output<br>• 100% increase in incomes earned by farmers<br>• 60–80% reduction in time spent by farmers irrigating their plots |
| **Beneficiaries** | Estimated that at least 50,000 smallholder farmers have adopted and benefited from the technology in Zambia and Zimbabwe between 1998 and 2008, with more farmers continually adopting the technology. |

### *Project description*

International Development Enterprises (IDE) has been in the forefront of promoting treadle pumps since the early 1980s as a way to get smallholder farmers to participate in market-oriented agricultural production and to increase their incomes. In India and Bangladesh, IDE has been able to distribute more than one million treadle pumps that have transformed the livelihoods of poor smallholder farmers by raising their productivity, output and incomes. Encouraged by the huge success achieved in Asia, IDE decided to start similar initiatives in Africa. Work to promote treadle pumps in Zambia and Zimbabwe started in 1998 and 2003 respectively.

### *Technology*

The treadle pump is a foot-powered pump that was developed in the 1970s by Norwegian engineer, Gunnar Barnes. A person provides the power required to extract water from a source such as river, dam or shallow well and convey the water for irrigation. Typically, the pump can extract water from a depth of 7 metres and convey it over a horizontal distance of 20 metres or 3 metres vertical height. There has been continuous improvement in the treadle pump since the first version was produced. The version that has been widely promoted and is most popular in Southern Africa is the KickStart MoneyMaker. In 2008, the KickStart MoneyMaker was selling for US$200 in Zambia. Linkages have been established with local engineering firms to ensure local manufacture and distribution and hence increase access to the pump by smallholder farmers.

### *Delivery mechanism*

IDE promotes the use of local materials and skills for the production of treadle pumps. In both Zambia and Zimbabwe, local engineering firms produce and distribute treadle pumps. Linkages have also been established with micro-finance institutions to enable farmers to access loans for purchase of the pumps and for working capital. Typically, farmers who borrow money are able to pay back their loan within one year, due to increased productivity, output and higher incomes earned from sale of crops.

### *Finance*

Funding is required to pay salaries for IDE staff to mobilize and encourage farmers to adopt the treadle pump, establish linkages with local engineering firms to manufacture and distribute the pumps and identify and work with local micro finance institutions to provide loans to farmers. Farmers enter into commercial transaction relationships with all these players. The increased incomes they earn enable them to pay off their loans within one year. By year 2, many farmers start to invest in a second pump and other household assets that include radios, TV sets and solar panels.

### *Livelihood outcomes*

Use of the treadle pump has transformed livelihoods for about 50,000 farmers in Zambia and Zimbabwe between 1998 and 2008. The main benefits realized by farmers include:

- 50–80% increase in crop productivity and output;
- 100% increase in incomes earned by farmers;
- 60–80% reduction in time spent by farmers irrigating their plots;
- Farmers have more time available to conduct other activities and hence expand income earning opportunities.

### *Project outcomes*

Treadle pumps have made a huge contribution to transformation of smallholder farmers' livelihoods in Zambia and Zimbabwe. They enable farmers to engage in crop production (especially horticulture crops) all year round, raise productivity and output, and earn higher incomes. Local engineering firms that produce and distribute the pumps have expanded their product range and incomes. Micro-finance firms have expanded their credit portfolio and have found smallholder farmers to be reliable borrowers. The demand for treadle pumps continues to grow and it is evident that they are making a significant contribution to support farmers to participate in market-oriented production.

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## 5. GV-CTxGreEn biodiesel project

*With thanks to Namiz Musafer and Ramani Sankaranarayanan*

| | |
|---|---|
| **Initiative Name** | GV-CTxGreEn Biodiesel Project |
| **Location** | Kinchlingi, Gajapati District, Orissa, India |
| **Initiation date and duration** | November 2004–January 2009 (and continuing) |
| **Funder(s)** | World Bank Development Marketplace (2003), SDC, IDRC, SSHRC, Shastri Indo-Canadian Institute (SICI), volunteers and project proponents |
| **Project initiator** | CTxGreEn |
| **Overall output** | Viability of producing biodiesel from local oilseeds, human-powered biodiesel processing and local applications of biodiesel is demonstrated |
| **Beneficiaries** | 16 families / 73 residents accessing water and lighting, local utilization of oil seeds and cake and extension to 6 more villages with population of 800 is underway |

### *Project Description*

The residents of Kinchlingi, Orissa, India are an indigenous forest community practicing subsistence farming living below a dollar-a-day. Water was obtained from a well and stream about 16m below the village. There was no electricity. The project installed a 3.5HP (bio)diesel pumpset in 2005 providing water and sanitation until gravity flow water reached in 2008. A biodiesel-fuelled hybrid electrification system was commissioned in 2009 with a 3.5HP gen-set providing 3 hours of lighting each night. The community grows Niger, an indigenous oil seed, on fallows. It is supplemented with non-edible Karanja seed, bartered for salt from a village nearby. The next transformation is supporting livelihoods and income generation by biodiesel-fuelled agro-services (tilling, mobile irrigation, rice hulling and oil expelling) using a multi-purpose power tiller, thereby linking food and fuel security.

### *Technology*

Biodiesel is produced in 5 litre batches in Kinchlingi, each taking 4 hours to produce including 1 hour of pedalling, during which triglycerides in oil react with absolute alcohol and sodium hydroxide (lye) to form esters (biodiesel) and glycerine. A hand-operated oil press extracts oil from seeds. The CTxGreEn's package includes village-level refining units for oil, biodiesel and glycerine. The oil press processes up to 10 kg seed/hour (15–25 litres of oil per day). A biodiesel reactor processes 10 litres of oil into 10 litres of biodiesel daily. The biodiesel produced with this technology has been proven to be a good fuel for 3.5HP to 13.5HP diesel engines powering pump-sets, gen-sets and power tillers. The only modification required is the replacement of the factory-standard rubber fuel hoses with nylon-reinforced plastic or copper pipes. Kinchlingi's hybrid electrification system includes a 220V 60Hz mini-grid, 15W CFL's, AC-DC and DC-DC chargers, battery bank, and battery-powered LED lights. The community is trained to operate and maintain the production units and end-use devices, facilitated by a bare-foot technician.

### *Delivery mechanism*

CTxGreEn with an NGO, Gram Vikas, demonstrated feasibility of production and use of biodiesel as a model. First, village level operation and management for water supply was demonstrated. Kinchlingi needed 11-13 litres of biodiesel monthly to operate the pump-set one hour daily. For water pumping and electrification 2–3 batches of oil are needed monthly. They adopted a volunteer-driven model for water supply. Each family sent a member (each) once a month for production and cultivation/harvesting of Niger. They contribute Rs.30/month/family and provide required seeds for electricity. The pump-set ran for 700 hours using 455 litres of biodiesel and pumped 2,200m$^3$ of water between 2005 and 2008. These services are now being expanded to neighbouring villages, the mantra being, 'development of rural areas is tied to increasing value addition to local resources and sustainable agriculture'. Core activities undertaken were business plan development, assessment of seed availability and matching with livelihood needs; entrepreneurial training; demonstration of oil cake as manure, and policy engagement to access government support and financing.

### *Finance*

CTxGreEn provided know-how and brought in capital. Core funding was from World Bank Development Marketplace 2003 (US$230,000 shared among 4 projects including Kinchlingi). Grants from others and project proponents were added later. Water supply systems were built by bilateral funding. Communities contributed 40% of infrastructure cost, unskilled labour and local materials. Feedstock is grown by the community and a monthly tariff is collected. In 2006, production cost of biodiesel was about INR50 ( about 1 dollar) per litre and 80% of it was for oil as raw material. Converting glycerine into soap and recovery of excess methanol and glycerine shows potential to compete with fossil diesel. Providing agro-services by biodiesel-fuelled power tiller is projected to be self-sustaining.

### *Livelihood Outcomes*

The community used fallows to grow oil-bearing crops for 3 years. In 2006, about 140 kg of seeds were collected (harvest: 200 kg per hectare) with no cash outflow. In the water/electricity supply phase, expenses can be reduced but no increase of gross income. One bare-foot technician trained on biodiesel has set up a diesel-based rice-hulling unit on the expectation of using biodiesel. Oil cake is available for use as organic manure, while a process for converting glycerin into soap is finalised. Self-help groups are focused to be the catalysts for livelihood opportunities.

### *Project outcome*

A village of 73 people got access to water for drinking, sanitation and electricity for lighting due to their collective efforts. A new technology that uses biodiesel and human power is being demystified. It has been shown that the full potential of local resource based biodiesel can be tapped only when the service provision meets a range of local basic and productive needs. The potential to support local food and fuel security using a biodiesel initiative via mechanical power has been shown and the project will continue to develop further in this direction.

## 6. Multipurpose watermills of the Himalayas

*With thanks to Namiz Musafer*

| | |
|---|---|
| **Location** | Western Himalayas |
| **Initiation date and duration** | 2001–5 |
| **Funder(s)** | Self-funded |
| **Project initiator** | Himalayan Environmental Studies and Conservation Organization for individual mill owners |
| **Overall output** | Traditional watermills being disused replaced by a technically developed multipurpose improved watermill |
| **Beneficiaries** | 100 watermills from Western Himalayas |

### *Project description*

According to estimates, there are nearly 200,000 watermills in the Himalayas. Design of water mills is centuries old – some arguing it to be dated back to the seventh century AD. These mills were used for grinding wheat, maize and rice. Traditional mills have a power output of about 200–500 W and their milling capacity is about 5–10 kg of flour per hour. Traditional mills function in a single mode to grind flour. Due to lower efficiencies and availability of modern milling facilities, they were becoming disused. Socially accepted multipurpose and further developed models of watermills were introduced to gain wider benefits.

### *Technology*

Each watermill is unique to some degree, but all share fundamental similarities. These run on the principle of using the kinetic energy of a water stream running on a gradient. Water from a stream is diverted and made to flow down a chute to the turbine of the watermill. Flowing water turns the turbine. The vertical shaft of the turbine runs up through the floor of the mill house and turns a rectangular metal key which turns the top stone of a pair of grinding stones. A lever enables the mill operator to raise or lower the upper stone to adjust the gap between the two grinding stones.

### *Delivery mechanism*

Traditional watermills are built with local technical excellence and the traditional wisdom of people inhabiting the mountain regions. They function in a single mode for a single purpose, and have fallen into disuse, replaced by efficient diesel and electrical mills. The Himalayan Environmental Studies and Conservation Organization (HESCO) in Dehradum, a science and technology based NGO, developed a model promoting multiple uses of water for income generation, power generation, and agro-processing, by introducing modern technology. The project has ensured acceptability of the community, local repair and manufacture for replication and employment creation.

### *Finance*

Lal Singh of Dokwala village invested about US$810 to adopt the improved watermill. It is giving a return of US$135 per month; a payback period of about 6 months. Grinding capacity has increased from 10–15 kg of grain per hour to 25–30 kg per hour. The cost for modification of existing watermills to modern multipurpose watermills may lie in the same range. Watermills are owned by the mill owners and they finance the projects from their own means.

### *Livelihood outcomes*

Watermill owners have initiated floriculture linked to beekeeping. Around 2–10 boxes can be maintained easily and give a return of about US$580 per year. Promotion of fisheries, cultivation of vegetable and ornamental plants, nursery cultivation and daytime small-scale industries (lighting at night) are some of the livelihood outcomes communities have gained due to this technology.

### *Project outcomes*

Due to this integrated technology model, local communities have been empowered to use local resources in a sustainable way while directly benefiting from the mechanical and electrical power and many other livelihood improvement opportunities. Power use and efficiency has been increased by 80–90%.

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## 7. Dissemination of hollow-core briquette technology

*With thanks to Nararya Sastrawinata*

| | |
|---|---|
| **Location** | Lushoto, Tanzania and Mbale, Uganda |
| **Initiation date and duration** | 2007–ongoing |
| **Funder(s)** | McKnight Foundation (through EcoVentures International) |
| **Project initiator** | Legacy Foundation and Uganda Gender Rights Foundation (UGRF) |
| **Overall output** | The training of women for briquette production, approximately producing 2500 briquettes a week per press |
| **Beneficiaries** | 75 women – trained in briquette pressing<br>75 households – supplied with briquette |

### *Project description*

The Legacy Foundation has over 15 years of direct experience with development and application of a variety of technologies including: solar heating systems, rural and village water supply, wind energy, rural transportation, and low-cost housing. The Foundation is working with micro-enterprise-based briquetting technologies, and has released eight technical/training manuals and two devices on all aspects of briquette making. Briquette technology has previously been used by UGRF in Mbale, Uganda, but the briquettes were expensive and produced a lot of smoke. In 2006, UGRF learned of the hollow-core briquetting technology that was promoted by the Legacy Foundation. After obtaining a grant, UGRF were able to provide training and cross-learning opportunities at their location in Uganda and in Lushoto, Tanzania.

### *Technology*

A hand-powered briquette press and a thresher-mesher-chopper (TMC-1) are used for fuel preparation for the press. TMC-1 can process 300 kg of residues, such as browned leaves, grasses, nuisance aquatic plants, rice husks, and sawdust, each day. This is about the total demand for two, six-person microenterprise-based production teams. Two such teams at full production capacity would reach a market of about 100–150 families per day. A briquette production team will need good access to water (up to 300 litres per day) and ample sunshine for drying. Resultant briquettes weigh about 140g and each one burns for about 30–90 minutes, depending on its blend and shape. The hollow-core briquettes, when manufactured properly, can be very clean-burning.

### *Delivery mechanism*

The press can be made locally without electricity or welding and lasts eight years with basic maintenance. UGRF has a number of presses in their centre for briquette production, and they conduct training for women to spread the use of briquettes. The money generated from the sale of the briquettes is reinvested to purchase new presses, but a limited number of presses are kept within the centre and the older presses are given to groups of women that have completed the course for their own personal use. The women producing the briquettes are given free briquettes for their own use every day, before the remainder being sold to clients. The women have to pay to receive training in briquette pressing in the first instance.

### *Finance*

The materials for the basic press costs commercially US$200 and $350 for a TMC. The initial costs for the presses and TMC were covered by a grant, but maintenance and the purchase of subsequent tools is taken from the profits from selling the briquettes to clients in town, such as restaurants and hotels.

### *Livelihood outcomes*

Villagers are able to make their own cooking/heating fuels and generate income. Agro-residues are made into briquettes, which helps to maintain a cleaner environment. It reduces consumption of trees for fuel, as the community had previously used char-briquetting techniques. Compared to cutting wood, production of the equivalent in fuel briquettes has proved far less time-consuming, safer and less back-breaking.

### *Project outcomes*

The average fuelwood consumption is 1.2 kg per person per day, as quoted in FAO, the Swedish Beijer Institute, the World Bank, the French SEED organization and others. At this rate, one press team, in full production, reaching a market of 750 persons per day, is effectively reducing demand by over 300 tonnes of fuelwood per year, while giving employment to six persons.

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## 8. Gravity goods ropeways - Nepal

*With thanks to Namiz Musafer*

| | |
|---|---|
| **Location** | Districts of Mustang, Dhading and Tanahun, Nepal |
| **Initiation date and duration** | From 2002 |
| **Funder(s)** | EU, Trust Funds & Foundations in the UK |
| **Project initiator** | Practical Action, Nepal |
| **Overall output** | 7 gravity goods ropeways spread in 3 districts in Nepal |
| **Beneficiaries** | 7 farmer communities – increased income and reduced time spent and collective efforts of the communities due to the services provided by the gravity goods ropeways |

### *Project description*

A gravity ropeway is an intermediate means of transport between walking (or head-loading) and using conventional motor transport. Practical Action Nepal has supported seven ropeways in three districts of Nepal. These help communities transport their agricultural produce (such as fruits and vegetables) from the farmyards to the main roads. The technology was transferred from Northern India in 2002 in collaboration with the International Centre for Integrated Mountain Development, which has taken over this endeavour. The projects are implemented with the beneficiary communities.

### *Technology*

The technology simply works using gravitational force. There is an upper platform (the top end) and a landing pl–gle loop attached to two flywheels fixed at the top and bottom stations, and includes a braking system. A trolley carries the goods. Once the trolley is loaded with goods at the upper platform (up station) and released, it slides down. A lighter weight (less than one third of the load) can be transported upwards too. About 130 kg of goods can be carried a distance of about 1.3 km.

### *Delivery mechanism*

These projects are implemented with locally-available material and skills as far as possible. However, the steel cables are imported from India or China. Beneficiary communities contribute skill, time and land etc as part of the total project cost. Each ropeway is managed by a marketing group or a cooperative. They levy the user charges based on the weight, they employ operators at both stations, and they oversee operations, maintenance and occasional repairs and the marketing of transported goods.

### *Finance*

These projects are supported by external agencies while 35%–40% of the total cost is contributed by the communities as described above. Running costs after commissioning are met by user charges. The major cost component is for the imported cables where spanning around 1400m costs about around GBP £7000.

### *Livelihood outcomes*

Farmers hired porters to transport their produce downhill prior to the projects. Now they can save 85% in transportation costs with an additional time saving. After the commissioning of the projects, these porters have had to move to others areas to provide their services. Farmers have used the time saved for increased production and by diversifying high yielding crops. By obtaining market information for prices and negotiating with middlemen and traders, the marketing group has helped to get better prices. Improved incomes have helped the communities to afford better agricultural inputs: tools, fertilizers, seeds and irrigation.

### *Project outcomes*

The project has helped Save NRS1.55 per kilogram of goods carried. Due to the absence of the porter, the 3–4 hour delay in transport has now been cut to a mere five minutes. Project interventions have created a cadre of local and national experts who can take the initiatives into the future.

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# Glossary

**Animal drawn tiller, mower**
Pulled by animals (oxen, donkeys) but it still needs a person to guide it.

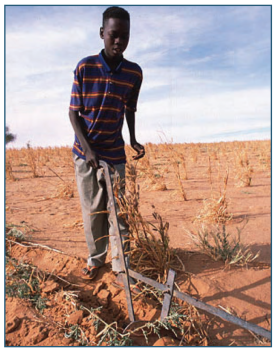
Photo: Practical Action
Animal drawn tiller

**Bed planter**
A possible attachment to a two wheel tractor to prepare land for planting. The attachment creates ridges along the field and seeds are planted on these raised beds, while irrigation and nutrients can be applied through the furrows between the ridges.

**Bottle cappers**
A hand powered tool that applies pressure to a bottle cap by means of a lever. The cap is pressed down and around the tip of the bottle.

**Chainsaw**
A row of teeth, linked in a chain, for continuous cutting, typically powered by a petrol engine or an electric motor.

**Diesel pump**
A motorised water pump.

**Expandable tube**
Typically a strong, elastic, rubber tube that will expand when hydraulic fluid is pumped into it using a motorised pump. It is inserted into an existing hole and will be able to enlarge the hole by pushing out on the walls. It is designed to be safer than using explosives to break off large rocks.

**Flail**
Usually made from two or more large sticks attached by a short chain; one stick is held and swung, causing the other to strike a pile of grain, loosening the husks (http://en.wikipedia.org/wiki/Flail).

**Hand pump**
Vertical or rotary action by the hand is translated to the vertical piston action that draws up the water.


Photo: Practical Action
Handpump

**Hand screen**
A membrane, typically a wire mesh, is propped at an angle and the material to be graded is thrown onto the screen. The finer grains will fall through while the larger grains will slide down the screen.


Photo: Practical Action
Handscreen

**Hand powered potters wheel**

A rotating plate is used to create circular ceramic goods. The hand powered version requires the potter simultaneously to turn the wheel while shaping the ceramic. This can reduce the quality of the product unless the potter is skilled. The speed of production is limited by the turning speed of the wheel.


Photo: Tim Ross

Potter's wheel

**Hand / foot-powered press**

A machine that leverages the input from the hand/foot to apply a high pressure needed to squeeze out the fluid in the briquette/brick mix and compresses the remaining materials solid.


Photo: Practical Action

Briquette press

**Hole punch**

A machine to punch holes into metal sheets; usually involves a sharp circular tool with a lever to apply the required force.

**Gravity ropeway**

Employs the power of gravity to transport goods between two different elevations. The load sent down is typically three times the load sent up. A breaking mechanism is installed to control the speed of arriving goods at the lower end. Side rails and seats are sometimes installed on the carriages for safety when used to transport people.


Photo: Practical Action

Gravity ropeway

**Manual percussion drill**

Relies on the vertical force generated when the drill (usually a heavy metal cylinder) is dropped onto the earth to break the earth apart. Water is used to turn the broken up earth into mud and the hole is then cleared periodically before more drilling can be done.

**Mill**

Versatile in its uses; rotary shaft power is used for various productive purposes, and to power other machines. Some examples are: grinding agricultural produce between millstones to make them finer; cutting up materials such as paper pulp or timber. High load applications will typically be water or fuel-powered.

**Mould and deckle**

Comprises a flat sheet of membrane which allows fluid to drain through while keeping the paper pulp. The deckle is the outer frame (to form the shape of the paper) and is removed when enough fluid has been drained, and transferred elsewhere for drying or pressing.

Mould and deckle

Photo: Practical Action

**Paper press**

Can be a vertical press or made of two rollers where the paper is passed through between them.

Paper press roller

Photo: Practical Action

Vertical paper press

Photo: Practical Action

**Persian wheel**

A large wheel with scoops at intervals along the wheel to draw surface water, usually animal powered. Some disadvantages are that the water has to be raised to the top of the wheel before it is discharged and water is prone to losses from spillage from the scoops.

**Pipe bender**

A machine used to deform metal pipes, usually using a screwing action by the hand to apply the force.

**Powered machineries**

These can be human/animal/renewable energies/fuel powered, but usually use rotary shaft power.

Power saw

Photo: Practical Action

Stone cutter

Photo: Practical Action

**Power tiller/two-wheel tractor**

A fuel powered small tractor that can have different attachments for agricultural processes. Some example attachments are for tillage, bed planting, row planting, harvesting and threshing.


Photo: Practical Action

Power tiller

**Ram pump**

It does not need any other input other than water head. It allows the delivery of a smaller amount of water, compared to the flow rate that passes through it, onto a higher elevation by using a water hammer. It is useful in areas where water source is located below the required site and can theoretically operate non-stop as long as there is enough water head at the source.

**River turbine**

Uses the kinetic energy in a flowing river or canal as the power source for a water pump. It floats in the free stream of the river or canal, tethered to one side, and pumps water onto the bank. Output is dependent on river speed and depth, and will be available for 24 hours per day.


Photo: Practical Action

River turbine

**Rope hoist**

Suitable for vertical lifts, it can reduce the force needed to lift a load by using a pulley system.


Photo: Practical Action

Rope hoist

**Rope pump**

Washers made out of rubber, plastic or metal are attached to a continuous rope which is drawn through a pipe. Water is pushed up by the washers and the flow rate is dependant on the fit of the washers and the speed at which the rope is pulled. It is usually hand powered using a rotary action.

**Row planter**

See seed drill.

**Seed drill**

An attachment to the two-wheel tractor which ‘drills’ the seeds onto the ground. It can be used with a metering mechanism to evenly space the seeds. It is sometimes called a row planter when there are more than 1 seed drills used at a time.

**Sheet metal bender**

A machine used to deform metal sheets, using hand power leveraged to increase the force.

**Treadle lathe, potter's wheel**

Utilises a flywheel to maintain the momentum of the rotation of the shaft. Typically foot powered so both hands are free to work on the goods and this, along with higher rotational speed, increases productivity.

Photo: Practical Action

Treadle potter's wheel

**Treadle loom**

Weaving on a treadle loom can be done more quickly than hand weaving because the threads can be lifted up and down easily using foot pedals, leaving both hands free to work on the fabric. Wider pieces of fabric can also be made easier using treadle looms.

Photo: Practical Action

Treadle loom

**Treadle pump**

Water is pumped by a stepping motion and can supply enough water even for irrigation. A mobile version is available, and is simple enough to be manufactured locally. Recent designs are able to provide enough pressure for spray irrigation using a hose.

Photo: Practical Action

Treadle pump

**Tuin**

Consists of a carriage suspended on cables across a valley or a river. Goods/people can be transported across by being pulled by the operators at both end of the tuin.

**Wind pump**

Uses the wind as a power source to pump water, either using a piston design pump or to rotate a rope pump.

**Winnowing basket**

It is used to separate grains from the husks after threshing. The grains are thrown into the air and the wind blows away the lighter husks while the grains will fall back down to the basket.

Photo: Practical Action

Wind pump

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