Small-scale energy systems on a large-scale in developing countries

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Abstract

This paper reviews the barriers to large-scale use of small-scale energy systems. It places the review in the context of the size of the challenge both in terms of the numbers of people who still need access to modern energy carriers and in the levels of finance to provide this access. It concludes that the main problems related to access are not technical but are motivational, financial and institutions. The paper provides examples from around the world as to how these issues have been addressed.

Introduction

There are around 30 million people in the LAC region without access to electricity, of whom 73% are poor, and a significant number still using wood for cooking[2] (United Nations, 2009). Providing these people with modern energy carriers and improved technologies[3] at home, in their communities (for example, schools and clinics) and for their productive activities is a major challenge facing the energy sector. However, capacity also needs to be expanded to meet population growth. Access is more than about having an electricity connection or an LPG cylinder; it is also about the quality and reliability of the service and being able to afford to use it (Legros et al., 2009).

In Latin American and the Caribbean (LAC), there are also social incentives for increasing energy access. A large number of families still use fuelwood which is one of the main indicators of social disparities in the region[4]. Indeed the use of fuelwood in the region, linked to the high oil price, appears to be on the increase including in urban areas. Poor households spend between 5 and 18 per cent of their average monthly income on fuels which can be considerably more than higher income households while at the same time using less energy (United Nations, 2009). Improved availability and access to clean and affordable modern energy carriers, such as LPG and electricity, will help end energy poverty[5] and enable us to reach development goals, such as the Millennium Development Goals (MDGs)[6].

Many of those without access to modern energy carriers live in the rural areas where the characteristics of the terrain, poor roads and the scattered nature of their settlements make grid extension and delivering gas/LPG difficult and expensive. It is estimated that rural grid extension

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[2] In the case of Colombia it is estimated that as of 2008 93.6% of the population had electricity while data for 2005 showed 14.8% of the population was cooking on wood and 0.4% used coal (Legros et al., 2009).

[3] An *energy carrier* is the form in which energy is delivered to a consumer. Modern energy is interpreted here as electricity, natural gas, LPG, and biogas, while 'improved technologies' refers in particular to improved biomass cookstoves.

[4] However, this is sometimes a cultural preference rather than an absence of alternatives.

[5] While there is no universally agreed definition of *energy poverty* it can be conceived as: an absence of sufficient choice in accessing adequate, affordable, reliable, clean, high-quality, safe and benign energy services to support economic and human development. Energy poverty can also be considered a dimension of poverty which is increasingly being recognised as more than monetary deprivation.

[6] For an explanation of the Millennium Development Goals see: http://www.un.org/millenniumgoals

costs from US$ 8,000 to 10,000 per kilometre which makes decentralised systems a more attractive option (Flavin and Hull-Aeck, 2005). These reasons are seen as good incentives for promoting small-scale decentralised systems particularly based on renewables. There are additional economic and environmental reasons for the promotion of renewables. The economic incentive is linked to oil prices in terms of the general trend upwards linked to volatility cause problems for governments and consumers alike[7]. The environmental incentive comes from climate change, linked to fossil fuel use, which has much wider impacts, for example, on food security, access to drinking water, and on health. However, diesel and petrol engines cannot be neglected entirely, particularly in an oil exporting country like Colombia. These engines are a mature technology supported by a distribution system built with large investment over many decades which will not disappear overnight; in part this system is driving the development of biofuels even in oil producing countries like Colombia. However, we should not lose sight of the fact that LAC has very high rates of urbanisation which has been accompanied by a rise in urban poverty, partly caused by rural migration with an influx of people lacking skills for the urban economy, and partly caused by the 2008 global finical crisis creating a pool of unemployed who entered the informal sector. There is an assumption that the urban poor have better access to modern energy carriers than the rural poor. To a certain extent this is correct, particularly in LAC, with relation to electricity but not necessarily to cooking fuels (Clancy et al., 2008). Understanding the specific problems of urban energy poverty and their solutions is not only important in the region but at the global level since the global trend is for increased urbanisation (UN Population Fund, 2007). It is therefore interesting to ask whether or not decentralised energy systems have a role to play in urban areas.

In this paper, we first look briefly at the benefit improved access to modern energy carriers can bring and the way that decentralised small-scale energy systems can contribute. The following section looks at three barriers to up-scaling of these systems to meet universal access. The paper concludes with some policy suggestions for up-scaling decentralised energy systems.

Benefits of improved energy access

Access to clean and affordable energy can bring many benefits to peoples' lives, for example, by reducing drudgery, improving income generation opportunities and creating better health and education services. Clean energy at the household level has additional health benefits through reduced indoor air pollution and when there are sufficient quantities of energy that allow for boiling water the spread of water-borne diseases can be reduced as well as enabling general hygiene improvements. Electricity is particularly valued for lighting (better quality than candles and kerosene as well as a lower fire hazard) and for providing communications and entertainment.
One of the main challenges to providing access to modern energy is the lack of income to pay the high upfront costs. However, energy is an important part in income generation helping to improve productivity and opening up new sources of income, such as mobile phone charging. Hearing market prices on the radio or sourcing on the internet can save wasted trips to market, with their time and financial costs, and open up access to new markets. For example, the Ugandan company 'Fruits of the Nile' upgraded the quality of its products by using solar driers to export standard and was able to identify new clients through the internet (Okalebo and Hankins, 1997). A survey in the Philippines found that 9 per cent of respondents reported "increased income and/or savings" and three percent reported an "increase in job opportunities" as a result of access to electricity (UNDP, 2004).
However, while access to energy is an important component to facilitate economic and social development, energy by itself is not enough and needs other inputs. For poor villages, there is little opportunity to use modern energy to expand services and products, as the market for luxury goods or services is limited, and the market for basic goods is stable. Therefore a growing local economy or the capacity to export outside of the locale is needed to generate income which will improve

[7] Even in oil exporting countries, consumers from all income groups often have to pay high prices for petroleum fuels.

livelihoods and enable consumers to pay for modern energy. Not only does this need good infrastructure, such as roads, but a level of business skills which might not be found in rural areas (Kooijman-van Dijk and Clancy, 2010).

Communities can benefit from the improved services that modern energy can bring. Education benefits when schools are electrified. Not only does the electricity help to retain good quality teachers in rural areas, but there can be improvement in lighting and quality of education, particularly if there is internet access. The school can also become an improved community facility, allowing for evening classes[8] as well as social and political events (Clancy and Kooijman, 2006). Health care centres can ensure standards of hygiene when there is thermal energy and electric lighting is an added advantage for night-time emergencies and delivery rooms. Electricity provides refrigeration for vaccines and medicines, as well as increasing the range of medical equipment available and access to the internet.

Much drudgery for women can be reduced through community services, in particular, grain milling and water pumping (Clancy et al., 2011). Street lighting can produce a feeling of safety.

Meeting those needs with decentralised systems

There are three general categories of energy needs: household, productive and community (hospitals, clinics, schools, community centres, religious institutions, barracks, and prisons). Each category uses (or would like to use) process heat, motive power (usually for transport) and electricity. These can all be provided by decentralised systems. There is a tendency to focus on electricity (solar home systems and micro-hydro dominating), and little attention given to mechanical systems such as wind pumps and standalone engines (Bates et al., 2009). Possibly in the development literature the most well-known use of a standalone engine is in the programme which started in Mali, known as the multifunctional platform (MFP) which has now expanded to serve five per cent of the rural population and has since been disseminated to several other countries in sub-Saharan Africa (see Box 1).

The focus on electricity takes away attention from cooking which continues to be the most significant household energy demand in both rural and urban households. Solar home systems cannot be used for cooking since their output is too low. However, their strength lies in the provision of good quality light and home entertainment. On the other hand, cooks who use biogas respond enthusiastically to its controllability and cleanliness. However, the cost of a digester and the number of animals required to produce sufficient gas for the household's daily cooking needs as well as the collection of the water needed as an input adds considerably to women's burden have been cited as reasons for poor uptake of the technology (Clancy et al., 2006).

Box 1: The Mali Multifunctional Platform

The platform consists of a small diesel engine mounted on a chassis, to which a variety of end use equipment can be attached, including grinding mills, battery chargers, vegetable or nut presses, welding machines etc. It can also support a mini grid for lighting and electric pumps for a small water distribution network or irrigation system. The original goal of the project which stared in 1997 was to install 450 such platforms. Through these platforms it was expected that approximately 8,000 women in rural areas will have access to better opportunities for improved micro-enterprises. A survey in 2005 found that the women were on average making US$44 per year of additional income (which at the time of the survey was equivalent to the mean income of those considered to be poor). Source: (Burn and Coche, 2001); (Bates et al., 2009)

[8] While this is a frequent assertion in documents related to energy and development there is very little empirical evidence to show that these classes materialise (Clancy et al., 2011).

In the introduction to this paper the point was made that there is an increase in urbanisation and whether or not decentralised systems could contribute to meeting household energy needs. Standalone generators are a familiar part of the urban landscape as a reaction to uncertainty about electricity by entrepreneurs for electricity or mechanical power generation (ITDG, 1998). These generators can also be used for informal mini-grids (Schutyser, 2003). The renewable energy options which could meet those needs in urban areas are biomass and solar. Passive solar could be used in building design, while solar energy could be used for water heating and solar home systems could meet some electricity needs but not all including a very important end-use for poor people: clean, ironed clothes. Solar energy can also be used for cooking but not so easily for process heat in commercial applications where output size is a constraint. The urban poor continue to use wood fuels for cooking and space heating. Here the major challenge is to ensure that these fuels are produced on a sustainable basis as well as improving conversion efficiency and cleanliness of household and commercial equipment for cost and health improvements. The main advantage of solid fuels biomass cooking over solar cooking is that it does not require a change in cooking practice, in particular moving the stove outside with the need for constant supervision against theft[9]. For food processing enterprises, solar cookers do not come in sizes capable of dealing with larger quantities of food.

There are practical considerations that make decentralised RE systems less attractive in urban areas. For example, lack of space surrounding dwellings can mean no room for installing a household biogas digester or shading from surrounding buildings makes solar water heaters or PV panels inoperable. On the other hand residents in high rise buildings complain of reflections from PV panels installed on top of lower level buildings.

What are the barriers to up-scaling access to decentralised small-scale energy systems?

The approach since the 1980s to increasing access to decentralised energy systems has primarily been through piecemeal projects with the probable exception of LPG which has used the market as the dissemination mechanism. While any level of improved access is to be welcomed, particularly by the beneficiaries, the numbers of people reached by projects are usually relatively small (a few hundred per project) and the imperative is to increase the scale significantly with better coordination of effort if we are to reach the millions still in need.

One of the difficulties for energy engineers is trying to understand why there is such limited use of our favourite piece of technology which can solve all the problems of energy access. While there are many interesting scientific and engineering problems to be solved related to renewable energy and energy efficiency, for example systems control in decentralised grids, the technical issues are probably not the main reason for lack of uptake. Indeed, there are three issues related to up-scaling access which are probably more influential, which will be discussed in this section: motivation, finance and institutions.

Motivational issues

Understanding the motivations for adopting a new energy carrier and its associated technology are important since it provides an indicator of the appropriate mechanisms that need to be introduced to stimulate energy end-users to make the change. Availability of dependable supplies of modern energy carriers in sufficient quantities at affordable prices would seem obvious barriers. Availability of LPG cylinders has acted as a barrier (Hosier and Kipondya, 1993) as has the initial purchase cost of

[9] This is also an issue for rural households as well as objections to cooking in the heat of the mid-day sun.

the cylinder and stove have hindered the switch to LPG (von Molthe et al., 2004), while refill costs can lead to the abandonment of LPG. Having to buy new equipment for the new energy carrier is an important barrier to switching, for example, the need to buy a different set of cooking utensils when switching from charcoal to solar cookers (Leach and Mearns 1998).

The switch to electricity is hindered by high initial connection charges, the high cost of wiring and high standing charges. The consequence can be getting a connection illegally or through a third party, often a "slum landlord or lady" who has a legal connection and charges exorbitant rates to tenants for their supply (Annecke and Endelli, 2006). Illegal connections appear to have grown in urban areas in LAC as the size of the poor urban population has increased (United Nations, 2009). Illegal connections are a problem for both utilities and households. For the utilities, illegal connections mean unpredictable loads, damage to the infrastructure and a loss of revenue. For example, in Bahia State, Brazil, it was estimated that, at the beginning of this century, around 11% of the electricity distributed was diverted to illegal connections (Andrade, 2004). For the consumer, illegal connections are unreliable and dangerous with connections being made without the usual safety mechanisms.

A simple economic model for households and small enterprises would assume that energy carriers are economic goods. Modern energy carriers (electricity and gas) can be seen as superior goods and traditional energy carriers (such as wood and charcoal) can be seen as inferior goods. If this is the case then it can be expected that as a household's income increases, it will switch from relying on traditional fuels to modern fuels. By extension, higher-income households will make greater use of modern fuels than low-income households do. However, such a model may be too simplistic, indeed high-income households do not completely abandon traditional fuels (Leach and Mearns 1998). Although much of the debate about the up-take of RETs centres on cost there are also non-financial factors which influence switching between energy carriers.

The nature of a stove can be a deterrent to switching energy carrier. In Mexico, the LPG stoves are not suitable for cooking tortillas in the quantities required for a family meal (the available LPG stoves cook two tortillas at a time compared to the traditional stove which cooks eight). The taste of food is not the same when cooked on LGP (Masera et al., 2000). The heat output of electric cookers is difficult to regulate and it takes time to learn the skill (Clancy et al., 2008).

Households have to make choices about expenditures. Poor people prefer to purchase fuels in patterns that match their incomes: small amounts on a daily basis. This purchasing pattern influences the types of fuel they use. Wood, charcoal and kerosene can be bought in small amounts on a daily basis. While many economists tend to see households as a homogeneous entity making rational choices based only on price, social scientists using gender analysis consider this not to be the case. In households where there are adult men and women, the gendered division of roles and responsibilities generally allocates to women the responsibility for energy provision related to their spheres of influence in the household, in particular activities centred on the kitchen. However, when energy has to be purchased, men enter the decision-making process, for example men although not usually responsible of cooking will often decide on the stove technology if it is to be purchased (Tucker, 1999). So it is men as well as women who must be motivated for switching energy carriers.

Most poor households have little capital to help them acquire energy conversion technologies and associated labour saving equipment, or to get grid connection or an LGP cylinder. For women, there are additional problems of access to capital not faced by men. Families are often the source of the type of capital needed for business ventures. There may be cultural barriers which deny women access to this source of family funds. Banks and lending institutions have conditions for lending, such as collateral and credit history requirements that exclude poorer borrowers. These requirements generally have a greater impact on women, who may face legal restrictions making it difficult for

them to own land or other assets, or to take action without their husbands' consent. They may also be discouraged from borrowing or engaging in business by social and cultural barriers limiting women's activities and mobility. Illiteracy, which is more prevalent for women than men due to less access to schooling can make formal loans virtually impossible. Even though it has been well documented that women have a better record of credit repayment than men, women still receive a disproportionately small share of credit from formal banking institutions. In Latin America and the Caribbean, women constitute only 7-11% of the beneficiaries of credit programs (UNDP, 1995).

Utilities are often reluctant to provide a service where there are doubts about the legal tenure of property and where the dwelling is not considered to be a permanent construction. Many low-income households fall into one or both of these categories. People on low-incomes will be less prepared to invest in their dwellings to bring them up to standard if they have no long term commitment to their houses and enterprises. The poor construction of many informal settlements makes them prone to the theft of possessions, including items such as LPG cylinders and solar cookers.

A pilot project in South Africa which tried to promote solar water heaters in low-income households found that high initial costs and lack of awareness about the technology and its benefits were significant barriers to up-take of the heaters (ITDG, 1998). In households with constrained budgets hot water may not be a priority [Nthabiseng Mohlakoana, unpublished research]. The insubstantial nature of informal sector housing, as mentioned above, is also problematic in terms of whether or not the structure is strong enough to support solar technologies. Also the lack of security of tenure of informal sector housing makes people reluctant to invest in equipment that cannot be easily moved to another location.

In conclusion we can say that there is no simple switch from one energy carrier to another to meet a certain need based on cost alone. At the household level more complex factors than a simple model of adopting clean efficient energy sources enabled by higher incomes are at play in what motivates the energy transition in households. Households retain the capacity to use a mixture of energy carriers for different needs and switch between carriers as circumstances dictate. Management decisions are made balancing preferences and habits with flexibility (influenced by access and availability) and time constraints. So it is not enough to focus on cost alone.

Financial issues

Projects are often financed with grants but to ensure universal access requires much larger levels of finance. It has been estimated that the level of investment in Latin America to enable universal access to electricity by 2030 is around US$ 15 billion[10] and for clean cooking fuels is US$ 4 billion[11] (OECD/IEA, 2010). It is primarily rural households that lack access to electricity although some urban poor households also find it difficult to get a legal connection[12].

Financial issues are found at two levels: at the macro-level for investment and at the micro-level for consumer access.

At the macro-level the financing mechanisms will depend on the characteristics of the energy system. Large-scale grid electricity requires different levels of financing to small-scale decentralised systems, which are different again for clean cooking options. However, improved access is not only through installing more capacity but also by improved energy efficiency which generally has much lower costs per kW. Renewable technologies often have higher costs than conventional energy technologies

[10] Based on a mixture of grid and decentralised systems.
[11] The options are improved biomass cook stoves, LPG stoves and biogas systems.
[12] Colombia has a good record compared to a number of other South American Countries in this respect: as of 2008, 99.6% of urban households and 76% of rural households had an electricity connection (Legros et al., 2009).

related to higher capital costs (unless a full life-cycle analysis is done), higher transaction costs and imported technology (Cosbey et al., 2008). The dispersed nature of RETs means many more sites, planning permission, and negotiations.

Although strictly speaking a good financial framework is part of institutional issues, it is mentioned in this section as part of the encouragement needed for investment in energy generating capacity and service delivery. It can also help to open up sources of finance. For example, poorly functioning banking systems may not tap into local savings, which may also move abroad when there is no faith in the local financial system (Kok et al., 2004).

A variety of funds will need to be used, including government revenue, banks, bilateral (eg GIZ[13]) and multilateral agencies, such as the World Bank, and specific funds for energy[14]. It has been suggested that in oil exporting countries, governments could finance access to LPG stoves and cylinders as well as electricity connections for low-income households by tapping into only a small fraction of the revenue they earn from these export (OECD/IEA, 2010). Indeed Colombia provides an interesting example, where the government has addressed issues of energy access by the poorest strata with cross subsidies and the natural gas expansion plan which has allowed access for around 2 million consumers from the two lowest income strata (United Nations, 2009). Carbon finance, linked to measures to address climate change, opens up new revenue sources to pay for investment in renewable energy technologies and energy efficiency improvements. Private sector energy companies can also be used as a source of funds, as has happened with the UNDP LPG Rural Energy Challenge[15]. However, foreign direct investment generally goes towards large-scale projects. There is a reluctance to invest in small-scale decentralised systems, partly due to past experience with project sustainability and poor returns (Cosbey et al., 2008).

At the micro-level ability to pay is a key barrier in access to energy services and to ensure people retain access. The access barrier is easier to overcome when the technology is linked to productive uses. Low-income households do have cash that they use for buying energy carriers, for example, batteries and kerosene, often at very high cost per kWh. However, these energy carriers are sold in small quantities which match the case flow in these households. The initial upfront costs of modern energy carriers are much higher so to enable access households, farmers and small businesses need credit at reasonable terms. Particular attention needs to be given to women since they face additional problems to accessing finance (see above). The availability of micro-finance for access to renewable energy equipment and energy efficiency improvements requires that the lending institutions are familiar with the technology otherwise they may not be willing to take the risk. A survey in Ethiopia of micro finance institutes (MFIs), who were expected to finance household biogas systems by the NGO promoting the system, found that the majority of the institutions surveyed were not aware of biogas technology and its benefits, hence they were not prepared to risk loans for such systems (Woldearegay, 2010).

Much has been written about the need for micro-financing and credit schemes, especially for women and there exist many innovative schemes. There is also some concern that the levels of micro-finance are not sufficient to pay for renewable energy technologies such as solar home systems. Loans are generally in the range of US$50 to US$ 500 for short periods (up to 1 year) (Cosbey et al., 2008). Women are often the target of such schemes and projects aimed at enabling women's access to technologies can still go wrong if they do not also take into account the reality of women's lives. A project in Uganda which set out to encourage women entrepreneurs to purchase solar systems by offering credit through a women's bank failed to reach the target group because interest rates were

[13] The German Government has provided €3.5 million for wind energy programmes in Colombia.

[14] For example, the Global Environmental Facility's Small Grants Programme has provided since 1996, US$18 million for more than 800 community-based energy projects for a variety of end-uses using a variety of energy sources.

[15] www.undp.org/energy/lpg.htm

set well above levels women could meet, repayment schedules were too short and collateral requirements did not match women's resources (Sengendo, 2001). An example of best practice in micro-credit is the ENSIGN project (see Box 2) of the Asia/Pacific Development Centre and UNDP, which combines micro-credit loans for energy services and for corresponding income-generating activities for the poor, including women. The services are co-financed by a revolving fund and national financing institutions.

Box 2: Financing Energy Services and Income-Generating Opportunities for the Poor (ENSIGN)
The ENSIGN project was implemented in eight countries in Asia in a UNDP-financed project by the Asia-Pacific Development Centre. Energy-linked microenterprise portfolios were developed through microcredit banks and institutions in each country. In urban areas, connecting to the grid and more efficient appliances were most important. In rural areas, however, renewable energy, coal briquettes, and diesel fuels were preferred. In both rural and urban contexts, process heat and motive power were more crucial to income-generation than lighting. The ENSIGN Revolving Fund offered 36 per cent of total loan funds, national financing institutions 50 per cent, and borrowers' equity 14 per cent. Interest rates were 15 to20 per cent, somewhat below market rates, with repayment periods of 2–6 years. Both individuals and communities were financed, with average increase in income of 124 per cent (higher for the community projects).
Source: (Ramani, 2002)

Subsidies as a mechanism for enabling access are not the 'poison chalice' they were a few years ago. There has been increasing realisation that access to modern energy for low-income consumers is unlikely to take place in many instances without some form of subsidy. The subsidies need to be target at the specific group and not blanket subsidies which benefit those who can afford to pay the full cost. Subsidies are considered most effective when applied to up-front costs rather than on operating costs, in this case fuels or electricity (The World Bank, 2004).

To ensure people stay connected requires payment systems that match household income levels and patterns of cash flow. In Bolivia, default rates on loans were reducing by using a model that allows loan payments to be rescheduled to match agricultural production cycles (WIlson and Garside, 2011).

In any sort of community scheme, the issue of financing operating costs has to be addressed. Communities can be left to operate a scheme that has been imposed from outside. The result can be a failure to apply cost effective tariffs or to collect revenue, particularly in small communities where there are strong kinship relations, which does not allow for the accumulation of reserves to pay for maintenance and replacement costs. Support is needed to build institutions that have a sense of ownership and responsibility for operation, maintenance and finance. These institutional issues are discussed in the next section.

Institutional issues

There are barriers not only at the household/enterprise level (micro-), but also at the meso- (institutional) and macro- (policy) levels. At the macro- and meso-levels, legislation and the attitude of energy utilities also play a role in access. In rural areas, who is trained to maintain and manage the systems can be a key to success.

How to develop a successful business model is just as important as getting the technology right. We need to look at the whole system not only the hardware aspects: delivery system (stand-alone, mini-grid, grid), purchase, ownership, management, financing models. A range of actors from the public and private sectors, communities and civil society, can provide energy derived from renewable sources or energy efficiency advisory services. The private sector can be encouraged to invest in

energy delivery. In Argentina, the private sector is offered 15 year concessions to supply off-grid electricity using renewable energy while Mexico allows private generation for own consumption by municipalities and industry as well as letting the private sector sell to the grid (The World Bank, 2004). Good governance of the energy sector is essential to ensure that energy supplies are sustainable. Transparency in licences for energy suppliers and ensuring that regulations and standards are not only in place but are enforced helps build consumer confidence and gain political support.

Utilities are often reluctant to provide a service where there are doubts about the legal tenure of property and where the dwelling is not considered to be a permanent construction. Many low-income urban households fall into one or both of these categories (Clancy, 2006). Often energy service providers have a poor perception of low-income consumers. When it comes to supplying electricity to poor districts, people in poor urban areas are seen as a problem rather than as (potential) customers. There appears to be a reluctance to engage with low-income end-users to work towards solutions.

The main dissemination mechanism to date for RETs has been through projects which have been aimed usually at rural areas. Projects are the main mechanism because the market is not generally well developed both in terms of energy sector service companies (ESCOs) to supply technologies and in the rural population's capacity to pay. This may in part explain why wealthy households have not taken up small scale renewable energy technologies in any significant numbers. (See for example, South Africa where there is a suitable market in terms of the number of wealthy households using electric water heater and sunshine levels are appropriate for solar water heaters, yet the switch solar water heating has been insignificant (Sowazi, 2005).

LPG providers appear to have a different client orientated service approach to the electricity utilities. The sector appears to be responding to consumer demand, for example, supplying different sizes of cylinder which affects the replacement cost. Orders can easily be placed by telephone with deliver cylinders by truck. In Kenya, rural areas have good availability of LPG through the use of petrol stations acting as selling points.

Informal ESCOs exist in low income urban areas to fill a market gap that the main suppliers leave. The informal sector on the one hand is prepared to go to inaccessible areas (for example where roads are made of soft sand or communities living on steep slopes) on the other hand, since they are unregulated, improper business practices can creep in. There are reports of informal kerosene distributors in Lima putting a false bottom in the kerosene tins which they sell at what appears to be a lower price per litre (Wakelin et al., 2003) and in the Philippines dealers have put false bottoms in LPG cylinders (Clancy et al., 2008). Urban poor households which purchase LPG from petrol stations or private dealers can pay a high price. In many cases, a cylinder passes through up to three levels of middle men before it gets to the end-user, at each level there is a mark-up (Clancy et al., 2008).

The informal sector has created a niche market supplying low-income settlements with energy carriers. However, if the entrepreneurs who run these mini-ESCOs are to take part in up-scaling access to modern energy they are unlikely to have the capital to build a stock of RET equipment since they often buy from suppliers on an "as needs" basis. Large conventional commercial banks would also not probably not be willing lend them the capital since they are new entrants into the market without financial track records or creditworthiness (Cosbey et al., 2008). Larger ESCOs therefore need to develop innovative ways of working with the entrepreneurs from mini-ESCOs to act as their agents for. In the informal sector gender issues are never far removed. Women face additional resource constraints to men, in particular skills and access to finance. They may therefore need additional support to establish ESCOs (Clancy et al., 2006).

It is not always the energy ministry who will be responsible for up-scaling, for example the health ministry would be responsible for energising rural clinics. These other sectors also have to understand what the options are and be prepared to finance them. This implies a need for cross ministry coordination.

To ensure sustainability decentralised energy systems also require more decentralised planning approaches involving local actors. However, energy ministries, unlike other sectors, are rarely represented at the local level[16] which can mean that local administrative authorities become involved in planning and implementing energy schemes probably in connection with other sector interventions such as agriculture, water and health. They are often ill equipped for the job (Nankya, 2009) and their capacity needs to be developed. There are examples of best practice in rural energy programmes in Bangladesh, Nepal and Mali and in urban energy programmes in South Africa (see Box 3 where decentralised planning has been successfully developed and local actors engaged in the process). However, these programmes seem to be the exception rather than the rule (Havet et al., 2009). There needs to be clear demarcation of authority and remit, particularly financial responsibility, between the national and district levels.

Box 3: Local government working with communities
Cape Town City Council in partnership with the non-profit developmental organisation, *SouthSouthNorth*, has over a three year period developed the Kuyasa Low Income Urban Housing Energy Upgrade Project. This involves retrofitting 2300 low income houses with energy efficient lighting, insulated ceilings and solar water heaters. The project provides numerous additional sustainable development benefits such as improved health, access to energy services, and employment creation. Savings of up to 40% on electricity bills are reported due to the reduced need for artificial heating and cooling.
Source: http://www.reeep.org/

Consultation with end-users is an important step in identifying the types of energy services needed. This can be seen as an advantage of decentralisation: it brings the demand side more into focus rather than the supply side which has the attention at the macro-level. Here it is important to ensure that men and women are consulted since they have different energy needs which influence their priorities. If communities are expected to be involved in service delivery, then they need to be involved in the entire decision making process. Box 4 gives an example of an approach to community management of a decentralised small-scale energy system.

Box 4: Thima Community Pico-Hydropower Project.
Thima is a small village in Kenya where 165 villagers have formed an association named the Thima Community Pico-Hydropower. They own a 2.2-kW hydropower plant which is currently supplying power for lighting to 165 households in the village. The villagers formed a Community Electricity Association (CEA) which elected a committee of 10 members. They were provided with training and technical support by a national NGO with many years of experience in decentralised energy projects. Consumers provided labour, purchased building materials and financed the cost of establishing a local mini-grid, the cost of house-wiring and the cost of purchasing energy-saving bulbs. A connection fee was established for the consumers. The CEA obtained necessary licenses, including the special permit from the Ministry of Energy and set up a bank account to save contributions made towards project costs. The money contributed by the community was matched by the grants provided through the NGO.
Source: (UNDP, 2006)

[16] This author knows of only one country where there is representation of the Ministry of Energy at district level: Mozambique.

There need to be sufficient number of technicians trained who are familiar with RETs. This can partly achieved by the development of local energy service companies which can include manufacturing and assembly of equipment, with the added boost of increasing employment. However, when it is communities which have responsibility for maintenance, who within the community is trained to do maintenance can be an issue in sustainability. When men gain technical skills, they have a tendency to migrate to town. On the one hand this can have financial benefits to the household if they send remittances back to the village; on the other hand it can leave the community with an energy system in need of repair. There is a strong case for training women in energy technology maintenance to have a greater chance of the skills remaining in the community.

Consumers need to be better informed about the choices available to them. TV and radio can be affective here but of course require an electricity source! Another alternative is the concept of an 'energy shop' where consumers can get advice and possibly see equipment.

Conclusions

The state must now re-engage with the energy sector by ensuring an enabling framework, such as promoting equipment standards and protection for consumers from private sector excesses. Well-defined policies which set targets for renewables and energy efficiency are a starting point. Targets for RETs as part of the supply mix are considered to have played a significant role in developing RETs markets in a number of both industrialised and developing (eg Thailand) countries (Cosbey et al., 2008)[17]. Other instruments that have proved useful in promoting a transition to the use of modern energy include:

- Establishment of an effective and reliable supply system
- Adoption of technology appropriate to local needs
- Introduction and enforcement of standards and regulations (particularly for the environment)
- Adoption of appropriate pricing and taxation policies
- Provision of attractive incentives for ESCOs and consumers (including low-interest loans that take into account women's additional problems of access to loans)
- Mounting effective information and awareness-raising campaigns

There is evidence to suggest that opening up the electricity generation market for independent power producers has been particularly beneficial not only in terms of increased generation but also for renewable energy, including for small-scale micro-hydro (Cosbey et al., 2008).

There needs to be better coordination between sectors if renewables and energy efficiency are to be implemented in a meaningful way, particularly for addressing energy poverty. This requires an adoption of integrated planning which includes interacting with stakeholders, such as household and business consumers and energy companies, to better understand their needs and capacities. Such approaches help create ownership of energy projects which is considered a condition for sustainability (The World Bank, 2004). Governments need to have much better energy data to provide better energy planning. There is very little demand-side data, particularly gender disaggregated data, which shows what people need and the reasons that they cannot access modern energy and its associated energy efficiency technologies[18].

[17] Colombia already has a blending mandate for biofuels.

[18] For example, more than half of the 140 countries surveyed by UNDP had no data on the number of improved cookstoves in use (including Colombia) – this is despite the undisputed positive health effects to be gained from this energy efficiency technology (Legros et al., 2009).

Box 5: Utilities working with communities
In Salvador, NE Brazil, the utility (COELBA) ran energy conservation campaigns for low-income households in 2001. The utility sent conservation teams to households to look for energy conservation opportunities. In most cases, households had very old refrigerators with old rubber seals around their doors that no longer were able to properly seal the doors. The company helped many customers replace these seals thereby benefiting the consumers with lower bills and helping the utility avoid investment in new generating plant.
Source: (Winrock International, 2005)

Institutional issues need to be addressed particularly related to a total reliance on market mechanisms which have been found not to address issues of energy poverty. This requires governments to develop policies which commit to enabling access to modern energy carriers for the poor. This can include specific policies which target the poor for example, by guaranteeing a basic amount of electricity, for example, sufficient for basic lighting and communication as in Argentina (World Energy Council, 2009). There needs to be more attention to cooking energy to support the transition to cleaner cooking fuels and improved (smokeless) stoves as well ensuring the sustainable supply of wood.

A reflection from the author

Perhaps the most difficult lesson for engineers is to recognise that 'their' energy technology is not the universal answer to all problems but that it increases the menu of options for solving a specific problem in a particular context. One of the first lessons I learned when I started working on renewable energy came from a Colombian who had worked for many years with rural communities on appropriate technology projects was: *be reality lead not technology driven*. This has been one of my guiding principles now for 30 years and I believe it has been a great help in my not experiencing too much frustration about the limited use of renewable energy technology and implementation of energy efficiency measures.

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