Renewable Energy for Productive Uses: Strategies to Enhance 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 industrialised 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 and interviews with project implementers. 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.

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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).[1] 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 industrialised countries.[2] On average, the agricultural sector accounts for 30 percent of GDP amongst less industrialised 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.[3]

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[1] The term 'renewable energy' is used here in relation to modern technologies that use solar, wind, biomass, geothermal, and small hydropower sources.

[2] The generic term 'agriculture' is used here to cover agricultural, livestock, forestry, and fishery activities

[3] About 2.8 billion people live in rural areas of less industrialised countries. Two billion people live without access to electricity and at least two thirds of this total are dependent on wood, dung, and crop residues for cooking and space heating (FAO, 2000, p.29). In countries such as Uganda 90% of all energy used in agriculture is from human power, animal power contributes about 8%, and fossil fuels (to power tractors) contribute about 2% (Turyareeba, 2001, p.454).

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.[4] These prevalent rural energy conditions directly hinder potential agricultural productivity gains and reduce food security.[5]

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. The projects were selected through purposive sampling (i.e. non-random), and were chosen because they are part of a new generation of initiatives specifically designed to address productive uses in rural areas. Although they do not contain exhaustive economic analysis or comparisons, nor constitute a geographically representative sample, they provide a synopsis of several different implementation approaches, institutional arrangements, and technological choices. Background information was obtained from project documentation and from personal and long-distance semi-structured interviews and discussions with policy makers and project implementers from Africa, Asia, and Latin America (for a list of participants please see Appendix). All the respondents were asked to summarise lessons learned from the implementation of ad hoc projects implemented in their country. They were also asked to identify the most salient barriers impeding the development of projects and key recommendations that should be considered for implementing new renewable energy projects aimed at productive uses. Their responses, comments, and insight have greatly informed the development of the paper; however, any omissions or errors are the sole responsibility of the author.

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[4] The World Health Organization (WHO) estimates that as many as one billion people –mostly women and children— are regularly exposed to levels of indoor air pollution exceeding WHO guidelines, by up to 100 times. The highest air pollution exposures are experienced within indoor environments located in developing countries (G8 Renewable Energy Report, 2001, p.20).

[5] Lacking access to electricity and commercial fuel sources presents technical and logistical problems that can preclude refrigeration and rural processing of agricultural products, constraint several applications of mechanised farm equipment, limit access to market information, and constraint the performance and activities of non-farm activities (such as commerce and cottage industries). Furthermore, according to the UN Food and Agriculture Organisation, not only the quantity of food produced is affected but also nutritional quality is compromised i.e. people are forced to eat uncooked food, or food that can be easily cooked but which may not give full nourishment (FAO, 2000, p.25).

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).[6] 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.

[6] For example see Campen et al. (2000, p.30); Weingart and Lee (2000).

Their research shows how this solar application is currently used commercially to dry coffee in Panama and Costa Rica. These and other renewable forms of energy generation can also be used in many non-farm applications as part of strategies aimed at increasing rural incomes and employment sources (e.g. to power small and medium enterprises engaged in processing and packaging of agricultural products, and to power other off-farm productive activities).[7]

Several of the problems faced by rural people are aggravated by the existence of national and regional policies favouring urban concerns over rural needs. The 2000/2001 World Development Report published by the World Bank notes that national energy policies often focus on urban needs (industry, transport, and urban infrastructure), and tend to overlook the energy requirements of rural populations (World Bank, 2000b). According to the UN Food and Agriculture Organisation (2000, p.67) the energy needs of rural areas in general and of agriculture in particular have long been considered as a secondary concern, while industrial and urban energy provision continues to take priority in many national energy programmes. Recent energy forecasts illustrate the magnitude and implications of this 'urban bias' for rural people. For example, the G8 Renewable Energy Task Force (2001, p.26) estimates that developing countries represent about 40% (or about 1.3 million megawatts) of the total global electric power capacity. Their estimates indicate that global generating capacity outside the OECD and the transition economies will increase by nearly 1.6 million megawatts over the next 20 years and that such expected growth would require investments of around US$1.7 trillion.
These estimates do not include any of the environmental and social costs (e.g. air pollution, climate change, respiratory ailments etc.) directly associated with increasing electricity supply by expanding conventional supply approaches.[8] Even if all these environmental and social considerations are totally ignored, the high capital costs of expanding electricity supply (i.e. about US$ 70 billion per year), combined with the existence of an 'urban bias' in energy planning, will likely delay or preclude the implementation of viable alternative energy solutions for people living in rural areas.

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[7] Increasing farm productivity and incomes while helping farmers take up off-farm income activities are key strategies to reduce rural poverty (Kartha and Leach, 2001, p.20).
[8] Often based on burning fossil fuels to generate electricity and grid expansions for distribution.

To visualise the magnitude of these figures consider that the OECD estimated that in 1998 total Official Development Assistance increased to US$51.5 billion (from US$47.6 billion in 1997), reversing a five year downward trend (Radka, 2000, p.73). Furthermore, total power sector investment in developing countries represents roughly US$40 billion per year (G8 Renewable Energy Task Force, 2001, p.27).

1.2 Conventional Approaches for Addressing Rural Energy Needs

The most prevalent strategy to address rural energy needs amongst less industrialised 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.[9] 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. According to the Food and Agriculture Organization of the United Nations (FAO),

> "renewable energy systems offer benefits in terms of reducing the local and global environmental impact of energy production; they can provide both employment opportunities and economic benefits in rural areas due to their inherent localised nature. Renewable energy sources are an important means of providing increased diversity and security of supply, and they also offer another set of energy supply options that can help

[9] During 1970-1990 close to 800 million rural people were the recipient of rural electrification efforts that expanded grids, and about 600 million people have participated in schemes to commercialise improved cooking stoves; biogas and producer gas systems; and renewable energy systems (UNDP, 2000, p.384). However, despite all these initiatives the population without access to such energy services remains at 2 billion (UNDP, 2000, p.384).

[10] Martinot et. al. (2002, table 1, p.312) estimate that as of 2000 over 50 million households are served by small-hydro village scale mini-grids, 10 million households get lighting from biogas, 1.1 million households have solar photovoltaic (PV) systems or solar lanterns, and 10,000 households are served by solar/wind/diesel hybrid mini grids.

mitigate the impact of climate change by substituting for fossil fuels" (FAO, 2000, p.10).

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).[11]

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. Existing Experience and Lessons Learned

Although accumulated experience from renewable energy projects designed to address productive uses is still quite limited, there is abundant information on renewable energy projects for rural residential energy needs (e.g. Acker and Kammen, 1996; Huacuz and Martinez, 1995; Kammen, 1999; Kozloff, 1995; Martinot et al., 2000). This accumulated experience contains valuable lessons for designing and implementing projects aimed at addressing productive uses in rural areas. The next sections discuss key lessons related to participation, gender issues, private sector focus, and government support.

[11] Burn and Coche (2000, p.16) note that although sustainable development discourse and practice have often tended to opt for renewable energy options, specific implementation questions (such as which decentralised technology is the best? And whether renewable energy options are more desirable than fossil fuel based alternatives?), should be asked to address particular considerations and issues present in each specific local context.

2.1 The Key Role of Participation in Energy Projects

Chambers (1994) notes that there has been a growing awareness since the 1970s that conventional, ‘top-down’ development approaches have failed to deliver results that meet the needs of resource-poor people. An alternative to top-down development approaches is provided by initiatives that aim at increasing local participation. Participatory approaches to development are based on the notion that local people, who are the focus of the investigation, implementation, or analysis, know more about their lives and environment –and what they need to improve their quality of life— than the professionals who are working with them (Ward, 2000, p.4). Until recently the use of participatory techniques has been mostly restricted to the fields of agriculture, natural resource management, health, and sanitation (Ward, 2000, p.4). Nevertheless, research that explores the role of participation in energy projects is beginning to emerge. Ward (2000) notes that decentralised energy options require more user participation on an individual or a community level than grid electricity projects.[12] There are numerous examples where attempts to implement off-grid, decentralised electricity schemes have failed and an important factor in the failure of these schemes has been the lack of participation of end-users in the planning and implementation of projects (Ward, 2000).

Neudoerffer et al. (2001) analysed rural and renewable energy programmes implemented at the national level in India to improve people’s quality of life and to reduce the existing pressure on the natural resource base. Their research documents that these projects have met with limited success because of the absence of a mechanism to ensure the genuine participation of the local inhabitants. Jafar (2000) analysed several renewable energy projects, implemented over the last fifteen years in small island nations of the South Pacific, and found that limited understanding of the energy needs of project recipients and inadequate involvement of the recipient community at the planning stage were key factors behind project failures. Anderson and Doig (2000) believe that participatory approaches to planning in the electricity sector are rare because such initiatives are highly technical in nature, a fact that can exclude most rural (and non-rural) people. After conducting research to develop guidelines for participatory planning of off-grid electricity supplies in Sri Lanka and Zimbabwe, Anderson and Doig (2000, p.326) conclude that:

"Accepting that community participation is an essential ingredient for the success of decentralised electrification projects, it must also be recognised that presenting the available options to rural populations will require certain simplifications. Issues such as how to decide on an appropriate technology, examining the resources, assessing the needs, finding the suppliers, financing, getting the system installed and maintaining them have to be dealt within the participatory process"

The potential for generalising the above conclusion can be contested not least because different locations can have unique characteristics that determine particular local strengths and weaknesses which in turn should influence participatory approach processes. Nevertheless, research and field experience illustrate that several critical success factors for ensuring the equitability, reliability, and effective management of decentralised energy schemes are directly related to high project participation levels and meaningful involvement of end-users in key planning decisions (Ward, 2000).

Participation in planning productive-use applications will allow a project to better reflect local needs and increase its social acceptability, especially at the local level. Since meaningful participation needs to actively involve both local men and women, careful consideration of gender issues is a key factor to ensure that participatory approaches are effective. The next section examines in more detail the role of gender in relation to renewable energy

2.2 The Importance of Gender Issues

It is becoming quite clear among energy and development practitioners that addressing gender issues as part of renewable energy projects improves project delivery and can enhance the quality of life of rural women (e.g. Cecelski, 1995, 1998, 2000; Parikh, 1995; Skutsch, 1998; Farinelli, 2000). More generally, "greater attention to the energy needs and concerns of women in developing countries can improve the effectiveness of energy policies and projects, and can also help promote overall development goals, such as poverty alleviation, increased employment, and improved health and education levels"

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[12] Decentralised systems (e.g. PV systems) are often installed at the user's home or end-use location and tend to require periodic maintenance by users (e.g. cleaning PV modules, battery maintenance).

(UNDP, 2000, p.3). Results from the few published empirical studies that have evaluated gender issues within RE projects (e.g. Balakrishnan, 2000) indicate that it is essential –at the very least— to provide training for women to ensure the long-term sustainability of RE projects (Cecelski, 2000, p.27).[13]

Empirical evidence by Balkrishnan (2000, p.321) highlights that when women beneficiaries have been given orientation and training on the correct use and application of new devices such as solar cookers, improved wood stoves, biogas, PV systems, solar lanterns and solar dryers, the programmes have been found to be sustainable. It follows that new productive use initiatives should also carefully consider the interplay of gender issues at the local level. For example, access to credit often has a clear gender bias, which in many rural areas severely limits women's access to capital, thereby constraining their productivity and social roles. Incorporation of gender considerations, such as facilitating women's access to both credit and skills development opportunities, into new productive-use initiatives can not only increase the efficiency of projects but most importantly can also have strong emancipatory potential.

Existing experience indicates that if renewable energy projects are purposefully designed to address both local participation and gender issues, the chances that they will deal more effectively with local needs are higher, which in turn also enhances the possibilities of project sustainability.[14]

2.3 Relevance of Private Sector Focus

At the project level, the appeal of private sector approaches as a potential strategy to satisfy rural energy needs is based on empirical evidence from project implementation which indicates that market-based mechanisms provide an incentive for quality control, after-sales services, and the development of new technology (Weingart and Lee, 2000). In addition, the accumulated experience of close to three decades of development

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Centralised systems are usually maintained by trained staff and not by end-users.

[13] Most decentralised systems require that energy end-users perform periodic maintenance. In many cases project implementers have only trained men to perform maintenance functions and have neglected training women, which has often resulted in poor system performance. Furthermore, training women can act as a form of empowerment and thereby help to increase their status at the local level.

[14] More recent experiences of renewable energy programmes suggest that acknowledging local needs and integrating them into technology transfer activities are the best way to ensure that new technologies can be adopted (FAO, 2000, p.59).

assistance for renewable energy projects indicates that several unsuccessful projects failed to generate sustainable markets for the technologies that they demonstrated (Barnett, 1990; Foley, 1993; Goldemberg and Johansson, 1995; GTZ, 1995; Kozloff, 1995).[15]

In recognition of the importance of developing sustainable energy markets, and the advantages of incorporating market-based mechanisms, financial and institutional assistance now often tends to target both private-sector needs and improvements in the regulatory and legislative structure of the energy sector (FAO, 2000, p. 60). However, a recent study that analyses changes to the regulatory and legislative structure of the electricity sectors of Argentina, Bulgaria, Ghana, India, Indonesia, and South Africa concludes that:

"electricity reforms —whether market-led or not— can best support socially and environmentally progressive outcomes when they are *explicitly* designed to do so" (Dubash, 2002, p.1, italics added).

This important conclusion is based on the realisation that reforms in the electricity sector of the aforementioned countries have been mostly driven by financial considerations aimed at maintaining existing generation capacity and developing new capacity, to the detriment of longer-term environmental and social interests (Dubash, 2002).
A clear implication for rural energy initiatives aimed at productive uses, is that concentrating on a private sector focus in not sufficient to ensure project sustainability. In fact, project sustainability seems to be directly dependent on the existence of a supportive enabling environment, which often can be tacitly shaped by governments.[16]

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[15] Many of these projects were implemented during the 1970s and 1989s as attempts to transfer small-scale renewable energy technologies (such as biogas, cooking stoves, wind turbines, and solar heaters), and are considered failures because of poor technical performance, lack of attention to user needs and local conditions, and lack of replication of the original projects (Hedger et al., 2000, p.122)

[16] "Enabling environments for technology transfer include national institutions for technology innovation, the involvement of social organisations, human and institutional capacities for selecting and managing technologies, macroeconomic policy frameworks, the underpinnings of sustainable markets for environmentally sound technologies, national legal institutions that reduce risk and protect intellectual property rights, codes and standards, research and technology development, and the means for addressing equity issues and respecting existing property rights" (Hedger et al., 2000, p.109).

2.4 Relevance of Government Support

Strong government support is crucial for the development and sustainability of rural renewable energy projects, as they control key institutional, regulatory, and financial tools (FAO, 2000, p.66). An emerging role for governments is the management of technology and innovation by incorporating them as an integral part of overall economic policy (OECD, 1999). Furthermore, governments have an essential role to play in the development and adoption of new policies to encourage the private sector, and public-private partnerships, to become involved in improving energy provision in rural areas. As Mansley and Martinot (2000, p.158) note, the existence of domestic regulatory policies can increase the contribution of private capital to sustainable development. This notion is echoed by the research of Weingart and Lee (2000), which analyses a diverse sample of renewable energy projects and initiatives implemented in China, Thailand, Japan, the Philippines, and the United States, and concludes that "successful projects reflect attractive market environments, often shaped by deliberate policy incentives". Strong market environments arise from supportive renewable energy policies and legislative frameworks within the context of comprehensive national plans (G8 Renewable Energy Task Force, 2001, p.40). This includes effective co-ordination on the activities of different branches and levels of government.

3. 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 summarised 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, fertilisation, 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

Precise information about the installed capacity, or the number of renewable energy systems, used for productive uses in rural areas of less industrialised nations is not readily available; furthermore, published data regarding these figures are scarce. This lack of precise information is particularly notorious in relation to off-farm productive activities (e.g. cottage activities and commercial services). Most of the existing information is anecdotal in nature and provides only a glimpse of the current and potential renewable energy applications.[17] Reliable information on renewable energy use for agricultural purposes is also limited; however, a few recent studies attempt to summarise existing installations and emerging trends. Campben et al. (2000) analysed the use of PV systems in rural areas and concluded that PV pumping for livestock and irrigation dominate in agricultural applications.[18] Martinot et al. (2002) estimate that between 500,000 and 1 million wind-powered water pumps are in use in Argentina after decades of efforts aimed at developing a local manufacturing base for small wind turbines. Their research also indicates that large numbers of wind-powered water pumps are used in South Africa (100,000) and Namibia (30,000), and that up to 20,000 water pumps are powered by photovoltaic (PV) systems, mostly in India. The Indian Renewable Energy Development Agency (IREDA) estimates that 4,200 solar pumps (ranging from 200 W to 2000 W) have been installed in rural areas as part of the Indian Solar PV Water Pumping Programme. Solar pumps are used in India for agricultural applications such as horticulture, animal husbandry, poultry farming, high value crops, orchards, and also for providing drinking water.[19]

Irrigation constitutes a clear example of the current potential that renewable energy holds to increase rural productivity. It also provides a lucid illustration of the caveats that need to be evaluated before blindly embracing any technological solution. Data from American and European sources suggests that between 8 and 12 percent of annual PV module production (in MWp) goes to water-pumping applications; projected on total global PV installed capacity, this would bring the total installed capacity of PV pumping systems to 100-150 MWp (Campen et al., 2000, p.26). Posorski (1996) notes that although the PV pumps scattered around the world can be considered a pioneering success, they have not yet achieved large-scale dissemination. Preliminary results of a PV irrigation initiative implemented since 1998 by the German Corporation for International Cooperation (GTZ) in Ethiopia, Chile, and Jordan have demonstrated solid technical reliability and economic competitiveness (Hahn and Schmidt, 2002). Presently, PV irrigation is not a solution for individual subsistence farmers due to high initial investment costs. However it is currently well suited for small-scale irrigation of high-value cash crops in arid climates on small plots of land (up to 4 hectares) (Hann and Schmidt, 2002; Hann et al., 2000).

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[17] For example, Campben et al. (2000, p.50) note that the potential applications for using PV for off-farm activities are numerous but also emphasise that their study found scarce information to quantify this potential.
[18] The research by Campben et al. (2000, e.g. pp.15-16) represents one of the few available sources summarising an inventory of PV systems used for agriculture and rural development
[19] For additional information see http://www.ireda.nic.in/solarwaterpumps.htm

PV and other renewable energy systems (e.g. wind pumps) can reliably power irrigation systems; however, the reliability of water resources is increasingly less promising. Water tables are now falling in key food-producing regions such as the North China Plain, the Punjab in India, and in the southern Great Plains of the United States (Brown, 2001).[20] Furthermore, most of the 80 million people added to the world population each year are born in countries that are already experiencing water shortages (Brown, 2001).[21] Postel (1999) describes in detail how the future productivity of irrigated agriculture is seriously challenged by stresses that are evolving simultaneously i.e. salinisation, siltation, faltering aquatic systems, mounting competition for water, growing imbalances between populations and available water supplies. A scale-up in the use of renewable energy systems for water pumping as part of conventional agriculture schemes, especially if implemented in marginal and water-stressed areas, could aggravate long-term water shortages. The good news is that emerging empirical evidence indicates that PV pumps are particularly well suited for small-scale irrigation purposes in arid climates and small plots of land when combined to water-saving and energy-saving micro-irrigation techniques (Hahn and Schmidt, 2002). This reality is analogous to residential PV installations, which in most cases are designed to be used in combination with energy-efficient appliances and lamps (e.g. compact fluorescent bulbs) to ensure that the electricity generated is not wasted and that systems are as cost-effective as possible. This required emphasis on efficiency could facilitate the implementation of agricultural practices that are less water-intensive as PV systems become more popular in rural areas.

The current limited availability of information regarding the supply and use of renewable energy in rural areas leads to a significant research need and poses a constraint on the development of clearer regional overviews, comparisons, and analysis. Nevertheless, the previous discussion on irrigation aims at providing background considerations to examine the potential and caveats of using renewable energy for

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[20] The North China Plain accounts for a third of China's grain harvest, the Punjab is India's breadbasket, and the southern Great Plains allow the United States to be the world's leading wheat exporter (Brown, 2001). Food supply and water supplies are closely linked, as close to 70 percent of all the water that is pumped from underground or diverted from rivers is used to produce food and 40 percent of the world's grain harvest is produced on irrigated land (Brown, 2001).

productive uses in rural areas. Its main goal is to provide 'food for thought' for the next sections, which provide a brief overview of renewable energy projects currently under implementation in rural areas of less-industrialised nations.

4. 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.

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[21] Postel (1999, p.257) notes that the number of people living in water-stressed countries is expected to grow from 470 million (in 1999) to 3 billion by 2025.

The key feature of environmental capital is that all its components are highly inter-related and therefore changes in one component usually causes variation in the others. The author recognises that the aforementioned definitions of capital are far from perfect, and that a comprehensive analysis of their significance is beyond the scope of the present paper. However they are provided, and used throughout the rest of the paper, as a starting point to facilitate comparisons between different projects.

4.1 Decentralised Energy Systems India (DESI Power)[23]

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

[22] Research on sustainable agriculture and natural resource management by Flora (2001) provides empirical evidence from the Philippines, Burkina Faso, and Ecuador that illustrates that overemphasising the value of a single form of capital can reduce sustainability.
[23] Project information provided by Mr. S. Gopinath and Mr. V. Joshi of DESI Power. For additional information see http://www.desipower.com/
[24] For more information on Development Alternatives see http://www.devalt.org

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.

4.2 Financing Micro-Hydro Dissemination in Peru[26]

A collaborative effort initiated in 1994 between Intermediate Technology Development Group of Peru (ITDG) and the Inter American Development Bank (IDB) has resulted in the installation of 24 micro-hydro plants (run-off-the-river schemes) in isolated rural areas of Peru. This on-going collaboration has focused on financial and human capital based on the provision of soft loans plus technical assistance. An integrated approach was implemented to address technological development, local training, development of pilot projects, research on institutional issues, and public advocacy work to promote organisation models to run small hydro systems. A key element of the approach was the creation of an effective financial mechanism to facilitate access of the rural population to funds for small micro-hydro development. The system consists of a revolving fund based on seed funds provided by the IDB, which allows ITDG to provide loans to small villages and rural entrepreneurs for the implementation of

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[25] In 2003 currency about US$ 47,000 (calculation based on $1 US = 47 Rupees)

small- hydro systems. The revolving credits vary from US$ 10,000 to US$ 50,000, at 8% interest rate, with five years pay back period and a grace period, which is granted on a case by case basis. As of 2000, 17 loans had been allocated benefiting more than 2 thousand families, which borrowed about US$ 2 million (about half million from the revolving fund and 1.5 million from other sources of co-funding, mostly coming from government). One of the key goals of the revolving fund has been to show by practical means the technical and economical viability of small-hydro energy schemes in isolated rural areas. Total installation costs in a sample of nine projects designed by ITDG in 1996 range from US$/kW 2,994 to 5,582 for projects with an installed capacity from 10 to 100 kW. However since these earlier cost estimates ITDG Peru has identified significant cost-reduction strategies involving civil works, modifications to penstock, transmission and distribution lines, and electromechanical equipment.[27] In Peru, key advantages of small hydro schemes over diesel systems and other renewable energy systems (e.g. PV and wind), is that almost all the equipment is manufactured within the country and civil works, which represent an important system cost component, can be built using local materials and labour.

The 24 plants developed thus far as part of this initiative represent 1.3 MW of installed capacity and provide electricity for about 15,000 people. The project facilitated the creation of small industries such as carpentry and welding shops, and battery-charging businesses. The electricity produced is also used to power education and health facilities, and communication services.

4.3 Greenstar[28]

Greenstar is an international NGO based in the USA that delivers solar power, health, education and environmental programmes to small villages in less industrialised 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

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[26] Project information adapted from Carrasco and Sanchez (2000) and updated in November 2002 by Mr. Teodoro Sanchez, General Manager of ITDG Peru. For more information visit www.itdg.org.pe
[27] For more details see "Small Hydro as an Energy Option for Rural Areas: The ITDG-Peru Office Experience" available at http://www.itdg.org.pe/Programas/energia/enerpub.htm
[28] Information adapted from G8 Renewable Energy Task Force (2001) and www.greenstar.org

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.

4.4 Grameen Shakti, Bangladesh[29]

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).[30] 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.

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[29] Information was adapted from G8 Renewable Energy Task Force (2001) and was updated in November 2002 by M. Mujibur Rahman, General Manager of Grameen Shakti. For more information see http://www.grameen-info.org/grameen/gshakti/programs.html

[30] The Global Environment Facility (GEF) was established in 1991 to fund projects and programs in developing countries aimed at protecting the global environment. The GEF (www.gefweb.org) is the designated financial mechanism for international agreements on biodiversity, climate change, and persistent organic pollutants. The GEF also provides funding to projects that combat desertification and protect international waters and the ozone layer. The GEF implementing agencies are the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

4.5 Nepal Rural Energy Development Programme (REDP)[31]

The Rural Energy Development Programme (REDP) initiative was initiated in Nepal during 1996 with the support of the United Nations Development Programme (UNDP). REDP is based on the larger development plans and perspective of the Government of Nepal, which considers the expansion of sustainable energy systems as an entry point for socio-economic development and poverty alleviation. The REDP envisions renewable rural energy systems as a means to provide energy for reducing drudgery (especially for women), conserving and utilising resources, generating employment, and increasing income. REDP initiatives are focused on enhancing social capital. The implementation of REDP is based on community mobilisation as the basis for planning, implementing, operating and managing rural energy systems. REDP's community mobilisation process is based on six principles focused on local participation: organisation development, skill enhancement, capital formation, technology promotion, women's empowerment, and environmental management. By December 2001, 56 micro-hydro demonstration schemes had already been installed in remote communities of Nepal, representing a total installed capacity of 1,053 kW, and benefiting 9494 rural households. In addition, REDP has helped install 20 peltric-sets[32], 1,167 solar home systems, and 1183 household biogas installations. REDP has also distributed 5847 improved cooking stoves. The programme assumes that energy can be an instrument for poverty eradication in rural areas only when it is specifically directed to satisfy the needs of low-income people. This is in contrast to he "trickle-down" approach to poverty alleviation, in which new energy supply is directed to larger scale, commercial/urban enterprises that directly benefit the owners of capital. As part of the program, training is provided to promote agricultural and home-based businesses such as bakeries, food preparation, agricultural-processing mills, saw mills, photo studies, incense making, and grocery shops. Community members are encouraged to identify the specific skills needed to successfully manage and operate rural energy systems and to initiate income- generating activities. Equity and empowerment of local men and women are addressed through the

[31] Project information adapted from Rana-Deuba (2001) and http://www.redp.org.np/

[32] A peltric-set is a small vertical shaft pelton turbine with a generator co-axially coupled to it. It generates electric power from a small quantity of water, which is dropped from a large height to operate it. For more information see www.panasia.org.sg/nepalnet/crt/peltric.html

establishment of separate male and female community organisations. These community organisations vote to decide what is needed in their villages and collaborate on specific projects with equal numbers of male and female representatives. This system has enabled women members to have their voices heard equally with those of their male counterparts. Each of these community organisations decides on a fixed amount of weekly savings to undertake income-generating activities. The programme's emphasis on gender issues and the inclusion of women provides a model in gender-sensitive energy planning.

4.6 Philippines: Rural Energy Service Enterprises[33]

Shell Renewables Philippines Corporation, Community Power Corporation (CPC), and the Aklan Provincial government initiated a public-private sector collaboration in 1999. Their initiative aims at developing ten Rural Energy Service Companies (RESCOs) in the Philippines. Their efforts concentrate investment in financial and manufactured capital. The first RESCO was installed in the community of Alaminos and provides electricity generated by a PV/LPG (liquefied petroleum gas) hybrid plant to about 100 residential customers (about 85% of all households of Alaminos). The next step in the project is the implementation of a small modular biopower (SMB) system developed by CPC that generates power from waste coconut shells (coconuts are a key local agricultural product). Shell is working with the Alaminos Coconut Development Co-operative to expand and diversify coconut farmers' incomes while assuring a supply of coconut shells to run the SMB system, which in turn provides heat and power to the Co-operative and electricity to the local community. Initial products will include geo-textiles (mats used for soil stabilisation), plant growing media made from coconuts, dried copra, and soap. This process will integrate the village electricity loads (dominated by evening lighting), and productive-use loads during the day.

[33] Project information reproduced from Weingart and Lee (2000). For additional information see http://www.gocpc.com/

4.7 African Rural Energy Enterprise Development (AREED)[34]

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.[35]

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[34] Information adapted from http://www.areed.org/ and UNEP (2003)

[35] For more details see http://www.b-reed.org/ and http://www.uneptie.org/energy/act/re/creed/index.htm

4.8 Renewable Energy for Agriculture, Mexico[36]

The Renewable Energy for Agriculture initiative began in 1999 as a collaborative effort between the GEF, the World Bank (WB), and Mexico's Trust Fund for Shared Risk (FIRCO).[37] This project was the first GEF initiative aimed specifically at reducing greenhouse gas emissions by using renewable energy in the agriculture sector. To stimulate rural renewable-energy markets and to increase confidence among farmers, the project will install 1,020 solar-powered water-pumping systems in 28 states, 50 wind-powered water pumping systems in 11 states, and 24 solar-powered refrigerated milk-storage tanks in eight states. The project focuses in social capital development and is aimed at promoting the use of renewable energy for productive uses such as irrigation and refrigeration by removing existing barriers and by reducing implementation costs (through addressing barriers and by introducing renewable energy equipment among 1/3 of Mexico's 600,000 un-electrified farms within 10 years). The key barriers impeding penetration of renewable energy technologies in Mexico's agricultural sector include:

- Limited awareness among farmers that currently lack electricity services regarding renewable energy technologies
- Farmers' perception of renewable energy technologies as risky, simply because they are novel
- Lack of trained technicians and vendors that can design, install and service renewable energy systems, and that can advise farmers on their proper operation
- Uncertainty regarding the potential market for renewable energy in the agricultural sector and potential applications of renewable energy technologies on farms
- High initial cost of renewable energy systems, relative to conventional alternatives, coupled with deficient rural finance services that prevent farmers from financing their higher initial cost over time

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[36] Project information adapted from http://www.gefonline.org/and from information gathered during a personal interview conducted in Mexico City between the author and Mr. Octavio Montufar, Manager of FIRCO

[37] For a detailed description of the programme (in Spanish only) see http://www.sagarpa.gob.mx/Firco/Energia/Principal-ER.htm

- lack of technical specifications and certification processes for renewable energy equipment

The project supports and compliments ongoing rural development programs of the Mexican Government (which are aimed at providing financial and technical assistance throughout the rural areas of the country). By relying on these existing government arrangements, the project avoids the development of a new infrastructure to reach farmers, thereby reducing project-delivery costs and benefiting from pre-established relationships and contacts in rural areas. The social-development objectives of this initiative are to provide farmers living in isolated areas with a reliable and sustainable electricity supply for productive purposes (using renewable energy where feasible), to increase the productivity and income of farmers by supporting productive investments, and to improve farming practices. The project's executing agency (FIRCO) estimates that between 80,000 – 100,000 farms could directly benefit from using renewable sources to energise their productive activities. The project's key goals are to develop an enabling environment and the local capacity necessary to stimulate Mexican farmers to make the transition towards a new agricultural paradigm that is more sustainable and cost-effective than the currently dominant agricultural model (which is based on the use of fossil fuels).[38]

4.9 Uganda Energy for Rural Transformation Project[39]

The project Energy for Rural Transformation in Uganda is the first initiative submitted under the GEF/World Bank *Global Environment Facility Strategic Partnership for Renewable Energy*. The Strategic Partnership was implemented to expand and increase the effectiveness of the renewable energy activities of the GEF and the WB by shifting efforts from an individual project approach to long-term programmatic activities. The idea is to provide less-industrialised nations with the time and resources required for developing renewable-energy markets and technologies in a comprehensive and

[38] Renewable energy systems (and specifically solar- and wind-powered water pumping systems and solar-powered refrigerated milk storage tanks) are currently more expensive to purchase than conventional systems. However, they can be less costly on a life-cycle basis. For example, Foster et al. (1998) conducted a life cycle cost analysis of 105 PV water pumping systems installed in Mexico and concluded that "PV water pumping systems are highly competitive with conventional water pumping energy sources for array sizes from 2 kW or less when compared on a life cycle cost basis"

sustainable way. The Ugandan project aims at removing market barriers for the development of renewable-energy installations in the private sector. The long-term purpose of the project is to develop Uganda's rural energy and information/communication technologies (ICT) sectors, so that they make a significant contribution to bringing about rural transformation through investment in social capital. The project strategy is to adopt a commercially-oriented approach towards rural electrification, with the government playing the role of a market enabler. The project will support the energy and ICT sectors to (i) improve agro-processing potential by electrifying areas where lack of adequate and reliable electricity is a critical constraint to agricultural production, agro-processing and post-harvest storage, as farmers switch from subsistence to commercial farming; (ii) increase access to market information. This second area of support is based on the notion that timely price information could be quite important for farmers, as could be building business relationships with outsiders. The project will address the following critical barriers that impede renewable energy development in Uganda:

- Very limited renewable-energy resource data
- Inadequate capacity to promote the use of renewable energy and to identify, prepare, and appraise projects
- Inadequate regulatory environment and financing intermediation mechanisms
- High costs and limited product range for PV products

It is expected that the project will displace diesel power sources and result in the installation of about 70 MW of biomass, hydro, and solar sources to satisfy rural development needs and objectives, and increase rural electricity connections from 1% to 10%. Activities will be directed at capacity building, institutional strengthening, and the introduction of 'light regulation' approaches designed to facilitate the growth of environmentally sustainable private-sector mechanisms. The loans provided for the project are divided into three trenches, each linked to the accomplishment of key objectives (i.e. achievement of specific infrastructure changes, finalisation of long term renewable energy plans, and targets for renewable-energy-system installations).

[39] Information adapted from G8 Renewable Energy Task Force (2001) and http://www.gefonline.org

5. 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.

The projects presented here provide an early indication that local conditions and social context should dictate both the final choices of technology and project strategies to satisfy local needs. The importance of these considerations is highlighted by an evaluation of energy projects conducted by Misana (2001, p.20) which lucidly notes that:

"energy needs should be considered within the overall context of community life, and energy policies and projects should be integrated in a holistic way with other improvement efforts relating to health, education, agriculture, and job creation".

This observation indicates that projects should be designed, selected, and implemented so as to avoid, or at the least minimise, unwanted and unexpected detrimental social consequences. For example, if projects aimed at increasing rural productivity are not carefully planned and executed, they can eliminate existing local employment sources and therefore result in significant social dislocation. This observation is especially relevant for those rural areas that have large labour pools and limited job opportunities. Similar caveats also apply to potential detrimental environmental consequences that can be directly related to project implementation. As stated earlier, large-scale RE water pumping projects implemented in environmentally sensitive areas could contribute to increased levels of water scarcity and accelerate depletion of aquifers (already by the end of the past decade at least 40% of the world's population lived in conditions of water scarcity). Similar arguments can be made about topsoil depletion, pollution of water bodies, and many other kinds of environmental degradation that are directly associated with attempts to increase the productivity of conventional agriculture.

The issues of who will benefit from new renewable energy projects (and how?) should also be a priority for project design to ensure that benefits reach all segments of rural society, not just top rural earners. Providing answers to these important questions in relation to the projects summarised in section 4 is a task beyond the scope of this paper but constitutes a valuable consideration of forthcoming project evaluations. Nevertheless project designers, implementers, and proponents should always keep in mind the less publicised lessons provided by the Green Revolution. Although widely regarded as one of the great successes of technological development to increase agricultural production and food resources, the Green Revolution was based on the use of newly-developed grain seeds that required large amounts of chemical fertilisers, herbicides, and irrigation systems which too often only wealthier families could afford (Pearse, 1980; Chambers, 1983; Stewart, 1997).

5.1 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 cost-effectiveness (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.

[40] Furthermore irrigation and drinking water constitute key areas of strategic importance for rural poverty reduction, which can currently be effectively powered with renewable energy sources. Increasing the availability, quality and efficient use of farm water is a major challenge to reduce rural poverty (IFAD, 2001, p.3)

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

Results emerging from the implementation of the case studies summarised in section 4 suggest that new project initiatives are needed to overcome institutional factors that too often prevent the integration and collaboration of the energy and agricultural sectors. International organisations and governments need to acknowledge that the energy sector generally develops rural electrification and renewable energy projects as supply-oriented initiatives that usually lack integration with other rural sectors. Meanwhile, these other sectors tend to develop agricultural and rural development projects that too often consider energy requirements as a 'black box' to be provided by others (Best et al., 2001, p.4). The Ugandan project, summarised in section 4.9, represents a very recent attempt at addressing these issues by implementing an inter-sectoral approach to rural development.

A specific area that requires focused effort is the development of energy policies that encourage new private sector and public-private sector partnerships for the provision of energy services in rural areas.[41] These initiatives must include calculated steps to enable innovative financing options (e.g. through leasing or loans) for entrepreneurs,

[41] A number of comprehensive studies highlight the importance of developing a favourable energy policy environment (e.g. FAO, 2000; Weingart and Lee, 2000; G8 Renewable Energy Task Force, 2001).

households, and communities so high initial capital costs can be converted into manageable operating costs (Reddy, 2002, p.132).

The African, Bangladeshi, Mexican, and Peruvian initiatives, summarised in sections 4.2, 4.4, 4.7, and 4.8, provide illustrations on alternative modalities that offer financing opportunities for rural people that hitherto could not use renewable energy.

Information provided as part of the interviews conducted for this research, analysis of the case studies presented in section 4, and consideration of the barriers mentioned in this section suggest that the use of renewable energy for productive uses can be increased in the following ways:

- By implementing new information initiatives to increase political support and policy development
- By developing local and regional capacity to use and maintain RE systems
- By establishing centres of excellence in R&D and training
- By effecting market transformations, that is, changes in consumer and supplier expectations
- By developing new business models for productive uses of RE systems

These concepts are briefly discussed in the next sections.

5.2 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).[42] The aforementioned issues indicate that new information initiatives are needed to raise awareness among decision-makers and to share existing policy experience more widely.

5.3 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, summarised in section 4.2, 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.

5.4 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).

[42] In addition to the 'urban bias' of energy planning mentioned earlier in this paper, Dubash (2002) notes that in reformed markets, where profitability is a central operating principle, interest in serving poor populations tends to wane. This situation can be specially detrimental to the rural poor, which as Dubash notes, are often costly to serve because they live in remote locations characterised by low population density, poor credit and minimal collateral, and lack of purchasing and political power.

Some of the local partners of the African Rural Energy Enterprise Development (AREED) initiative, summarised in section 4.7, are currently implementing these ideas.[43]

5.5 Effect Market Transformations and Foster New Collaborative Opportunities

The sustainability of renewable energy projects is directly linked to their ability to capture an increasing market share. The use of GEF and other funds as patient capital and collateral funds may help to attract public and private sector investment to develop new business opportunities, and to change risk perception amongst financiers.
For example, funds can be provided as debt or equity at near market conditions but with a significantly higher tolerance for risk and without the concomitant expectation of higher capital returns inherent to venture capital. As section 4.7 summarises, AREED is using seed capital, business training and patient capital so clean energy enterprises can develop to eventually attract private sector capital on their own. This is a relatively new form of investment for international funds, which will be perfected as empirical evidence from existing projects accumulates. This concept may hold strong potential for developing and facilitating new collaborative efforts between the public and private sectors.

5.6 Development of New Business Models for Productive Uses

The recent development of new energy delivery models such as the rural or renewable energy service companies (RESCOs) developed in the Philippines and the renewable energy enterprise development (REED) initiatives under implementation in Africa, Brazil and China show that significant niches for RE exist within rural economies. New context-specific business models for productive uses need to be fostered and encouraged to incorporate accumulated lessons. As part of their comprehensive analysis of renewable energy markets in developing nations Martinot et al. (2002) emphasise that:

- a very limited number of donor programs have effectively assisted rural renewable energy-based enterprises to build a sustainable and viable business;
- rural energy enterprises are confronted with a high-risk, low-margin business with high transaction costs;

[43] For example see www.malifolkecenter.org

- commercial banks and financial intermediaries are key decision makers, who must understand technological options and manage risks; and
- demonstration of a viable business model that as time progresses can generate sustained profits for the enterprise is key to achieving market sustainability

Projects such as the Philippine's Rural Energy Service Enterprises and the African Rural Energy Enterprise Development initiative summarised in sections 4.6 and 4.7 will provide a wealth of information to design new policy initiatives to foster innovation and entrepreneurship.

6.0 Concluding Remarks

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).

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[44] Furthermore, the introduction of large scale, capital-intensive technology, originally designed for industrialised economies, has been a powerful contributor to underemployment in the South (Smillie, 2000)

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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Appendix
List of Experts Interviewed

Dr. Wisdom Ahiataku Togobo
Dr. Togobo works for the Ministry of Energy in Ghana and has significant experience implementing Ghana's PV programme

Carlos Avalos Ortiz
Mr. Ortiz works with the Canadian International Development Agency (CIDA) in Guatemala and is very familiar with renewable energy negotiations, energy legislation, and sustainable development

Anil Cabraal
Mr. Cabraal is a specialist in renewable energy working for the World Bank. He has vast experience with the design and implementation of renewable energy projects in Asia.

Elizabeth Cecelski
Ms. Cecelski is Director for Advocacy & Research of ENERGIA International Network on Gender & Energy. She is an internationally renowned expert on renewable energy and gender issues and author (e.g. Enabling Equitable Access to Rural Electrification: Current Thinking and Major Activities in Energy, Poverty and Gender)

Aldo Fabris
Mr. Fabris currently works as an energy consultant for NRECA in Guatemala. He helped develop the Argentinean Renewable Energy Program with support from the World Bank

Ricardo Gallo
Mr. Gallo works for the Argentinian Energy Department (Secretaría de Energía - Proyecto PERMER)

Dr. Jose Goldemberg
Dr. Goldemberg is a professor at the University of Sao Paulo, Brazil and is an internationally renowned energy expert and author.

Lalith Guneratne
Mr. Guneratne has significant experience with the development of PV initiatives especially in Sri Lanka

Dr. Jorge Huacuz
Dr. Huacuz is Director of the Renewable Energy Department of the Electricity Research Institute of Mexico (Instituto de Investigaciones Electricas). He is an internationally renowned expert on renewable energy and has been working for many years in the implementation of the Mexican Renewable Energy Project

Dr. Francis Lelo
Dr Lelo is a geographer and heads the Environmental School at Egerton University in Kenya. He works in the renewable energy sector and has significant expertise in the areas of community participation and social development.

Carlos Pastor
Mr. Pastor has been involved in the design and implementation of renewable energy projects in Argentina

Dr. Rachel Polestico
Dr. Polestico is a physicist and experienced faculty member of the Searsolin Institute at Xavier University on Mindanao in the Philippines. She works in appropriate technologies and has developed a grassroots, peoples approach to development and does a lot of workshops, training and consulting throughout Asia on participatory approaches to development, technologies and rural livelihoods, gender, and social analysis.

Teodoro Sánchez
Mr. Sanchez is Director of the Energy Programme of ITDG Peru. He has worked in many renewable energy projects for productive uses in rural areas. He has significant expertise on the implementation of rural micro-hydro schemes

David Orosco Zumaran
Mr. Orosco is Director of Electric Service Quality Department of the Peruvian Energy Investment Agency (OSINERG - Organismo Supervisor de Inversión en Energía of Perú)