Chapter 5
Energy Sources for Small-Scale Development

Contents

The majority of Africans can neither access nor pay for "modern" forms of energy, including electricity, bottled gas and kerosene. They must rely on wood and charcoal.

5.1 Biomass Energy Sources

Brief Description of the Sector

Africa's poor use energy primarily for cooking, with other uses including transportation, heating, lighting and power for appliances. Biomass, in the form of wood or charcoal used for cooking, is the main source of energy in sub-Saharan Africa. It accounted for 71.5 percent of total primary energy on the continent in 1995, and in many African countries it accounts for up to 90 percent of the total national energy supply.

Although biomass can be an environmentally sound source of energy, the current methods of harvesting wood and producing charcoal in most African countries are unsustainable. These practices are doing serious harm to Africa's natural resource base and environmental well-being.

Biomass dependence in Africa reflects several factors. One is poverty: "modern" forms of energy, including electricity, bottled gas and kerosene, are still beyond most people's economic reach in many African countries. Moreover, many areas have no access to non-biomass energy or lack the infrastructure to distribute it. There are two principal reasons for this situation:

- Although Africa possesses substantial and diverse non-biomass energy resources, the sources and demand for these resources are not distributed evenly throughout the continent. For example, 96

Project Benefits

Small energy projects can:

- Improve public health
- Protect the environment
- Better the quality of life for the poor, especially women
- Generate business opportunities
- Make it easier to carry on business or education

percent of oil reserves are located in North Africa, Nigeria, and Angola, while 95 percent of the workable coalfields are in southern Africa.

- The infrastructure needed to produce and distribute non-biomass energy is often capital-intensive. Thus, even where natural resources are available, production and distribution facilities are often absent or inadequate. For example, hydroelectric resources are found in both East and West Africa—but as of the early 1990s, sub-Saharan Africa had exploited only 4 percent of its hydroelectric resources for energy purposes. In general, electrification rates are low. Kerosene and gasoline are the only "modern" forms of energy with near-universal availability.

During this century, Africa's forest area has been cut in half. Deforestation drives down farm production and biodiversity, raises prices of fuel and other forest products, and boosts the greenhouse effect.

Biomass dependence is not expected to lessen in the foreseeable future. It is true that per-capita consumption of "modern" energy has been declining over the past 20 years in sub-Saharan Africa. The downward trend is expected to continue as production and distribution infrastructures fail to keep pace with Africa's projected growth in population. However, the population increase will almost certainly lead to an increase in *total* consumption of both biomass and modern energy. Over the next decade, estimates of annual growth range from 2.7 percent to 4.5 percent, compared to 0.9–1.6 percent for the industrialized countries. This increase will be amplified by urbanization; Africa's urban populations are forecast to increase substantially over the next 50 years, and urban dwellers consume higher energy per capita.

Africa's primary energy use is for cooking. Using biomass energy sources contributes to the degradation of African forests and severely affects the health, and quality of life, of the African people.

This increased pressure on already overstressed biomass energy sources makes energy projects all the more important. Small-scale energy development projects are generally designed to improve public health, protect the environment, and better the quality of life for poor populations, especially women. They may also have ancillary benefits, such as generating entrepreneurial opportunities. They do so by supplying energy where it was not previously available or by substituting perpetual or self-renewing locally available sources of energy for those that are in limited or exhaustible supply and that, in some cases, must be imported.

Mitigation and Monitoring:

This section discusses ways to address the environmental impacts of initiatives in:

- Fuelwood
- Solar energy
- Biogas
- Ethanol
- Hydropower
- Wind power

Development projects often focus on improving the efficiency of cooking with wood or wood-derived fuel—e.g., by promoting improved cookstoves—or by replacing biomass with an alternative energy source, such as biogas or solar energy, for biomass energy. Other projects focus on providing alternative sources of electricity—solar, micro-hydro or biogas—to power modern lighting, appliances, and remote telecommunication, especially for rural communities that lack access to electrical grids. The availability of dependable electricity can let householders, especially adult women, develop additional income by working at home after dark. Lighting also facilitates education, and it is a valued convenience, making activities such as cooking and bathing easier at night. Photovoltaic systems are used to provide electricity to rural health posts for small cold-chain refrigeration systems used to store vaccines. They also provide power for health post's radio communication and night lighting.

This module discusses various approaches to the problem of fuelwood-driven deforestation. It also addresses possible environmental damage from other energy projects, such as those involving solar dryers and ovens as well as photovoltaic, biogas, micro-hydro and wind power. Social impacts are treated to a lesser extent. Micro-hydro power is discussed in a special sub-section.

Potential Environmental Impacts and Their Causes

Deforestation. During this century, Africa's forest area has been cut in half. Between 1990 and 1995 alone, Africa lost over 18.5 million hectares of forest—3.5 percent of its total forest cover. This is equivalent to an annual deforestation rate of 0.7 percent, the highest of any continent in the world.

The vast majority of this loss occurred in tropical Africa, though rates varied considerably from country to country. Niger lost no forest, while Kenya's forest cover declined at a rate of 0.3 percent a year, Tanzania lost 1 percent

Trees cut for charcoal production in Zambia. Indiscriminate cutting can quickly lead to deforestation.

per year, and Sierra Leone lost a shocking 3 percent per year. While such factors as agricultural expansion and increases in human population are the major underlying causes of deforestation in Africa, consumption of wood for fuel is also a significant factor. As noted above, population increases will raise the pressure on biomass resources.

Potential Impacts of Biomass Energy

- Deforestation
- Lost economic productivity
- Damage to health from smoke inhalation

Fuelwood and charcoal production in Africa has increased significantly during the last two decades and is projected to continue growing. In 1994, 84 percent of wood from trees was used as fuel. In the mid-1990s, it was estimated that 32 percent of the total African population lived in areas where biomass resources cannot be sustained under present use practices. The demand for charcoal and fuelwood by urban populations is a major contributor to deforestation, particularly in arid and semi-arid regions. The deforestation in turn is driving down agricultural productivity (e.g., loss of soil from increased erosion, destruction of watersheds) and biodiversity (e.g., loss of wildlife habitat and species diversity). Unsustainable extraction of fuelwood also contributes to the greenhouse effect by releasing stored carbon and reducing the region's capacity to sequester carbon.

In Africa, great distances often separate the location of biomass energy and consumers. As forests fall, the distance widens, raising the price of charcoal and fuelwood. Also, as householders, especially women and children, walk longer distance to find fuelwood, they lose time for other productive activities, including school.

Land tenure complicates the problem further. In many African countries, ownership of resources, including tenure over trees and forest lands, remains vested in the state, a holdover from centralized colonial control over resources. In others, individual farmers and communities may be unaware of recent laws devolving ownership to them. These conditions can discourage the planting of trees and the sustainable use of fuelwood.

Health impacts. In addition to environmental impacts, the burning of wood, charcoal and other biomass in poorly ventilated houses or areas exposes users to high levels of smoke. Continuous exposure of this type can seriously damage human health, particularly that of women and children, who often spend much time indoors and are therefore exposed for longer periods.

Sector Design Elements

- Find or complete local energy analysis
- Survey existing public incentive programs
- Get local input
- Assess community's long-term energy aspirations
- List beneficiaries
- Figure costs to transport fuel
- Examine socioeconomic incentives and obstacles

Sector Program Design—Some Specific Guidance

If your organization is planning new activities to develop renewable energy development activities, it may be helpful to ask the following questions before you start designing them.

- Has the World Bank or another international organization completed an energy-sector or biomass analysis for the country? What are the current patterns of energy use in the immediate project area?
- Could existing tax or incentive programs be used, publicized or modified to increase the use of renewable resources and decrease dependence on petroleum-based fuels and wood energy?
- Have local communities been consulted? (Their suggestions and needs may be of critical importance in developing the project.)
- What are the long-term aspirations of rural communities regarding energy? Will fuelwood alone accommodate these aspirations? If a community is interested in developing small industry/enterprises (such as agroprocessing), could it consider other forms of energy?
- Who will be the project's customers? Will the project benefit local households or other sectors?

- If it is a fuelwood project, how accessible will the fuelwood be to the area where it is to be consumed? What transportation costs are related to the project?
- What are the socioeconomic incentives and constraints associated with the project (e.g., tree-tenure systems, community ownership, credit availability, etc.)?

Environmental Mitigation and Monitoring—Issues and Guidance

Potential adverse environmental impacts, along with guidance on mitigation and monitoring issues, are considered below for fuelwood, solar energy, biogas, ethanol, and windpower. Micro-hydro is treated in the section that follows.

Fuelwood Initiatives

- *Assess biomass (including the availability of, and demand for, fuelwood)*. Establish baseline conditions and identify patterns of deforestation over time. Provide information on promising energy initiatives in the area. Where available, remote-sensing Global Positioning Systems (GPS) and Geographic Information Systems (GIS) mapping techniques can be used for this purpose.
- *Develop a biomass strategy based on the assessment*. The strategy should identify areas requiring technical assistance, policy reforms, and practical incentive and disincentive systems, and indicate where conditions support the use of economical energy sources other than fuelwood.
- *Develop action plans*. Action plans, at both the local and national levels, should combine measures aimed at increasing production (e.g., agroforestry), reducing consumption (e.g., improved cooking stoves), and enhancing protection of remaining forest resources (e.g., developing tree nurseries). Include incentives for tree planting and disincentives for use of fossil fuels. Foster multisector planning to manage fuelwood resources.
- *Ensure community participation*. Ensure that the local community has early input into project design and implementation. (Insufficient farmer, family and community participation is a common weakness of fuelwood projects that makes them much harder to sustain.)
- *Reflect economic value*. Adjust fuelwood and charcoal prices to reflect the true value of forest resources by applying natural resource and environmental accounting. Often the biological, economic and social values of forest resources are not incorporated into the total price of fuelwood.

- *Protect resources*. Protect existing sources of fuelwood in natural forests by involving neighboring communities in sustainable forest management and sharing of forest resources.
- *Provide for ownership of fuelwood resources*. Where needed, participate in a policy dialogue to establish legislation that provides for private or communal ownership and management of fuelwood resources.
- *Select tree species*. If trees are to be planted for fuelwood, select the most appropriate ones, drawing on local and national-level expertise. The short rotation required for fast-growing, exotic tree species allows increased production of fuelwood; however, their rapid growth can also accelerate the depletion of soil nutrients or water resources. Consider using fertilizer for plantations of rapidly growing species. Match species to local soil and climatic conditions. In areas of low or sporadic rainfall, avoid species that require much water.
- *Assess potential for improved cookstoves*. Commercializing of improved charcoal cookstoves is another means of encouraging people to conserve fuelwood. Typically built of metal with an insulating clay lining, these stoves trap heat, causing charcoal to burn more efficiently, thereby significantly reducing charcoal consumption.

Many tree species serve multiple wood and non-wood purposes, with fuelwood being a secondary product. For example, pruned branches from some *Prosopis* species can be used for firewood, while the trees themselves can be used as living fences.

Action Plans for Fuelwood Initiatives

These should include:

- Raise fuelwood production
- Lower fuelwood consumption
- Better protect remaining forest resources
- Create incentives for tree planting
- Discourage use of fossil fuels

5.2 Alternative Energy Development

Renewable energy technologies must satisfy several criteria. These should be simple, affordable systems adaptable to small-industry/private-enterprise development at the community level. While the installed cost of an alternative energy technology may be a constraint, operating costs tend to be much lower than with conventional energy systems. Credit schemes can, in some cases, help address the capital cost barrier, and thus allow long-term cost advantages to be realized. This section will consider solar, biogas, ethanol and wind power. Hydropower is another important alternative energy source, but since its potential impacts are fairly complex, it will be discussed separately in the next section of the chapter.

Solar ponds can be a source of energy or can be used to dry food for storage. They need strong safeguards, however, to prevent leaks, prevent drowning and protect water from evaporation.

Solar Energy. The sun is an important source of clean and abundant energy in many parts of Africa. But the use of solar energy is not yet widespread, for both technical and economic reasons.

Adverse environmental impacts associated with solar energy include pollution caused during the manufacture of solar devices, acid battery spillage and improper disposal of batteries. These impacts, which are usually manageable, should be weighed against solar power's potential to reduce deforestation and improve air quality for women and children.

Some examples of solar energy devices and the potential environmental impacts associated with them include:

- *Solar food dryer*. A solar food dryer is a box with at least one transparent side through which solar energy enters, raising the inside temperature and setting up a convection current of air. Fruit, grain, vegetables and fish can be dried inside. Food dries rapidly, compared to direct sunlight, allowing greater vitamin retention.
- *Solar ponds*. A solar pond operates on the same principle as the solar food dryer. Instead of trapping heat rays under a transparent window, heat is trapped under several layers of fresh and salt water. The heat generated may be used for low-temperature industrial and agricultural processes; pre-heating for higher-temperature industrial processes; and electricity generation. Unlike solar food dryers, however, solar ponds can create serious environmental damage. Because large amounts of salt are used, a leak in the bottom of the pond could seriously contaminate groundwater supplies. The steeply sloped sides of the pond may also present a hazard. Without adequate fencing, animals or small children may fall in and become trapped or drown. Because of the high temperatures, objects sinking to the bottom of the pond cannot be easily retrieved without special equipment. The hot brine of a solar pond

Criteria for Renewable Energy Technologies

A proposed system must be:

- Simple
- Affordable
- Adaptable as a small, private, community-level industry

Credit schemes can address a high initial cost if the system offers long-term cost advantages.

Solar Power Issues

Solar energy can combat deforestation, air pollution and the greenhouse effect. But problems may include:

- High initial cost
- Pollution from manufacturing solar devices
- Acid battery spillage
- Improper disposal of batteries

Solar ponds may have other serious impacts:

- Salt leaks that contaminate groundwater and soil
- Drowning hazards
- Metal corrosion from hot brine
- High water loss from evaporation

corrodes many metals. Finally, water evaporated from the pond surface must be replaced by water from other sources.

- *Solar cooking*. Solar ovens trap and/or reflect solar energy that is converted to heat when it strikes the surface of a black pot. A substantial increase in use of solar cooking apparatus took place over the last several years, but use is still not widespread, for several reasons. Designed for slow baking or simmering, they cannot be used for traditional foods that require frying or stirring. Solar stoves that use parabolic reflectors must be constantly refocused as the sun moves. Other deterrents include their initial cost, restriction of cooking time to bright daylight hours, incompatibility with local cuisine and people's unfamiliarity with the devices. Solar cookers are frequently used in camps for refugees and internally displaced-persons. While costly, they help reduce the high rates of deforestation that often occur around these camps.
- *Solar water heating*. Increasingly, governments, utilities and the private sector are promoting residential solar water heating systems in areas with low cloud cover. Under these conditions they are now economically competitive over the longer term (10–20 years) with water heating using electricity or gas, though up-front installation costs may be significantly higher.
- *Photovoltaic cells*. While the cost of converting solar energy into electricity continues to fall, it is still high enough to discourage widespread application in Africa. Nevertheless, in remote locations away from power grids, where the costs of electrical generation from diesel engines are high, photovoltaics can be competitive for certain applications such as lighting, cold-chain vaccine refrigeration, and radio and microwave communication. To maintain a photovoltaic system, people need only clean the panel surface regularly. However, trained individuals must do the cleaning to avoid damage to the cells. Systems must also be protected against theft and vandalism.

Biogas Issues

Biogas has many possible uses in cooking, lighting, power generation and repairing environmental damage.

Potential problems include:

- High initial costs
- Difficulty getting communities and organizations to participate in larger, community-size installations
- Lack of training in construction and maintenance
- Side effects of "bioenergy crops" for biogas—may displace food crops, add to deforestation, or become invasive
- Disease carried in fecal wastes used as fuel
- Offensive liquid overflow
- Biogas leaks and losses that can cause asphyxiation and explosions
- Conflicts over the right to use "communal" manure

Biogas. Technologies, such as anaerobic digestion, used for the conversion of organic materials to biogas are far from new. However, their application is not widespread. Biogas production involves the biological fermentation of organic materials (e.g., agricultural wastes, manures or industrial effluents) in an oxygen-deficient environment to produce methane, carbon dioxide and traces of hydrogen sulfide. The gas can be used either directly to be burned for cooking or lighting, or indirectly to fuel combustion engines delivering electrical or motive power (Bokalders and Kristoferson, 1991). The slow diffusion of this technology is related to (a) the initial cost of construction; (b) the lack of organizational and community involvement, particularly for larger, community-level digesters; or (c) insufficient training opportunities in construction and maintenance.

Recently, more bioenergy is being produced using crops raised specifically for this purpose, by contrast with the use of agricultural wastes. This practice may both help and harm the environment. Bioenergy crops can be used to revegetate barren land, reclaim waterlogged or salinated soils, and stabilize erosion-prone areas. They can provide habitat and increase biodiversity, if properly managed. However, their use may also displace agricultural production, contribute to deforestation, and even introduce invasive, and potentially harmful, non-native species.

The operation of a biogas digester presents several potential environmental problems, but these problems can be minimized with proper planning and operation. For example, if the digester is built close to a lavatory or livestock shed, the excrement may be deposited directly without unnecessary handling. However, special precautions are required if human or hog wastes are used in digesters. For example, humans and some animals share similar feces-borne parasites and pathogens. For this reason, some authorities feel that even treated fecal waste is extremely dangerous and do not recommend applying sludge to soil where root and vegetable crops are cultivated.

The disposal of liquid overflow (supernatant) from the digester may occasionally have adverse effects. Normally this liquid is clear and odorless and has some value as a dissolved fertilizer. If water is scarce, the supernatant may be recycled into the digester with new organic feedstock. Otherwise, it can be used to water plants or moisten compost materials. However, with an improperly working digester, the supernatant may be dark and offensive. If it is not recycled, this liquid should be buried or mixed with soil in an isolated spot.

As with natural gas, biogas composition should be tested and precautions taken to prevent leaks and losses. Surveillance is also important, since biogas is usually odorless and difficult to detect. In closed rooms, leaking gas can lead to asphyxiation or explosion.

In areas where manure or dung is considered a free community resource, the installation of biogas digesters can cause unwanted changes in local economics. For example, if manure suddenly becomes more valuable than usual, it can become a marketable commodity that is no longer available to the poor. In the initial planning stages, the question of who stands to lose or gain from an energy project is one that deserves attention. Thus, community input is important.

Ethanol Issues

Fermenting farm by-products can produce a useful liquid fuel, plus solid residues for animal feed. Problems are:

- High volumes of water must be used in production
- Production generates large amounts of liquid residue that can damage soil and contaminate lakes and streams

Ethanol. Liquid fuel in the form of ethanol can be produced through the fermentation of biomass (e.g., sugar cane leaves or bagasse). The production of ethanol involves the washing, fermentation and distillation of biomass. Again, the long-term economic costs and benefits need to be weighed carefully before developing these systems.

Solid residues from ethanol production can be disposed of easily as a high-protein dietary supplement for livestock; however, the disposal of liquid residues, which may amount to 12 to 13 times the volume of the final product, is more difficult. This "thin stillage" has a strong odor and high acid content and contains many organic solutes. Land application of thin stillage could be harmful to many types of soils, especially those with high clay content. Stillage should not be disposed of in areas where it can flow into and contaminate lakes and streams.

Ethanol from maize yields 50 percent more energy than the total amount required to farm the maize and make the ethanol. This is not bad, but other ethanol crops (e.g., grasses, trees) are more efficient, yielding four to five times as much energy as the amount needed to farm the crops and make the ethanol.

Significant amounts of water are used in the production of ethanol. For every unit volume of ethanol produced, approximately 16 volumes of water are needed to generate steam. This demand for water must be evaluated against its available supply and the merits of alternate uses.

- Ethanol has environmental advantages over fossil fuels such as coal and oil, but like any liquid fuel it may cause damage through leaks and spills. There are also potential indirect impacts associated with the methods used to grow ethanol-producing crops, including pest management.

Wind Power. If properly designed and well placed, wind machines can provide a reliable source of energy. A wind-powered water pump can be used for irrigation and supplying potable water. Larger wind machines may compete favorably with other forms of electrical generation.

Economic cost-benefit analysis against other energy sources is needed before selecting wind power as an energy source. The strength and constancy of the wind is especially important in this calculation, as is the proven ability of the wind machine to withstand high wind events. Since historical meteorological data are often absent in many African countries, wind power needs to be approached cautiously.

Wind Power Issues

Wind can be a reliable energy source, pumping water for irrigation and home use. Possible problems:

- Historical data on wind strength/constancy are hard to find
- High winds may damage the machines, endangering people and animals
- Standing water around pumps

One potential adverse effect associated with wind-driven water pumps is that standing water from spillage around the pump can become a health risk. An automatic shut-off mechanism can potentially solve the problem. As with any water system, overgrazing near the water supply can be a serious problem, especially in arid and semi-arid environments.

As with the other technologies mentioned earlier, the discussion of this technology does not cover all possible wind-related environmental issues such as noise, and effects on birds, land use and visual aesthetics.

Wind power can be a reliable source of energy. Be sure to assess all the environmental impacts of wind generators, from possible standing water, to the affect on birds and aesthetic values.

5.3 Small-hydro Power Projects

Brief Description of the Sub-Sector[1]

Sub-Saharan Africa has exploited only 4 percent of its potential hydrological energy resources. If developed in an environmentally sound way, the remaining reserves of hydroelectric energy could meet significant portions of the region's energy needs (UNDP 1992) particularly in remote rural areas.

Micro-hydro installations range in size from a few kilowatts to 100 kilowatts. They are of two general types:

- **Run-of-the-river** micro-hydro installations involve no reservoir. They rely instead on the natural flow of the river or stream to provide motive power to the turbine(s). They typically involve diverting a portion of river flow through a spillway, side channel, or pipeline. The diverted water is returned to the river downstream from the turbine.
- **Impoundment** micro-hydro installations use a dam to create a reservoir either to stabilize electricity supply against variations in flow; to provide greater head, or pressure, to power the turbine(s); or both. The reservoir may also be used for irrigation.

Micro-hydro Projects:

This special subsection on micro-hydro power projects discusses:

- Run-of-the-river projects
- Impoundment projects

Potential Environmental Impacts and Their Causes

The single most important factor in determining the extent of environmental impacts from micro-hydro projects is whether or not an impoundment needs to be created.

Dams on the scale considered for funding through PVO/NGO programs should be constructed only with the assistance of skilled professionals. Even with assistance, not all the problems associated with dams may be immediately apparent.

Run-of-the-river

For run-of-the-river operations, the greatest impacts occur during the construction phase. The primary concerns are the impacts on the stretch of river from which water is diverted to support the micro-hydro operation; the method of returning the water back to the stream; and effects on downstream users. Impacts are generally on-site and relatively easy to assess. Potentially adverse impacts are summarized in table 6.1

[1] The micro-hydro material presented here is in large part adapted from "Environmental Guidelines for Micro-hydroelectric Projects," developed in support of USAID/Dominican Republic's PVO Co-Financing Project No. 517-0247 and Electrical Energy Sector Restructuring Project 517-0270. Preparers of the original text were Odalís Pérez, Energy & Environment Team, USAID/DR and Karen Menczer, USAID Bureau for Latin America and the Caribbean Office of Regional Sustainable Development/Environment (USAID/LAC/RSD/ENV).

Table 5.1: Environmental impacts of run-of-the-river micro-hydro

Activity phase	Impact
Construction	• Movement of soil may increase erosion, which may increase sedimentation of the waterway affecting downstream users (humans, fisheries and wildlife). • Increased activity along the stream and transmission line route may disrupt wildlife. • Construction and placement of pipeline may block waterway temporarily or permanently. • Construction and placement of pipeline and construction of transmission line routes may disturb wetland, floodplains or agricultural land. • Increased activity along the stream and transmission route may disrupt recreational/cultural/subsistence activities there. • Power transmission lines/pathway may result in destruction of wetlands or other sensitive habitat. • Decrease in downstream water flow may affect downstream users (humans, fisheries, and wildlife).
Operation	• Decrease in stream flow between point of diversion and water return point may affect fisheries and wildlife. • Decreased stream flow between point of diversion and water return point may change the flooding pattern (regime), harming wetlands. • Re-entry pipe may cause increased scouring of stream bank where water is returned to the stream. • Power lines may harm viewsheds and aesthetic values.

Impoundment micro-hydropower

If the project requires the creation of an impoundment, potential environmental impacts may be greater than for run-of-the-river systems. As with run-of-the-river installations, environmental impacts may result during both construction and operation. Primary concerns are the stretch of the river from which water is removed; the area that is being flooded; and downstream users, including humans, fish, and wildlife.

Note that impoundment micro-hydro typically triggers an environmental assessment (EA) under USAID's environmental procedures. Potential environmental impacts are summarized in Table 6.2.

Table 5.2: Environmental impacts of impoundment micro-hydro

Activity phase	Impact
Construction and operation	All the impacts caused by construction of run-of-the-river hydro, plus:
Construction	• Movement of soil at the impoundment location may increase erosion. • Increased activity at the impoundment location may disrupt wildlife. • Impoundment construction may result in disturbing wetlands, floodplains, or agricultural land. • Increased activity at the impoundment location may disrupt recreational and cultural activities, or disrupt the local resident’s way of life.
Operation	• Change in water temperature in the impoundment may affect water quality in the impoundment and discharge from the impoundment. • Submersion of land covered by the impoundment destroys existing habitats and ecosystems and creates new (aquatic) habitats and ecosystems; it may reduce the amount of land available for growing crops. • The impoundment may create a breeding ground for pests and disease. • The impoundment may change the overall water flow pattern (regime), which may alter water flow in the stream. • The impoundment may change general hydrology of the area, altering habitat along stream banks. • Altering normal stream flow reduces the availability of nutrients and sediment downstream for crops and fish. A dam can also threaten fish migrations. • Insufficient attention to an area’s geology and topography may result in designing a dam that is too weak. Failure of the impoundment may cause flooding, erosion and downstream destruction.

Sector Program Design—Some Specific Guidance

The local community must be involved in designing, implementing and monitoring all small-scale projects. However, since the proper operation and maintenance of micro-hydro facilities are essential to minimizing environmental damage, community involvement is particularly critical for these projects.

Given that impoundment micro-hydro projects are likely to require an EA, the basic axiom of environmental impact assessment should be underlined: *Consider the full range of alternatives to achieving project results*. For micro-hydro ask these questions:

- Are there other options available for producing needed power?
- Are there other locations where the project might be constructed?
- Would any other feasible options result in fewer environmental impacts than the proposed activity?

Micro-Hydro Sector Design Issues

- Consider all alternatives first.
- To assess benefits vs. costs of impoundment, examine:
    - Present use of land
    - Effects of transmission system on area
    - Downstream activities

Environmental costs of the project should be weighed against its economic benefits. To estimate the costs and benefits, a number of questions should be considered, including:

- What benefits does the stream provide in its natural state? (Examples include water supply, fisheries habitat, wildlife habitat, commercial/recreational fishing, attenuation of floods, tourism, cultural values, etc.) Will any of these benefits be affected by the activity?
- How is land currently used in the impoundment location? What benefits are offered at the location? (Examples include crop production, wildlife habitat, residential dwellings, cultural activities, etc.) Will constructing and operating the dam affect these benefits/land uses?
- How might the land area be affected by routing of powerlines across the land? (Or if batteries are used, transportation of batteries to and from the microhydro site?)
- What are the present downstream activities and land uses that may be affected by the activity? Will the micro-hydroelectric project affect any of these adversely?

Environmental mitigation and monitoring

Mitigation

The mitigation and monitoring issues and measures which apply to small-scale construction also apply to construction of microhyrdro installations. Please see the chapter on Small-Scale Construction in these *Guidelines*.

General guidelines for mitigating micro-hydropower impacts include:

- Avoid stockpiling soil in wetlands or floodplains. Stockpile soil in already disturbed areas.
- Do not block stream flow during construction. For temporary stream diversion, use concrete forms rather than soil. (Using concrete forms will result in less stream sedimentation).
- Following construction, return topsoil to its original location, and restore land contours to match the original topography.

- Avoid construction during wildlife breeding seasons.
- Ensure that construction does not harm the habitats of endangered or threatened species.

Mitigation of operations-phase impacts depends on both careful design and proper operation and maintenance (O&M) of the system. In the case of impoundment structures, proper O&M is especially vital to:

- maintaining critical downstream flows
- safeguarding the integrity of the impoundment structure—the water level in the reservoir must not be allowed to exceed the rated level, and required maintenance must be performed promptly.

Monitoring

Both types of micro-hydro installations require monitoring for the operations-phase impacts outlined above. In addition, impoundment hydro requires a regime for testing quality of water in the impoundment, as well as regular monitoring of the quantity of downstream flows. Monitoring plans should detail:

- What criteria will be used in testing?
- How often will tests be conducted?
- What process will be used to correct problems in the system?

In addition, the integrity of the impoundment structure (dam) must be monitored on a regular basis.

Micro-hydro Mitigation and Monitoring Guidelines

- Avoid soil stockpiling
- Keep streams and water flow open
- Return topsoil to original site
- Restore land contours
- Avoid wildlife breeding seasons
- Protect habitats of endangered wildlife
- Maintain downstream flows
- Safeguard dam structures
- Develop testing criteria and schedule
- Specify process for correcting problems

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