International Journal of Civil Engineering Research.
ISSN 2278-3652 Volume 5, Number 4 (2014), pp. 417-430

http://www.ripublication.com/ijcer.htm

Renewable Energy for Increasing Environmental Protection and the Quality of Rural Life

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Abstract

Most of the renewable energy projects implemented thus far in the rural areas of less industrialized nations have concentrated on residential applications. A limited but growing number of rural projects are currently being implemented to use renewable energy (RE) for productive uses. This study analyses the linkages between energy and productive uses in rural areas and examines the potential benefits of implementing sustainable energy options as a component of strategies to improve rural conditions. Research methods are based on a review of the literature on RE project implementation. The analysis illustrates how these new initiatives are evolving from a ‘traditional’ focus based on satisfying residential needs towards a much broader local community development approach. Although the use of renewable energy is not a panacea for environmental protection or for poverty reduction, emerging evidence suggests that very carefully designed productive-use projects can contribute to the enhancement of rural sustainability and to improvements in the quality of rural life.

Keywords: Renewable energy, environmental protection, rural life, sustainability.

1. Introduction

Most of the renewable energy projects implemented in the rural areas of less industrialised countries have concentrated on residential applications such as illumination and media access (i.e. radio and television), and also, albeit to a lesser extent, on community needs (e.g. electricity provision for health clinics and schools). A limited but growing number of rural projects are currently being implemented to use renewable energy for productive uses. The ‘term productive use’ as used here, refers broadly to projects that aim at enhancing income generation opportunities and productivity in rural areas (e.g. small industry, agriculture, commercial activities, telecommunications, education and health facilities, clean water, refrigeration, etc.), to improve quality of life and increase local resilience and self-reliance. These new initiatives are based on the notion that renewable energy projects need to evolve from their ‘traditional’ focus on residential needs (such as lighting) towards a much broader local community development approach.

Agriculture is a primary economic activity amongst less industrialized countries. On average, the agricultural sector accounts for 30 percent of GDP amongst less industrialized countries (FAO, 2000, p.25). The significant economic contribution of the agricultural sector has not yet resulted in a concomitant accumulation of widespread benefits for most rural inhabitants. Lack of access to adequate, affordable, and convenient sources of energy is one of the key challenges faced daily by rural inhabitants.

A figure, often quoted in most current energy publications, states that close to two billion rural people world-wide still lack access to electricity. A great proportion of these two billion rural inhabitants must rely on wood, dung and crop residues for cooking and space heating.

Reliance on these energy sources is directly linked to significant and widespread health problems (e.g. respiratory ailments from smoke inhalation), and also implies drudgery and hard physical work for vast numbers of people. These prevalent rural energy conditions directly hinder potential agricultural productivity gains and reduce food security.

This paper explores the linkages between energy and productive uses in rural areas and the potential for sustainable energy options as a component of strategies to improve the quality of rural life. The analysis is based on an examination of recent projects involving renewable energy for productive uses.

1.1 Background

Greater access to energy is not a panacea for alleviating poverty, and addressing energy needs does not automatically improve living conditions. However it is becoming increasingly clear that rural development depends on a clean, reliable, and stable energy supply, which often represents a vital component for powering a number of productive activities and to ensure the smooth operation of essential services. A number of projects have shown that a secure energy supply represents a basic input to most components of the rural development process (e.g. clean water, improved health facilities, enhanced educational capability and community infrastructure facilities, better communication systems, enhanced agricultural production). As Balkrishnan (2000, p.323) notes intangible social benefits accrue from the implementation of these schemes including improved health and sanitation, reduced women’s drudgery and increased family efficiency and consequently, the development of skills and entrepreneurship.

Linking renewable energy to productive uses can facilitate increases in rural access to modern energy services. This is because low load factors increase costs considerably, and therefore energy systems can become more cost-effective if they can be linked to a secure baseload source of demand such as a local enterprise, irrigation pumping, desalination, or sales to the grid (Kartha and Leach, 2001). Several renewable energy options such as solar thermal, photovoltaics, wind energy, and biomass hold significant potential as part of strategies to help increase farm productivity and rural sustainability. Campen et al. (2000, Table 5, pp.15-16) provide a detailed and comprehensive inventory of PV systems used for a variety of agriculture and rural development purposes. Martinot et al. (2002, p.319) note that although the rural use of wind-driven water pumps for irrigation and live-stock declined during the 1950s and 1960s (due to rural electrification and the use of diesel-driven pumps) several countries are using wind-powered pumps on a large scale. Their figures indicate that Argentina has between 500,000 to 1 million wind-powered water pumps, while South Africa has about 100,000 and Namibia has 30,000, with thousands more in Brazil, China, Colombia, India, Peru and Thailand. Lorriman and Hollick (2003) note that solar drying is very well suited for crops that are mechanically dried at lower temperatures.

1.2 Conventional Approaches for Addressing Rural Energy Needs

The most prevalent strategy to address rural energy needs amongst less industrialized countries has been the implementation of residential rural electrification programmes. These initiatives have doubled the number of rural households with access to electricity during the 1970-1990 period. However, this significant expansion has barely kept pace with population increases (FAO, 2000). People living in rural areas often live in isolated areas, which means that the capital costs of expanding electricity grids are higher than in urban areas. These facts –combined with concerns about the environmental problems directly associated with fossil fuel-based forms of electricity generation— have fostered the development and implementation of rural electrification schemes based on decentralised systems and renewable energy sources.[10] These schemes are being implemented throughout the world by government agencies, non-governmental organisations (NGOs), and by public/private sector partnerships. Renewable energy systems are being widely deployed in rural areas by national and international organisations because they are perceived to offer several important advantages.

Although renewable energy systems can provide a number of advantages to rural people, rural electrification efforts face an uncertain future. Rapid and sweeping changes are occurring in the energy and electricity sectors of many nations (e.g. deregulation and privatisation) but there has been little discussion about how people living in remote areas will be affected by these changes (Remmer and Kaye, 2001, p. 367). Furthermore, broader discussions about the role of renewable or stand-alone fossil fuel energy sources, as part of rural development strategies, are rare despite their obvious importance to rural electrification and the benefits of linking marginalized areas to the formal economy (Kammen, 1999, p.34).

Most rural electrification initiatives thus far have focused on household and community needs for lighting (FAO, 2000). Placing rural electrification as part of a broader development approach entails allocating a much higher priority on strategies for using energy for productive uses.

2. Renewable Energy for Productive Uses

Agricultural modernisation has resulted in three distinct types of agriculture: industrialised, Green Revolution, and traditional (Pretty, 1995). Most rural people live without access to grid electricity and practice traditional agriculture. This form of agriculture receives scant attention from policy makers even though it supports close to two billion people. Pretty (1995) notes that traditional agriculture is often practised in remote areas (far from markets and infrastructure) and is characterised by low agricultural yields, complex and diverse farming systems, and dependency on wild resources (non-domesticated plants and animals).

The existence of significantly different agricultural systems implies that rural projects need to be carefully designed for meeting quite different challenges. The key challenge for the Green Revolution areas is to maintain yields at current levels while reducing environmental damage. For the diverse lands of traditional agriculture the challenge is to increase yield per hectare without damaging natural resources (Pretty, 1995, p.19).

Project goals need to reflect local needs and aspirations, which as previous sections illustrated, can be better understood and incorporated by using gender-sensitive participatory approaches during all the steps of both the policy and project cycles. The major emerging productive uses for renewable energy in rural areas include agriculture, powering small industry and commercial services, and production of electricity for social services such as drinking water, education and health care facilities (Martinot et al., 2002). As Table 1 illustrates, addressing the energy components of agriculture and off-farm activities can increase the potential for income generation of rural households and enterprises by providing energy for such processes as irrigation, food processing, food preservation, and delivery to market. As summarized in Table 1, renewable energy sources (RES) can provide technically viable alternatives to conventional energy for several of the tasks related to agricultural production and processing. These tasks usually include land preparation, planting, fertilization, irrigation, harvesting, transport, processing and storage. RES can reduce the drudgery associated with using physical labour and animal power to perform these tasks and can help to increase the productivity of several agricultural tasks. RES can be effectively used to provide a variety of energy services that can enable rural households and enterprises to pursue value-adding activities.

Table 1: Energy Services and Income Generation (adapted from Kartha and Leach, 2001, p.19)

Energy Services	Income-generating value to rural households and enterprises	Renewable energy options
Irrigation	Better yields, higher value crops, greater reliability, growing during periods when market prices are higher	Wind, photovoltaic (PV), Biomass
Illumination	Reading, many types of manual production during evening hours	Wind, PV, Biomass, Micro-Hydro, Geothermal
Grinding, milling, husking	Create value-added product from raw agricultural commodity	Wind, PV, Biomass, Micro-Hydro
Drying, smoking (preserving with process heat)	Create-value added product. Preserve produce to enable selling to higher-value markets	Biomass, Solar Heat, Geothermal
Refrigeration, ice making (preserving with electricity)	Preserve produce to enable selling to higher-value markets	Wind, PV, Biomass, Micro-Hydro, Geothermal
Expelling	Produce refined oils from seeds	Biomass, Solar Heat
Transport	Reaching markets	Biomass (e.g. biodiesel)
TV, radio, computer, internet, telephone	Education, access to market news, entertainment, co-ordination with suppliers and distributors, weather information	Wind, PV, Biomass, Micro-Hydro, Geothermal
Battery charging	Wide range of services for end user	Wind, PV, Biomass, Micro-Hydro, Geothermal

3. Renewable Energy Projects for Productive Uses

Although rural renewable energy projects have often concentrated on residential applications, and to a lesser extent on community needs (such as provision of electricity for health clinics and schools), a growing number of projects are being implemented to use renewable energy for productive uses. A detailed and systematic effort to accumulate and disseminate widely the lessons emerging from these, and other, projects constitutes a unique and crucial opportunity to improve the design and implementation of future initiatives. A number of such projects are documented below.

The next sections will focus succinctly on the type of capital addressed by each of the projects. This focus is based on the notion that overemphasising a single form of capital can reduce sustainability (Flora and Kroma, 1998, p.105).22 Flora (2001, pp.43-45) provides definitions and a lucid explanation of some of the key linkages between different forms of capital. *Financial capital* includes money and/or credit instruments for investments or speculation. *Manufactured capital* refers to physical infrastructure (machinery, chemical fertilisers, schools, water systems, etc.). *Financial capital* can become *manufactured capital* by the activities of the private or public sector. Particular choices of investment in manufactured capital usually have a strong gender determination with substantial implications for long-term sustainability. *Human capital* refers to individual capacity, training, human health, values, and leadership. According to Putnam (1993) *social capital* includes the features of social organisation (e.g. networks, norms, and trust) that facilitate co-ordination and co-operation for mutual benefit. Social capital enhances the benefits of investment in manufactured and human capital. *Environmental capital* refers to air quality, water (including quantity and quality), biodiversity (plants and animals), soil (including quantity and quality), and landscape.

3.1 Decentralised Energy Systems India (DESI Power)

DESI Power is a not-for-profit collaboration between DASAG (a Swiss engineering company) and Technology and Action for Rural Advancement (TARA is the commercial wing of the non-profit corporate organisation Development Alternatives which is based in New Delhi).[24] TARA is dedicated to the promotion of renewable energy to satisfy local energy needs and to generate new employment sources. The goal of DESI Power (DP) is to develop Independent Rural Power Producers at the village level as joint ventures between local communities and entrepreneurs to provide electricity to remote villages not connected to the national power grid in India. Their efforts have been focused on developing manufactured and human capital. The first DP biomass

gasification power plant was installed in 1996 at Orchha, Madhya Pradesh at a capital cost of Rupees $ 22 Lakhs.[25] This 80 kW plant supplies power to a facility developed by TARA to conduct research, demonstration, training and production activities using appropriate technology. The production facilities employ more than a hundred workers.

They include a handmade recycled-paper unit; a paper- products development unit; several enterprises producing micro-concrete roofing tiles, mud blocks, ferrocement and other low cost building materials; and a charcoal-briquetting unit. The handmade-paper unit employs 35 women and seven men. The female operators have been provided with on-the-job training, and productivity in the unit has increased from 1 to 4.5 tons per month (operating with eight-hour shifts) since its inception. The experience of this handmade-paper unit has demonstrated the importance of technology development in tandem with the development of markets. Although local conditions will undoubtedly determine the potential for replication and success, TARA estimates that similar efforts have potential to be replicated in other rural decentralised production units. Encouraged by the economic success of this enterprise, TARA is setting up a 16-ton-per-month unit at Jhansi, in Central India. According to estimates by DP, based on theoretical calculations and the actual experience of the Orchha Plant, plant load factor (PLF, or capacity utilisation) is a key parameter to which their economics of power generation are extremely sensitive. DP calculations indicate that breakeven PLF for the Orchha Plant is between 50% and 60%. DP also estimates that above 60%, the Orchha Plant be highly competitive and able to sell electricity at prices below the grid. DP also has observed that even with less than 40% load factor, very high biomass cost, and lower than optimum diesel replacement caused by large variations in the plant load, the cost of electricity has been in the range of 4.00 - 4.50 Rupees (about US 8.5-9.5 cents) per kWh, which is considered by DP to be competitive with electricity from the grid.

3.2 Greenstar

Greenstar is an international NGO based in the USA that delivers solar power, health, education and environmental programmes to small villages in less industrialized countries, and helps to connect those villages to the global community and global markets via the Internet. To achieve these goals, Greenstar has designed a portable community centre that uses a PV system to power a wireless link via satellite to the Internet (which enables e-commerce), a digital studio, a classroom, a water purifier, a small clinic, and a vaccine cooler. Greenstar addresses social capital development and is operational in the four villages of Al-Kaabneh, West Bank, Palestine; Swift River, Blue Mountains, Jamaica; Parvatapur, Andhra Pradesh, India; and Patriensah, Ghana. Greenstar employs local musicians, teachers, and art professionals to record the voice of the community and works with the people of each village to develop an e-commerce web site. Greenstar helps 'package' materials directly for Internet consumers and through licensing to business. The goals are to provide new jobs and skills, strengthen local culture and language, and affirm people's independence. Villagers own the Greenstar Village Centre (GVC) themselves and become shareholders of Greenstar, which is a profit making business (the first priority is to provide profits to its partners in less industrialised nations, then its global investors, and then to Greenstar itself). Greenstar's goal is to expand their activities to 300 GVCs world-wide over the next five years and thereby help local people increase their literacy levels in a manner that enhances their cultural assets instead of mining their local resources or exploiting their labour.

3.3 Grameen Shakti, Bangladesh

Grameen Shakti, a not-for-profit company of the Grameen group of companies in Bangladesh, is involved in a range of activities related to small-scale photovoltaic (PV) systems, including: marketing, sales, servicing, training, research and development, credit provision, payment collection, and credit guarantees. Its programmes are focused on financial and human capital and actively promote the use of PV systems for income generation activities such as: electrification of educational facilities; powering cellular phones for commercial purposes; illumination for rice mills, tailor shops, saw mills, grocery shops, poultry farms, health clinics, restaurants, bazaars, Radio/TV repairing shops; and as micro-utilities (selling power to

neighbouring shops). In 1998 Grameen Shakti was the recipient of a soft loan provided by the Small and Medium Enterprise
Programme of the Global Environment Facility and International Finance Corporation (GEF/IFC SME). This loan enabled Grameen Shakti to offer improved credit terms to its customers and thereby significantly increase the demand for PV systems. Customers have three credit purchasing alternatives. The first option allow customers to pay 15% of the total system price as down payment during installation time and the remaining 85% of the cost (including a 12% service charge) must be repaid by installments within 36 months. In the second option customers pay 25% of the total price as down payment during installation and the remaining 75% of the cost (including an 8% service charge) must be repaid within 24 months. For the third option customers pay a 15% down payment during installation and the outstanding 85% (including a 10% service charge) must be paid by 36 cheques in advance. If a customer chooses to select a cash purchase he/she receives a 4% discount. Grameen Shakti has installed 14,000 Solar Home Systems as of May 2003 (which represents an installed capacity of 700 kWp). Buyers of PV systems have reported increases in income and productivity by extending working hours after dusk and due to the introduction of computers powered by PV. Grameen Shakti is training technicians in PV installation and maintenance, thereby creating employment for local people, facilitating technological transfers, and developing skilled technicians-cum retailers in rural areas. Trainees provide after-sales services to PV buyers, supply accessories and retail solar systems, increase local awareness regarding renewable energy technologies, and popularise the use of renewable energy.
Grameen Shakti has already trained 550 technicians and 3500 customers as part of its PV program. Grameen Shakti is also promoting the use of bio-digesters for producing biogas for cooking and for using residues in fields and in ponds as an alternative to chemical fertilisers. Bio-digesters reduce expenditure for firewood and can enhance household income from increased production of crops and fish.

3.4 African Rural Energy Enterprise Development (AREED)

The African Rural Energy Enterprise Development (AREED) is an initiative of the United Nations Environment Programme (UNEP) and the United Nations Foundation (UNF). Since 2000, the UNF has provided AREED with a total of $4.3million. AREED aims at developing energy enterprises that use clean, efficient, and renewable energy technologies to meet the energy needs of under-served rural populations in Botswana, Ghana, Mali, Senegal, Tanzania, and Zambia. The approach used by AREED focuses in financial and human capital and consists of nurturing new energy companies by providing seed capital for early-stage enterprise development and training services to help entrepreneurs start and develop energy businesses. AREED provides a working capital loan on a cost-sharing basis with the business owner(s). These loans typically range from US$15,000 to $120,000 and financing can be provided as local currency or USD denominated loans. In addition, the services provided by AREED include enterprise start-up support in areas such as business planning, structuring, and financing; and assistance to develop partnerships with banks and NGOs involved in rural energy development. This approach has fostered the development of companies involved in energy efficiency, biomass, biogas, PV, solar thermal, water pumping, and wind energy. Several of these companies intend to use renewable energy for productive uses. For example, an entrepreneur in Ghana plans to use a wind turbine to provide electricity for a local factory and a mini grid, a company in Mali is using solar energy to produce dried foods, and a co-operative in Senegal repairs and services wind-powered water pumps. The ultimate goal of AREED is to help these new energy companies become self-sustaining and able to attract outside investment. By working with African NGOs, development organisations, and financial institutions, AREED is trying to develop their capacity to foster and support clean-energy entrepreneurs. The enterprise development approach used in Africa by AREED is currently been adapted by UNEP to develop similar initiatives in Brazil and China.

4. Emerging Lessons and Future Directions

Most of the projects presented in the previous section are still ongoing; therefore, thorough and complete evaluations are still pending. Nevertheless, several salient project clusters are highlighted for subsequent evaluations. Among these, a key consideration relates to financial support and implies that innovative funding approaches are required to ensure that projects promote the development of viable markets for renewable energy technologies. This is an essential consideration to increase the chances that new projects become self-sustaining in the long run, and also to ensure that new initiatives improve negative risk perceptions and unfavourable financial conditions, to thereby facilitate subsequent tapping into private-sector capital to stimulate project replication at larger scales. Pending evaluations from the Mexican and Ugandan projects (summarised in sections 4.8 and 4.9) will provide valuable information about the viability and challenges associated with using collateral funding support to back vendor programmes, as a potential replacement for more traditional grant investment support.

In particular the project, Mexico: Renewable Energy for Agriculture, will provide empirical results regarding the strategy of providing finance to vendors as a strategy to overcome the absence of rural credit systems for farmers. These two projects also illustrate how GEF funds are being used to simultaneously stimulate several forms of capital and not merely financial and manufactured capital (both projects are also investing heavily on the development of human and social capital).

The importance of moving beyond the prevalent notion of projects as mere technology demonstration efforts and toward initiatives that develop strong enabling environments is becoming more widely recognised, at least in theory, but still needs to be translated into actual project design and implementation. This realisation comprises a labour-intensive, and to a great extent, context-specific set of activities that needs to be supported at all levels (international, regional and local). This is of special importance to achieve private sector involvement and to develop innovative and more effective public-private sector partnerships.

4.1 Key Areas that need Support to Scale-up the Development of New Renewable Energy Projects for Productive Uses

The projects summarised in section 4 indicate that renewable energy sources can provide alternative energy services for agricultural production and processing, rural industry, and community facilities. Project developers need encouragement and support to use renewable energy, even where renewables already have demonstrated their advantages and in some cases costeffectiveness (clear examples are irrigation, livestock watering, solar crop drying, and telecommunications). 40 As Campben et al. (2000) note in their study of potential markets for PV rural applications, a number of barriers often act in a vicious circle, impeding the full exploitation of renewable energy. High investment costs, lack of financing mechanisms, lack of infrastructure, lack of familiarity, low volume of sales, high transaction costs, and lack of political commitment and adequate policies all combine to impede the adoption of renewable energy even for those activities that are currently cost-effective (Campben et al., 2000). Most of the case studies presented here are dealing with several of the aforementioned problems. Interestingly these problems are not very dissimilar to those identified by the G8 Renewable Energy Taskforce (RET). Table 2 illustrates the key barriers identified by the G8 RET summarised as part of an analysis of world-wide experience regarding implementation of renewable energy projects.

Table 2: Key Barriers to the Introduction of Renewable Energy Projects (reproduced from: G8 RE Task Force, 2000, p.38)

Key Barrier
1. Lack of business and technical infrastructure
2. Financial and economic constraints
3. Policy and institutional barriers
4. Lack of consultation, co-ordination and co-operation
5. Vested interests and inertia
6. Human resource limitations
7. Lack of information exchange and awareness

4.2 New Information Initiatives to Increase Political Support and Policy Development

Personal interviews, conducted as part of this research with key renewable energy and rural experts, revealed that a prevalent obstacle for project development is the limited knowledge regarding current renewable energy technologies among political representatives and members of the private sector. Often this translates into a higher level of risk perception that makes access to financing sources difficult. As Murthy (2002) as noted in relation to PV sales in developing nations, financing institutions tend to be conservative and not willing or unable to provide innovative or alternative financing mechanisms. In addition to this problem, ongoing efforts to deregulate and privatise the energy sector can have detrimental impacts on rural electrification (unless specific policy counter-measures are implemented to ensure that urban electricity supply does not become the main focus of post-deregulation scenarios). The aforementioned issues indicate that new information initiatives are needed to raise awareness among decision makers and to share existing policy experience more widely.

4.3 Development of Local and Regional Capacity

Smilie (2000, p.183) notes that without a local industry capable of testing and adapting technology to local needs, a country remains totally beholden to outside interests and influences. The GEF project *Renewable Energy for Agriculture*, currently under implementation in Mexico, illustrates the importance of providing training opportunities to develop local technical capacity to design, implement, maintain and replicate projects.

The Peruvian project also provides an interesting illustrative example of local capacity enhancement and indigenous technological development. To scale-up the use of renewable energy for productive uses it will be essential to implement similar initiatives in as many regions as possible.

4.4 Establishment of New Centres of Excellence

A key strategy to facilitate efforts to increase awareness amongst decision-makers, develop local capacity, and conduct public education initiatives is the establishment of local centres of excellence to showcase renewable energy options and to facilitate training opportunities. These new centres should be established, wherever possible, as part of existing local institutions (universities, rural organisations, schools, municipal, buildings) to minimise infrastructure costs and to maximise the use of existing human resources within established institutions. R&D activities represent an essential additional component to facilitate the development of the RE sector (e.g. development of standards, quality certification, design and adaptation of RE technologies to local conditions and available materials, establishing collaborations to develop local expertise).

5. Conclusion

Renewable energy sources can often be a more environmentally sound option to conventional energy generation; however, if holistic approaches and care are not exercised, the end-uses facilitated by any energy source may result in serious environmental degradation (e.g. soil erosion, depletion of aquifers, salinization, loss of biodiversity). New projects should be closely scrutinised to ensure that attempts to increase rural productivity are designed holistically to avoid environmental and social degradation. It is imperative to carefully consider –before project implementation— how the use of renewable energy will affect local labour arrangements, and if its use will result in permanent losses of employment sources. As Smillie (2000, p.214) notes, the introduction of modern technology has increased agricultural and industrial production, but in most cases it has done the opposite for employment.[44] The connections between income generation and employment creation should be made explicit at the earliest stages of project design and should be closely examined to ensure that project implementation indeed maximises both. Questions such as which specific social groups will benefit? And how? are imperative in evaluating whether project implementation will result in poverty alleviation or will become a subsidy to upper income earners. As Gertler (1999, p.137) notes, projects that squander or destroy social and environmental capital can only generate temporary affluence and just for a few. Furthermore, projects can have very different impacts and implications for local women and men; therefore, consideration and analysis of gender issues is imperative to ensure that new projects are sustainable and have strong emancipatory potential.

Although the use of renewable energy is clearly not a panacea for environmental protection or poverty reduction, very carefully designed productive-use projects can contribute to the enhancement of rural sustainability and to improvements in the quality of life locally. The use of renewable energy for productive rural purposes constitutes a significant departure from many of the renewable energy projects implemented in the twentieth century, which often solely addressed residential energy needs and to a lesser extent community needs (such as power provision for health centres and schools).

To achieve broader community development goals, new renewable energy projects aimed at productive uses need to invest in the development of all forms of capital and not only in financial and manufactured capital. Several of the projects summarised earlier are investing in the development of human and social capital alongside financial and manufactured capital. Furthermore, new productive-use projects need to be specifically tailored so funds are properly used to enhance environmental capital. This clearly means that new projects need to be carefully designed and implemented to make certain that new rural energy uses of renewable technologies do not result in the degradation of water, soil, and biodiversity, which are all essential components for the survival and quality of life of rural communities.

If new rural initiatives for productive uses are carefully screened and monitored to ensure that environmental capital will not be degraded –and that economic impact will be favourable for both local women and men— renewable energy applications could become a significant tool for environmental protection and for improving local quality of life.

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