Renewable Energy Technologies for Rural Development

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Introduction

This paper guides users on how to choose the right combination of sustainable energy solutions in remote areas without electricity. It aims to help development practitioners understand basic concepts and the principles of the provision of sustainable energy service, and familiarises them with a number of important issues and criteria to consider before choosing alternative renewable energy technologies. The purpose here is not to describe the numerous renewable energy technologies available, but to provide guidelines for choosing the right options and implementing them. The guidelines should be used together with other available materials and methods used in development planning, such as gender sensitive evaluation of effects, social mobilisation, integrated development methods, and participatory action research.

Why Decentralised Renewable Energy?

Energy is an important instrument for development. It contributes to fulfilling the most basic and essential needs for human survival. Historically, rural communities in Afghanistan have been meeting their energy needs from traditional sources such as fuelwood and other biomass. But growing population, poverty, and environmental degradation, have made it increasingly difficult for the communities to meet their daily needs for electricity and energy from traditional sources. The use of modern forms of energy, especially electricity, is comparatively new and limited, and at present almost 99% of Afghanistan's rural population have no access to electricity. Making electricity accessible to large segments of the rural population remains a challenge. Moreover, electricity does not address the rural communities' cooking and heating energy needs.

Programmes for renewable energy technologies have been initiated (refer to ADB, 2006 and MEW 2007). Unfortunately, despite their great potential, these have not resulted in a significant increase in their adoption or use. In fact, the promotion of renewable energy technologies is hampered by several factors including: 1) the absence of appropriate policies to ensure matching energy resource and technology with local needs; 2) lack of technical, organisational, and financial support; and 3) failure to fully understand the unique characteristics of mountain areas, such as mountain fragility and marginality, among others, but also the unique opportunities they offer.

Hydropower is a key source of energy in mountain areas

When a crisis in energy is rampant in the rural areas, it is important to tackle the energy poverty first, to be able to combat the broader issues of hunger and poverty and achieve development in a sustainable way. Properly designed renewable energy supply and technologies, including micro, hydro, solar, wind, biogas, and others, can benefit communities in many ways, such as through savings in fuel and time, particularly cutting down the drudgery associated with collecting traditional biomass such as fuelwood, dung; improving human health; and reducing greenhouse gas emissions. Renewable energy and energy efficiency – the two pillars of sustainable energy – are increasingly becoming an integral part of the global effort to reduce poverty and improve livelihoods and the environment. International experts agree that without a rapid expansion in renewable energy, the Millennium Development Goals (MDGs) including reduction in greenhouse gas (GHG) emissions might be difficult to achieve.

Unlike big hydro dams, small-scale decentralised renewable energy options meet the needs of the poor, particularly dispersed populations in rural areas, more effectively. Such an approach is less damaging to the environment, and can be developed on a basis that is financially, institutionally, and environmentally sustainable. It would allow communities to identify their own needs and create the conditions necessary to make efficient use of local energy resources (micro hydro, solar, biomass, wind, others), as well as develop indigenous manufacturing and technical capability.

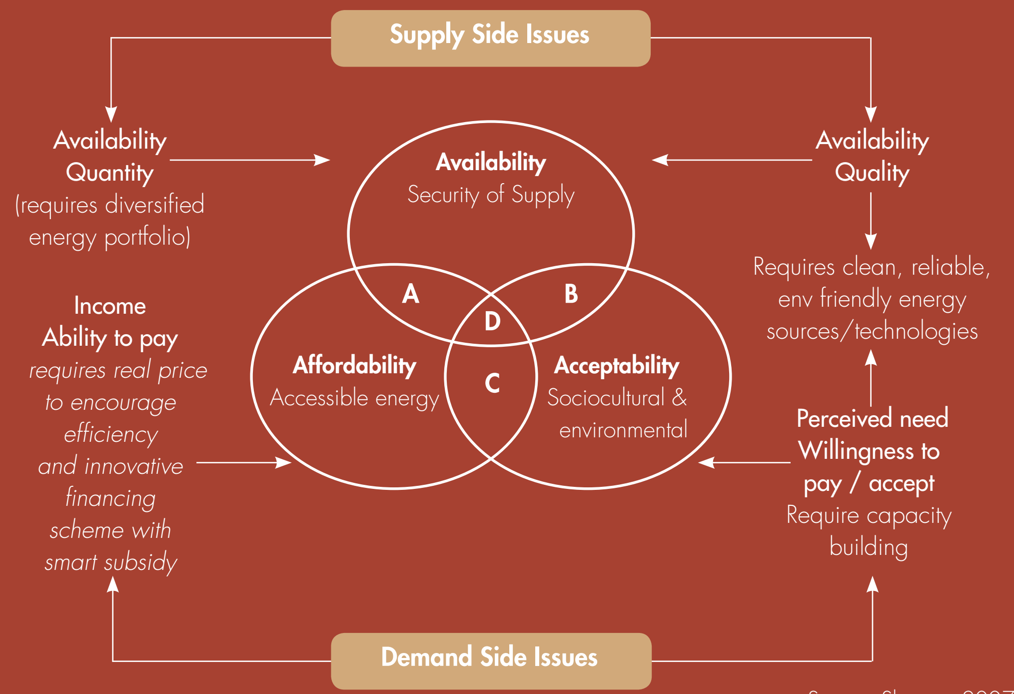
What is Sustainable Energy?

Sustainable energy is not just about using renewable energy. It is about wise and efficient energy use utilising energy generated from clean sources and clean technologies, and introducing energy efficient measures. Energy efficiency means utilising less energy to provide the same level of service and usually refers to installing energy-efficient technologies, or eliminating energy losses in existing systems. Being efficient with energy use reduces energy bills, decreases the amount of energy we need to produce in the first place, and cuts down energy-related greenhouse gas pollution. The key question is not the use of clean energy like electricity, but whether electricity is generated from clean energy sources. Renewable energy such as wind and solar energy are good to consider because they can be replenished, and are clean and do little to harm the environment. But by the nature of their availability at certain times of the year (not all-year round), we need to ensure their reliable supply.

Framework for Addressing Sustainable Energy Service

Sustainable energy service calls for providing energy service from sources that are available, acceptable, and affordable. A holistic framework for this is shown in the Venn diagram below. The vast majority of mountain people cannot afford alternative energy sources even if they are available. Even when they can afford renewable energy, households may not use them if they are much more expensive than traditional biomass, or if they are not culturally acceptable. If a renewable energy system is not in place, households cannot obtain access to modern fuels, even if they can afford and accept them. In the diagram, area D represents a situation where all three criteria for sustainable energy services are addressed, meaning they they are available, affordable and acceptable. A, B and C represent situations where two out of three criteria and assessed.

Figure 1: **Framework for addressing sustainable energy services**



Source: Sharma 2007

Sustainable Energy Choices: Choosing the Right RET Solution

Finding sustainable solutions to the energy crisis is important not only in reducing poverty but also in addressing the impacts of energy consumption on the environment and human health. An increasing share of energy supply must come from non-polluting, non-depleting, environmentally and gender-friendly, and locally available renewable energy resources such as biomass, solar, wind, among others. Available energy should be conserved and used more efficiently than is being used at present. Choosing the right renewable energy technology solutions involves the following major steps.

1. **Discuss local problems and resources**. The process must start with discussions among local people on the problems and potential problems regarding energy supply, environmental problems, prioritised or ranked energy needs of men and women (gender needs assessment for energy), available financial resources, and people's ability and willingness to pay.

2. **Investigate demand for energy based on local consumption patterns and energy resource potentials or supply, and prepare an energy balance table**. To establish demand for energy, gather baseline data on energy use patterns for different energy purposes (cooking, heating, lighting etc) in the area. On the supply side, assess available energy resources using meteorological data on wind, solar, ambient temperature and others, in order to introduce suitable renewable energy options. They could be a stream available for micro hydro (Box 1), dung for a biogas plant, loose biomass for bio-briquetting, dry land for planting energy crops or biofuels, solar and wind energy potential, and others. Investigate both energy demand and supply and make this the basis for preparing an energy balance table and for forecasting energy consumption with new development.

3. **Assess the feasibility of renewable energy options**. A feasibility assessment aims to reduce the risks of a potential project by assessing whether the project is practical and workable and requires identifying its technical, financial, and socioeconomic impacts and drawing conclusions about the project's viability. The main factors affecting the economics of an energy installation are initial capital cost to install, and annual operating cost over the life of the installation. Life cycle cost analysis compares these costs to the energy output of a system. The factors affecting economic decision on the project include net present value, internal rate of return, benefit-cost ratio, payback period, annualised energy cost, energy cost at various levels, among other factors (Box 2).

4. **Identify the right mix of technologies**. Feasible alternatives identified by the feasibility assessment in step 3 should be discussed with the beneficiaries in the village. For local people, the influence factors are often initial costs to set up the technology (investment costs), convenience and profitability of the system, ease of operation and maintenance, reliability of the technologies, available spare parts (after sales service), safety and health concerns, among others (Box 3).

5. **Elaborate an action plan**. The plan should describe how solutions with the highest priorities can be introduced and integrated with other sectors, how they can be financed, what villagers should commit to, organisational solutions, uncertainties, and a financing plan. For a detailed decision making checklist refer to Box 4.

Box 1: **How to assess if a village could use micro-hydropower**

If a stream is located nearby, it is likely that the installation of the micro-hydropower option is technically feasible, meaning possible or do-able for a village.

To calculate how much power can be generated:

- Measure available flow (refer to ICIMOD 1999).
- Measure available head (refer to ICIMOD 1999 a).
- Calculate the power that can be generated using the following equation:

Power output in kilowatts (kW) = 0.5 x flow rate in cubic metres per second x available head in metres x 9.81

Other important factors to consider

- Rule of thumb for power requirements for lighting: the number of households multiplied by 100 watts [W]
- The demand for agro-processing services and other enterprises; higher daytime uses will increase the plant's income
- How much people are willing to pay for lighting
- The track record of the community for community organisation and leadership; if experience was lacking, the installation of an entrepreneur-led micro-hydro project would be easier
- Assess if there would be conflicts between downstream and upstream communities regarding the installation of a micro-plant

Operation and maintenance

It takes a trained and skilled technician to operate and maintain a micro hydropower plant. Therefore, it is essential to provide training to potential operators so that they can look after the plant once it is operating. Good operation and maintenance procedures increase the sustainability and life of the plant (refer to ICIMOD 1999 b).

Box 2: **Basic steps in benefit-cost analysis**

- Prepare physical input and output flow tables: include all purchased or owned input and output, sold or self-consumed.
- Create unit value tables for project input and output: in financial analysis, the prices of all inputs and outputs should be estimated at the time of purchase, sale, or consumption. In economic analysis, prices of inputs and outputs are valued at their opportunity cost (is the value of the next best choice that one gives up when making a decision.) to arrive at efficiency prices.
- Prepare financial cash flow and economic value flow tables. This could be obtained by multiplying the physical input and output flow tables (step 1) by their respective unit value tables (step 2).

Investment decision criteria: net present value (NPV), internal rate of return (IRR), benefit-cost ratio (BCR)

- Any project providing positive NPV is an efficient use of resources involved
- Internal rate of return is essentially a breakeven discount rate; at this rate, the present value (PV) of benefit equals the present value of cost (i.e., NPV = 0 and BCR = 1)
- Financial IRR illustrates to investors the average earning power of an investment
- Economic IRR shows decision makers what a society could expect to receive as a benefit from any given investment in a scarce resource

  The criteria generally used to select a project are:

  1) If the financial IRR is greater than the market rate of interest

  2) If economic IRR is greater than economic discount rate or opportunity cost of capital

Table 1: **Criteria for the choice of renewable energy technologies**

End Use Purpose	Available Technology	Renewable Sources of Energy	Availability	Reliability	Ease in operation	Operational efficiency	Environmental implication	Repair and Maintenance	Durability	Socio cultural acceptability	Capacity or Size of Plant
Lighting	Peltric set	Water	H	H	H	H	N	M	H	H	1 kilowatt (kW)
	Solar PV cell	Sun	M	M	H	H	N	M	H	H	15 watt (W)
	Biogas plants	Biomass	H	H	H	H	N	M	H	M	10 m3 plant
	Improved water mills	Water	H	H	H	M	N	M	H	H	1 kW
	Small scale wind mill	Wind	H	M	M	M	N	M	H	H	
Water heating	Solar water heater	Sun	H	M	H	H	N	M	H	H	20 litre (l) (2 panel)
	Small scale wind mill	Wind	H	M	M	M	N	M	H	H	
	Biogas plants	Biomass	H	H	H	H	N	M	H	M	4 m3 plant
	Briquette	Biomass	H	M	H	H	N	M	H	M	
	Electric cooker	Water	M	H	H	H	N	M	H	M	2 l capacity
	Electric bucket	Water	M	H	H	H	N	M	H	H	20 l300 W
	Back boiler	Wood	H	H	H	M	M	M	M	H	200 L capacity
Space heating	Solar passive heating system	Sun	S	M	H	H	N	M	H	M	
	Small scale wind mill	Wind	H	M	M	M	N	M	H	H	
	Improved cook stove (ICS) domestic/ institutional	Wood	M	M	H	S	M	H	M	H	
	Briquette	Biomass	H	M	H	H	N	M	H	M	
	Back boiler	Wood	H	H	H	M	M	M	M	H	100 L capacity
Cooking	Solar cooker	Sun	S	M	H	H	N	H	H	M	Card board box and parabolic type
	Hay Box cooker	Insulation	H	M	H	H	N	H	H	H	
	Biogas plant	Biomass	H	H	H	H	N	M	H	H	6 m3 plant
	Electric Cooker (Bijuli Dekchi)	Water	M	H	H	H	N	M	H	H	8 l
	Heat storage cooker	Water	M	H	H	H	M	M	H	H	per unit
	Domestic ICS		H	H	H	H	M	H	M	H	per unit
Grain milling	Improved water mill	Water	H	H	H	M	N	M	H	H	with 5 no rice huller
Agri- produce drying	Solar dryer	Sun	S	M	H	H	N	H	H	H	
Water lifting	Hydraulic pump	Water	M	H	H	M	N	M	H	H	
Water pasteurisation	Water pasteurisation	Sun	S	H	H	H	N	M	H	H	Piece

S = somewhat, M = moderate, H = high, N = not/no

Source: ICIMOD and CRT 1997

Box 3: **Decision checklist when planning and financing renewable energy projects**

Identify the needs and financial resources of the beneficiaries

- ✓ What are the households' energy needs (e.g., for cooking heating, lighting, etc.)?
- ✓ What are the households' monthly energy expenses?
- ✓ What is the ability and willingness of the users to pay for renewable energy technologies?
- ✓ How much can users afford to pay each month or year?
- ✓ What have been the experiences with source of loans in rural areas (money lender, micro credit, bank) and how could these experiences be used?

Identify appropriate renewable energy technologies and their dissemination

- ✓ What have been the experiences with renewable energy technologies in the localities?
- ✓ Which technology is most suitable and viable for the user?
- ✓ Can adequate servicing and spare parts supply be found?
- ✓ Are there local NGOs or experienced cooperatives on renewable energy technologies?
- ✓ Are there energy service companies in the area? If not, is it viable to establish such a company?
- ✓ What mechanisms are utilised by existing distributors for energy distribution or dissemination?

Establish financial disbursement scheme

- ✓ Are there rural credit savings and rural banking facilities in the localities?
- ✓ What interventions function with banks and borrower?
- ✓ Is international seed money or grant aid available for energy related activities?
- ✓ Will intermediaries be needed (e.g., community-based organisation for payment collection or running a revolving loan fund)?
- ✓ What will be the transaction cost?
- ✓ Over what period will repayment be made?
- ✓ How do these compare with the income streams of households?
- ✓ Determine payment level through cash flow analysis.
- ✓ Establish an incentive scheme such as smart subsidy with a clear-cut exit strategy.

Develop a business plan

- ✓ What will be the cost of managing the project? (revenue collection, training specification, standard development, quality control, and staff costs, among others)?
- ✓ What will be the internal rate of return, the rate of return on a capital investment from a business?
- ✓ Where will the funds come from and under what terms?
- ✓ How could borrowing and lending risks be minimised?

Establish an implementation and management infrastructure

- ✓ Local community mobilisation (refer to MEW/ADB/TA 2006, in Persian)
- ✓ Select financially experienced staff and train other staff or community members as required
- ✓ Establish networks with other organisations
- ✓ Develop a marketing and promotion plan
- ✓ Establish management responsibilities (who does what)
- ✓ Train energy service operators
- ✓ Are the lending parameters or measures acceptable or comfortable (lending and default rate per month, interest rates)?
- ✓ Establish criteria for monitoring and evaluating the project
- ✓ Adjust financial implementation parameters as necessary

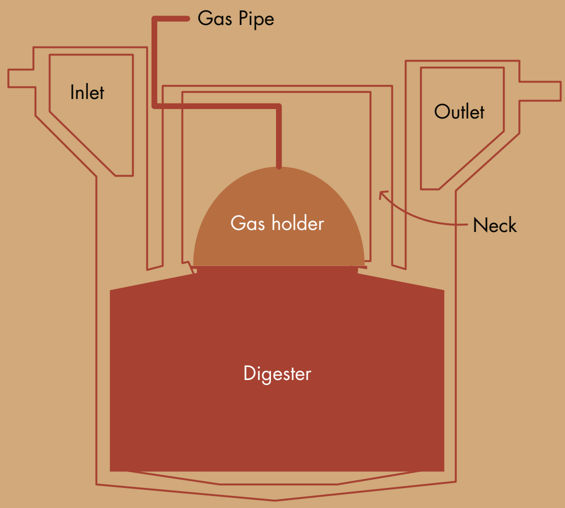
Some Promising Renewable Energy Technologies for Afghanistan

Based on examples from the ICIMOD Demonstration and Training Centre, Godavari, Nepal

Puxin model biogas plant

Biogas can be used for cooking, lighting, and generating electricity. Besides producing energy, residual slurry from the process can be used as fertiliser. Using dung in a biogas plant generates more energy than when using it in direct combustion. For example, 25 kg of fresh dried dung, when used to fuel cook stoves produces ultimate useful energy of about 1046 kilo calories. The same amount of dung can generate 2592 kilo calories of energy when used in a biogas plant and generated gas is used in a biogas stove. This is more than 100% of the energy generated in direct combustion.

Figure 2: **Schematics of Puxin model biogas plant**



The Puxin model biogas plant developed in China is a fixed dome-type biogas digester designed to operate in a batch feeding mode. Animal dung and other wastes such as grasses, fodder, and biodegradable household waste can be fed into the model at the ratio of one is to five (1:5), one part dung, five parts other wastes during initial loading. Properly used, it can generate gas good for six months, after which the materials should be replaced. It has a hydraulic pressure biogas digester which consists of a fermentation tank made of concrete, and a glass fibre reinforced plastic gasholder. The gas cover is installed in the tank neck and sealed up with water. The water seals the gasholder and protects gas from escaping while it also puts pressure on the gas cover, which is completely air tight. The level of water in the plant should always be above the gas holder. Water needs to be drained from the water trap regularly.

Beehive briquette making

Bio-briquetting

Briquetting makes use of compacted agricultural wastes for fuel. When produced manually by compacting biomass using some kind of binder, one can make about 30 round beehive briquettes with 19 holes which emit blue fire-flame when burnt. Beehive briquettes (a honeycomb beehive-shaped biomass briquette) are made using a hand mould although this does not produce a high briquette density. The weight of a hand-made, dried briquette is about ½ kg. Hardwood biomass charcoal briquettes with 20% clay content produce about 18 MJ/kg or about nine MJ/briquette. In practice, this may heat two litres of water in 15 to 20 minutes using an insulated (one briquette) metal stove. Depending on the quality of briquettes, one beehive briquette burns for about an hour and a half, which is enough to cook a normal meal for a family of four to five members.

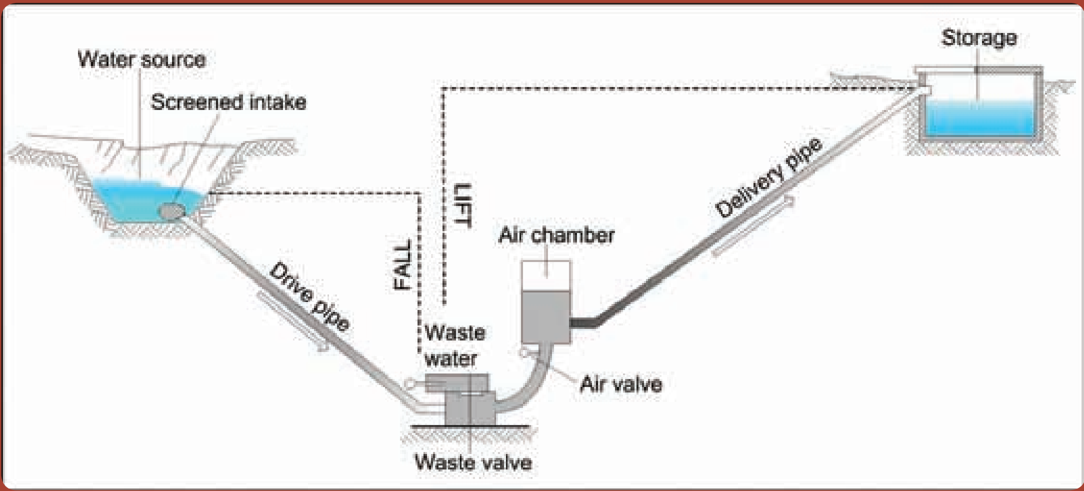
How to make beehive briquettes

- Collect and dry biomass for a few days. Put them in a pit and burn for 1-1.5 hours.
- Cover the carbonised charcoal with green biomass and then with soil.
- Collect the charcoal portion (not the ash) from the pit after 6-12 hours.
- 100 kg of biomass provide, on average, 25-30 kg of charcoal material.
- Grind the charcoal material and mix with bentonite clay at the ratio of 3:1 (3 kg charcoal powder and one kg bentonite clay)
- Put the mixture into the iron briquette mounder and dry the briquette for 2-4 days in the sunlight

Hydraulic ram pump

A hydraulic ram pump is useful where there is a water source which flows constantly and the usable fall from the water source to the pump is at least 91 cm (3 ft). The ram pump can be used for lifting drinking water from springs to settlements on higher ground, for pumping drinking water from streams that have significant slope, or lifting irrigation water from streams or raised irrigation channels. A hydraulic ram is a device which uses the energy of falling water to lift a lesser amount of water to a higher elevation than the source (see Figure 3). It is an attractive solution where a large gravity flow exists and where the water source can provide at least seven times more water than the ram is to pump.

Figure 3: **Schematics of hydraulic ram pump**



Before a ram can be selected, the following design factors must be known:

- difference in height between the water source and the pump site (vertical fall)=F
- difference in height between the pump site and the point of storage or use (lift)=L
- quantity of flow available from the source=S
- quantity of water required
- length of drive pipe from the source to the pump site
- length of delivery pipe from the pump to the storage site

Once this information is obtained, it is possible to see if the amount of water needed can be supplied by a ram using the formula as follows: D = (S x F x E)/L, where:

D = Amount delivered to storage/use site in litres per 24 hours
S = Quantity of water supplied from the source in litres per minute
F = Fall or height of the source above the ram in metres
E = Efficiency of the ram (for commercial models use 0.66 and for home-built use 0.33)
L = Lift height of the point of use above the ram in metres

To convert the pumping rate expressed in litre per day to litre per minute, divide by 1440.
Suppose E = 0.6, S = 80 litre per minute, L = 24 m, and F = 4 m. The maximum pumping rate delivered by the hydraulic ram pump operating under these conditions is 11,520 l per day, or 8 l per minute

References

ICIMOD (1999) *Manual for survey and layout design of private micro-hydropower plants*. Kathmandu: ICIMOD

ICIMOD; CRT (1997) *Manual of rural technology with Implications for mountain tourism*. Kathmandu: ICIMOD and CRT

ICIMOD (2007) *Technology manual on suitable renewable technologies for rangelands,* prepared for ongoing project 'development of sustainable energy for rangelands'. Kathmandu: ICIMOD

ADB (2006) *Social mobilization manual for rural electrification* (in Persian). Kabul: Ministry of Energy and Water/ and ADB TA 4461

ADB; MEW (2006) *Policy for renewable energy for rural electrification, Government of Afghanistan*. Kabul: Ministry of Energy and Water

MEW (2007) *Power sector strategy*. Kabul: Ministry of Energy and Water

Qaderdan Rural Technology Workshop. www.qrtdw.com, email: qaderdan@qrtdw.com

Sharma, B (2007) 'Energy efficiency and renewable energy in the HKH region'. A paper presented at 7th meeting of Global Forum on Sustainable Energy (GFSE-7) in Vienna, Austria November 15 - 20, 2007