Delivery Models for Decentralised Rural Electrification

Case studies in Nepal, Peru and Kenya

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This publication is based on the author's doctoral work that was conducted at the University of Cambridge (Centre for Sustainable Development, Department of Engineering) between 2008 and 2011.

Access to Energy series
Series Editor Emma Wilson

First published by International Institute for Environment and Development (UK) in 2012

ISBN: 978-1-84369-868-5

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www.iied.org/pubs

A catalogue record for this book is available from the British Library

Citation: Yadoo, A. 2012. Delivery models for decentralised rural electrification: case studies in Nepal, Peru and Kenya. International Institute for Environment and Development, London.

Designed by
SteersMcGillanEves 01225 465546
Printed by
Calverts Cooperative www.calverts.coop

This report is printed on FSC certified paper using biodegradable inks

MIX
Paper from responsible sources
FSC® C007915

Edited by Tom Hickman

All photography: Annabel Yadoo
Cover photo: The hydro plant at Thiba

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List of abbreviations

ADINELSA – Administrative Company for Electrical Infrastructure. Created in December 1994 by the Peruvian government, ADINELSA is responsible for the operation and maintenance of non-profitable electrification projects (normally in rural areas) that are implemented by the government.

AEPC – Alternative Energy Promotion Centre. Government institution that oversees local and international donor off-grid electrification programmes in Nepal. The AEPC also coordinates research and development, sets and administers the renewable rural energy subsidy policy and supervises the Rural Energy Fund.

AGECC – Advisory Group on Energy and Climate Change. Advisory Group to the United Nations Secretary-General.

CBO – Community-based organisation.

EILHICHA – Chacas Local Interest Hydroelectric Company. Electricity Company in Peru established by Don Bosco, an Italian missionary organisation.

ESAP – Energy Sector Assistance Programme. Danish, Norwegian and Nepali government energy programme in Nepal.

ESMAP – Energy Sector Management Assistance Programme. Administered by the World Bank.

GDP – Gross Domestic Product.

GIZ – *Deutsche Gesellschaft für Internationale Zusammenarbeit*, German Development Agency.

HDI – Human Development Index. United Nations endorsed assessment of life expectancy at birth, gross national income per capita, mean and expected years of schooling.

IEA – International Energy Agency. Intergovernmental organisation established by the Organisation for Economic Co-operation and Development.

KPLC – Kenya Power and Lighting Company.

MEM – Peruvian Ministry for Energy and Mines.

MFI – Micro-financing institution. Institution that provides finance to low income clients.

NACEUN – National Association of Community Electricity Users in Nepal. Support network for community-based organisations involved in extending the national grid in Nepal.

NEA – Nepal Electricity Authority.

NGO – Non-governmental organisation.

OSINERGMIN – *Organismo Superior de Inversión en Energía y Minería*. Government regulatory body responsible for energy and mining in Peru.

PV – Photovoltaic.

REA – Kenyan Rural Electrification Authority.

REDP – Rural Energy Development Programme. United Nations Development Programme, World Bank and Nepali government energy programme in Nepal.

SEF – Solar Energy Foundation. Non-governmental organisation working in Ethiopia. Also known as *Stiftung Solarenergie*.

SHS – Solar Home System.

T&D –Transmission and distribution.

UNIDO – United Nations Industrial Development Organisation.

Executive summary

Access to affordable, reliable and clean energy is fundamental for poverty reduction and sustainable development; without it, the Millennium Development Goals cannot be achieved. Electrification, along with access to modern cooking fuels and mechanical power, is a catalyst for improvements in the fields of poverty reduction, food security, health, education and gender equality. Nevertheless, 1.3 billion people still lack access to electricity, over 95 per cent living in sub-Saharan Africa or developing Asia and 84 per cent of them living in rural areas.

There are many different ways to electrify rural areas, not only with regard to the different technologies used, but also to the types of delivery models applied. Common rural electrification technologies include grid extension, community mini-grids, stand-alone household systems, multifunctional platforms, and central charging stations with battery banks. This report will focus on the delivery models used for community mini-grids, as there is evidence to show that mini-grids can be one of the cheaper forms of electrification (on a per unit basis, calculated over the system's lifetime) and also potentially offer a 24 hour AC service that can power a wide range of appliances.

The purpose of this report is to analyse the impact of delivery models on the creation of sustainable welfare benefits. Three case studies are selected, one renewable energy mini-grid project or programme from each of Nepal, Peru and Kenya. Although rural electrification poses a great challenge to all three countries (only 32 per cent of rural Nepalese, 23 per cent of rural Peruvians and 10 per cent of rural Kenyans have access to electricity in their homes), their different physical, institutional, economic and socio-cultural contexts have led to different approaches to rural electrification. These approaches, alongside some of the countries' major electrification challenges, are described in **Chapter 2**. The case studies are compared and analysed in terms of their ability to generate sustainable welfare benefits for their intended beneficiaries (**Chapter 3**). A series of 43 Sustainability Indicators (based on five dimensions of Sustainability – Economic, Technical, Social, Environmental and Institutional Sustainability) – are designed and used to assess the projects' impact and their likely sustainability. The key findings from the case study analysis are as follows:

- A holistic approach to sustainability – that is, consideration of its technical, economic, social, environmental and institutional dimensions – should be adopted in the project planning and implementation stages in order to create sustainable welfare benefits. Neglect of one or more dimension will detract not only from sustainability, but also development impact and resilience.
- The broader a project's remit (for example, not only focusing on electricity access but also introducing toilet assisted biogas, raising awareness on environmental issues and improving the local gender balance), the greater its potential to improve a community's overall development.
- Project management can be made more efficient, transparent and effective when it is clearly separated from ownership and a formal

system of checks and balances is established. Effective management can also improve resilience to internal and external shocks and stresses.

- Wherever possible, practitioners should aim to future-proof systems by including demand growth margins in the original project design. Project resilience can be enhanced if detailed risk analyses are conducted and contingency plans agreed by all the key stakeholders *a priori*.

The second stage of the analysis focuses on examining which elements of a project's delivery model are particularly important for the creation of sustainable welfare benefits. Delivery models generally comprise several variables. For the purpose of this research, these have been subdivided into the intervention's technology choice, implementation process and surrounding support infrastructure (its enabling environment) and include the following elements: the assessment of community needs, desires and availability of local resources; management models; productive end uses; the implementing agency's approach; ownership and governance; local skills and training; local job creation; financing; dissemination strategies; and the project's interaction with hardware suppliers and the various financing, regulatory, legal and political institutions and policies that form its enabling environment. The findings, presented in **Chapter 4**, are based on analysis of the data generated by the three main and several less in-depth satellite case studies, 67 expert interviews and a literature review.

Three cross-cutting themes are identified as having a particularly strong influence over the creation of sustainable welfare benefits: responsibility, impetus and scope. Different elements of a project's delivery model feed into each of the themes and their boundaries are not entirely discrete. Their key features are summarised thus:

Responsibility: The extent to which a sense of duty for the off-grid electricity system among users, managers and local support staff (such as implementing agencies, governments, manufacturers or financiers) has been created. Responsibility is arguably the most important factor that will influence the likely sustainability of a project or programme.

- Ownership is only important to the extent that it encourages key stakeholders to take responsibility for the effective management of the electricity system. As the perception of ownership can increase responsibility, it can be more relevant than legal ownership.
- Financial contributions, 'sweat equity', project showcasing and local participation in planning and decision-making can create a sense of ownership and responsibility for users. Responsibility in management can be instilled through rigorous training, selection tests, ongoing monitoring and community mobilisation.
- A community mobiliser can provide guidance and external objectivity.
- More formalised management, a wider group of owner-stakeholders and a clear auditing process can improve transparency and accountability to users and financiers.

Impetus: The need for incentives that will encourage users, managers and investors to provide ongoing support for the electricity system, as well as to scale-up and replicate the project's activities.

- It may not be necessary for users to have initiated the electrification process, or shown particularly proactive leadership in the first instance, provided that their interest and desire for the project can be aroused through facilitation (for example, by a community mobiliser).
- The interest of users is only likely to be sustained if the system meets their needs and desires, and generates additional welfare benefits, income and, wherever possible, employment for the local community. Therefore, the development of productive

uses could play a significant role, as could community mobilisation processes that encompass training and support across different development areas. Where there is local impetus for a project or programme, users may independently attempt to scale-up activities or replicate them elsewhere (or encourage other communities to do so following demonstration).

- A system's managers and operators should be paid an appropriate wage for their services in order to maintain their drive and motivation.
- Impetus from local authorities such as district governments can be better sustained across successive changes in administration if the project has adopted a non-partisan approach.
- External investors and entrepreneurs will usually require a degree of financial impetus before they are willing to invest in a rural electricity system. Therefore, sustainable business models should be sought to incentivise private sector involvement.

Scope: The extent to which holistic development benefits are achieved and a project's institutional environment is strengthened so as to create a sustainable sector and increase a project's chances to be sustained, scaled-up and replicated.

- A broad range of welfare impacts, income-generating uses of electricity and local employment opportunities should be created.
- Awareness-raising, training, seed capital and investment in surrounding infrastructure may be needed to develop productive uses and increase their ability to alleviate poverty.
- It is recommended that mobilisation processes be used to create welfare impacts that are not exclusively linked to energy, thereby widening a project's scope and making it more holistic.
- The enabling environment can be improved by increasing access to financing and technical support networks, improving monitoring practices, raising awareness of off-grid technologies among local governments and development planners, and working alongside national governments to improve policies and institutions.

The report considers a number of strategies to encourage the scaling-up and replication of successful interventions, most notably strengthening the enabling environment and incentivising private sector approaches to rural electrification (**Chapter 5**). It proposes a sample hybrid business model for mini-grid development that capitalises on the comparative advantages offered by the different stakeholders: a private company's greater access to the necessary financing and technical skills for the hardware's installation and continued maintenance, and a community's greater willingness to engage in, and often greater efficiency (lowered instances of theft and improved tariff collection) to manage, the distribution side of the system.

The model proposes that a private company could finance and service rural electrification infrastructure (or subcontract a qualified firm to do so), and a local management committee such as a cooperative or local micro-enterprise could buy the energy in bulk and manage the distribution to local residents. The private company could be a designated energy services provider or a nearby telecommunications operator or factory that requires off-grid electrification for their own use. The use of an anchor load (such as a factory or another commercial end user) should improve financial sustainability. However, adequate institutional and financial support is likely to be required before a private company will be interested in the business venture. The government should ensure that effective regulation is in place to monitor its activities. Likewise, an auditing body – composed of the user group and the external company investing in the generation equipment – should be established to improve the effectiveness of the local management committee. The rights and obligations of each party (the external company, local management team and users) should be transparent, formalised and enforceable by law.

The majority of the report's conclusions are not country specific, despite the deliberate selection of case studies from three continents to reflect different physical, institutional, economic and socio-cultural domains. Nevertheless, the enabling environments in the three countries vary considerably, impacting upon the types of projects encountered, their sustainability and potential to be scaled-up and replicated. At the community level, the largest difference between countries relates to the choice of management model employed: micro-enterprises find it more difficult to gain traction in Nepal than in Kenya or Peru, as they are regarded with some distrust. Conversely, due to a strong tradition of cooperation and more closely-knit communities, cooperatives are generally considered more effective in Nepal than in Peru or Kenya where such traditions are not predominant. A decision support tree is presented (**Figure 5**) to incorporate the results of the research for the benefit of rural electrification practitioners worldwide.

In summary, the report presents the following core recommendations for the benefit of practitioners and institutions involved in the provision and implementation of rural electrification projects in developing countries:

- During a project's planning and implementation stages, overriding focus should be placed on generating a sense of local responsibility for the electricity system and its upkeep across all key stakeholders, growing local desire for the electricity services provided and stimulating providers to expand their business, and extending the scope of the project across different development arenas to create maximum welfare impact.
- A number of concrete steps can be taken to achieve this, many of which fall under the categories of ownership, management, productive uses, training and job creation, financing and implementing approach (see **Figure 3**).
- Rather than focusing exclusively on a project's micro level, attempt to influence and build the institutional framework and environment in which the project takes place (raising awareness of renewable energy off-grid technologies, training technicians, improving access to finance, establishing regulation and national support policies). In so doing, the ability for a project's benefits to be scaled-up and replicated should increase.
- Try to engage the private sector through more innovative partnerships and hybrid business models, provided a supportive institutional and financial environment is already in place. If successful, private sector involvement should help accelerate scaling-up and replication.
- Be aware that there is no one-size-fits-all solution. Take care to tailor the rural electrification system to cater for the specific needs, desires and cultural specificities of different communities. This will be particularly relevant with regard to the choice of management model.

1 Rural electrification in developing countries

This section sets the broader context of rural electrification in developing countries. Its key points are that:

- Access to affordable, reliable and clean energy is fundamental for poverty reduction and sustainable development; without it, the Millennium Development Goals cannot be achieved.
- Increased electricity consumption, economic growth and improved human development appear to be strongly linked; however, the direction of causality for the improvements is unclear and electricity access alone is unlikely to raise local incomes.
- The United Nations aims to achieve universal energy access by 2030, yet political will and commitment are needed for this to be met. Currently, 1.3 billion people still lack access to electricity, over 95 per cent living in sub-Saharan Africa or developing Asia and 84 per cent of them living in rural areas. Based on present policies, over 1 billion people will still lack access to electricity in 2030, of whom 85 per cent will live in rural areas.
- Climate change is a pressing global concern that is predicted to most severely affect the developing world where communities are least resilient. However, achieving universal electricity access would only increase greenhouse gas emissions by 1.3 per cent, even if all the additional power were provided by fossil fuels.
- Grid extension, community mini-grids and stand-alone household systems are examples of rural electrification. Community mini-grids can be one of the cheaper forms of electrification and have the potential to offer a 24 hour AC service that can power a wide range of appliances.

Access to modern energy services is intrinsic to achieving the Millennium Development Goals (DFID, 2002). Electrification, along with access to modern cooking fuels and mechanical power, is a catalyst for improvements in the fields of poverty reduction, food security, health, education and gender equality (GNESD, 2007). Due to the higher cost of traditional, lower quality energy sources such as candles, kerosene lamps and batteries, on average the poorest people in the world spend almost 30 per cent of their household income on energy (Gradl and Knobloch, 2011). This expenditure is often reduced when households are electrified: in Guatemala, 1kWh of light costs USD 13 from candles, USD 5.87 from kerosene and USD 0.08 from the grid (Foster *et al.*, 2000). In rural areas, electricity is most commonly used for lighting, entertainment and education (radio, television, computers and electronic learning material in schools), telecommunications (internet and mobile telephones, which provide local market information for farmers, greater social connectivity, banking and medical services), cooling (refrigeration of vaccines and food storage), water pumping and purification, and small household and business appliances (irons, blenders, sewing, cutting machinery, woodworks and food processing).

The links between economic development, human development and electricity access are strong. Clear correlation can be observed between electricity access and gross domestic product (GDP) in all countries undergoing rapid growth in the 1980s and 1990s; electrical energy was the 'leading driver of growth in Brazil, Turkey and Korea' (IEA, 2004). Similarly, plotting per capita energy consumption against the Human Development Index (HDI) – an assessment of life expectancy at birth, gross national income per capita, mean and expected years of schooling – reveals a strong, non-linear relationship. Those countries whose citizens consume the least energy per capita (total electrical and non-electrical energy expressed in kWh) also have the lowest HDI values. Moreover, electrification bestows the greatest incremental benefit upon those with the lowest human development, levelling out once approximately 35,000kWh/capita/year is reached (IEA, 2004). The firm links between energy and human development, including their centrality to an adequate standard of living, have led some, including the government of South Africa (IEA, 2005), to consider access to basic energy services as a right (Cloke, 2010; Tully, 2006; Bradbrook and Gardam, 2006).

However, the relationship between electricity consumption and human development is far from simple: it is uncertain whether education, income or other environmental factors play a larger role in determining the quantity and type of energy consumed. Evidence surrounding the direction of causality between increased incomes and energy consumption is inconclusive (Aqeel and Sabihuddin Butt, 2001), with some arguing that energy is a 'derived demand' of economic development and not its instigator (Foley, 1992). Although a vicious circle between a lack of energy access and poverty can be identified as a result of reduced income-earning capability and purchasing power (this in turn limits access to energy, which could improve incomes), the inverse is not always true. As a result, electricity access alone is insufficient for increasing incomes; other interrelated factors include access to markets, local roads and transportation, communications, access to finance, local skills and competition (World Bank, 1995).

In recognition of the importance of energy services to economic and human development, in September 2010 Ban Ki Moon, Secretary-General to the United Nations, launched an ambitious goal: universal energy access by 2030. The year 2012 is also the United Nations' International Year for Sustainable Energy for All. Currently, there are over 1.3 billion people (approximately a fifth of the world's population) without electricity access in their homes and approximately 2.7 billion still rely on traditional three-stone fires for cooking (IEA, 2011). The vast majority are located in rural areas of sub-Saharan Africa and developing Asia: worldwide, 84 per cent of people without electricity live in rural areas (IEA, 2011). Despite the United Nations goal, the International Energy Agency (IEA) projects that based on current policies and future demographics, over 1 billion people will still lack access to electricity in 2030, of whom 85 per cent will live in rural areas, mostly in sub-Saharan Africa, India and other parts of developing Asia (excluding China) (IEA, 2011). The absolute number for those without electricity is even expected to increase in sub-Saharan Africa over the next two decades. In order for the 2030 universal energy access to be met, annual investment needs to average USD 48 billion per year, equivalent to less than 3 per cent of global investment in energy-supply infrastructure projected under current policies (IEA, 2011). The United Nations Secretary-General's Advisory Group on Energy and Climate Change (AGECC) stressed that the goal of universal energy access can be met by 2030, as long as political will and commitment is shown (AGECC, 2010).

Achieving universal electricity access is estimated to increase global greenhouse gas emissions by 1.3 per cent above current levels, even if all the additional power were to be provided by fossil fuels (IEA, 2009). Low carbon electrification options could be prioritised over fossil fuel alternatives provided that they would anyhow represent the best solution for the country in question (Nygaard, 2009). Although climate change is a pressing global concern that is predicted to most severely affect the developing world where communities are least resilient (Zerriffi and Wilson, 2010), from the 'poor people's perspective, energy access for development takes priority' over the choice of low carbon technology (Practical Action, 2010) and achieving universal energy access should be de-coupled from other agendas (Wilson and Garside, 2011). Given that industrialised nations have principally caused climatic change, developing countries do not feel that they should pay the price of fixing the climate 'problem' either directly (by paying the additional cost of low carbon technologies) or indirectly (by not developing at a speed they would have otherwise achieved through higher carbon technologies) (Zerriffi and Wilson, 2010).

Rural electrification can take the form of grid extension, individual household systems, community mini-grids, multifunctional platforms and central charging stations with battery banks. Due to the large distances, difficult terrain and low projected levels of consumption, grid extensions may be too costly to install or operate efficiently (Gouvello, 2002). In rural areas that have had the grid extended, the service may be poor or even non-existent. In rural India there are power cuts of '14–16 hours a day, on almost all days of the year' (Krishnaswamy, 2010). This may be due to poor transmission infrastructure, generation capacity shortages or mismanagement of the central grid that result in frequent black-outs or 'brown-outs' (large voltage drops that can damage appliances), particularly for rural customers at the ends of the network. The unreliability and shortage of grid power in many areas can severely hamper economic development. This economic cost has been estimated as 4 per cent of GDP in Tanzania, 5.5 per cent in Uganda and 6.5 per cent in Malawi (Foster and Briceño-Garmendia, 2010).

In many places off-grid electrification solutions represent the optimal means of extending electricity provision to rural populations in terms of the required investment, efficiency and quality of service (Yadoo and Cruickshank, 2012). Although each type of off-grid technology presents its own set of advantages and disadvantages, community-level mini-grids have the potential to be among the cheapest electrification methods available for rural areas on a per unit basis (calculated over the system's expected lifetime) (ESMAP, 2007), at the same time as providing an 'as good as grid 24-hour AC service capable of powering a wide range of applications (Yadoo and Cruickshank, 2012). They also give the opportunity for additional local benefits to be accrued such as empowerment through local management, payment for feedstock or, if grid-connected at a later stage, income from feed-in tariffs and the potential to leapfrog into a more resilient electricity network (Yadoo and Cruickshank, 2012).

2
Background to electrification in Nepal, Peru and Kenya

Nepal, Peru and Kenya are all countries where the challenge of rural electrification remains great. Only 32 per cent of rural Nepalese, 23 per cent of rural Peruvians and 10 per cent of rural Kenyans have access to electricity in their homes. Hailing from three continents and incorporating varying physical, institutional, economic and socio-cultural features, the countries adopt different approaches to rural electrification. This chapter will provide an overview of electrification as experienced in the three different nations. Its key points are:

- Grid electrification can be unreliable in all three countries: instances of load shedding are particularly high in rural Nepal and Kenya, the quality of service offered to grid-connected rural customers in Peru is often far inferior to their urban counterparts, and the grid fails to reach the most impoverished in rural areas. In Kenya, grid electricity tariffs and connection fees are unaffordable for thousands in both rural and urban areas.
- There is a clear institutional structure for electrification in Nepal. The centralised electricity authority's difficulty to administer the grid network has opened space for community-led grid extensions and these have been reasonably effective at increasing access in rural areas. After a dubious past, off-grid electrification has been rapidly growing in Nepal and its institutional environment is well developed.
- The privatisation and liberalisation of the Peruvian electricity market in the 1990s has created a complex legal and institutional framework that incorporates many different actors. Rural electrification is predominantly grid-based in Peru; both planning and funding mechanisms are biased in its favour. However, over 10 per cent of non-electrified households are not expected to receive grid power under current technical and economic constraints. Although many different organisations implement off-grid electrification projects in Peru, their actions are much less integrated or systematic than in Nepal. It is hoped that the development of regional and district level Master Plans will improve this situation.
- Kenya's power sector has also undergone several reforms over the past 15 years and there are ambitious targets to accelerate the pace of rural electrification. Grid extensions are the preferred option and there has been limited government-led off-grid electrification in Kenya to date. The majority of off-grid electrification takes the form of solar photovoltaic systems and is propelled forward by the private sector. However, telecommunication companies, tea estates and sugar industries have started installing off-grid technologies to meet their own power needs. A small number of decentralised renewable energy power projects have also been installed by non-governmental organisations (NGOs), local community groups and other institutions.

Extending the grid remains the most common form of electrification in Nepal, Peru and Kenya. However, grid-based electrification presents a number of problems in each country. A lack of generation capacity and heavy reliance on hydropower has led to frequent power cuts or 'load shedding' in both Nepal and Kenya, particularly during the dry seasons. Households in Kathmandu were denied electricity for up to 16 hours a day in the pre-monsoon months of 2008 and there were daily blackouts of 8–12 hours in the capital during the author's own fieldwork the following year. In Kenya, weak transmission and distribution (T&D) infrastructure has further exacerbated capacity problems (T&D losses surpassed 16 per cent in 2008/09) and as year-on-year hydropower generation dropped by 18.4 per cent in 2008/09 following three successive years of drought, increased thermal generation has led to a concomitant rise in consumer energy bills (KPLC, 2009). This increase, together with high connection fees, has made grid electricity unaffordable for many Kenyans in both rural and urban areas; it is estimated that hundreds of thousands live within grid-connected areas but are unable to afford a connection. As a result, a short-term (one year) loan has been introduced that provides up to 80 per cent of the cost of connection at 15 per cent interest. This loan is believed to be partly responsible for over 200,000 new connections in 2008/09 (KPLC, 2009).

In Peru, the quality of grid service in rural areas is often far inferior to that in urban zones as both the installation and management of rural electricity grids is unappealing to the distribution concessionary companies that are mandated to maximise profit. Due to their isolation, it is often more difficult and costly to isolate and fix any problems that might occur in rural areas. Given the higher installation, operating and maintenance costs of rural grid extensions, there is little economic incentive for concessions to extend access to rural areas within their zones, even if they are legally obliged to do so. As a result, concessions tend to prioritise the electrification of areas that are closest to existing grid lines, that is, those with the lowest marginal cost, as opposed to selecting areas on the basis of social factors such as poverty indicators as encouraged by their Ministry of Energy; therefore, grid extensions do not tend to reach Peru's most impoverished rural areas (Miranda and Soria, 2006).

Nepal

The electrification sector in Nepal is clearly defined. The Nepal Electricity Authority (NEA) has overarching responsibility for grid-based electrification, whereas the Alternative Energy Promotion Centre (AEPC) coordinates and oversees the majority of off-grid electrification that occurs within the country. In 1992, the Electricity Act was passed and independent power producers were allowed to generate and sell power to the NEA, increasing the country's generation capacity. However, as noted for Peru, conflicting pressures (the need to maximise profit, capital resource scarcity and an inability to control electricity theft) severely restricted the NEA's willingness and ability to pursue rural electrification. Therefore, in 2003, amidst parallel efforts to unbundle the generation and distribution functions of the NEA, the Community Electricity Distribution Bylaw was passed. This bylaw allows any organised rural group to buy electricity in bulk from the grid and retail it among its users. Communities must contribute 20 per cent of the total cost of grid extension (via labour, household donations, bank loans or loans and grants from the local Village

Development Committee and District Development Committee) and are responsible for any non-technical losses (theft) occurring within their distribution area. The National Association of Community Electricity Users in Nepal (NACEUN) was established in 2006 to support, train and facilitate community groups interested in power distribution. NACEUN currently represents 187 member community-based organisations (CBOs) in 42 districts and has facilitated the electrification of 180,000 households. Reminiscent of rural electric cooperative-led grid extension seen *inter alia* in the United States, Bangladesh, Costa Rica and the Philippines, this form of community-led distribution has been reasonably effective at increasing access, lowering the cost of supply and reducing the incidence of electricity theft in rural Nepal (Yadoo and Cruickshank, 2010a).

At the outset, off-grid electrification mainly took the form of micro-hydro plants installed by NGOs during the 1960s, 1970s and 1980s. However, a mixture of technical failures and loan defaults significantly lowered interest to invest in such projects. Momentum behind off-grid technologies only resumed from the mid-1990s. Solar Home Systems (SHS) started being installed from 1992, the AEPC was established in 1996, a new subsidy policy was put in place, a support programme focusing on end user applications (such as ropeways) was instigated by NGOs, and the Agricultural Development Bank of Nepal started lending money for off-grid electrification projects. The AEPC currently acts as the apex organisation for several donor-led off-grid implementation programmes including the United Nations Development Programme and World Bank Rural Energy Development Programme (REDP) established in 1996, the Danish and Norwegian governments' Energy Sector Assistance Programme (ESAP) established in 1999, and the European Union funded Renewable Energy Project. The AEPC also coordinates research and development on wind power in Nepal, sets and administers the Renewable Rural Energy subsidy policy and supervises the Rural Energy Fund, an institution established to assist with the mobilisation of external funding for community energy projects. Furthermore, there are a number of NGOs who work on off-grid rural electrification outside of the AEPC such as the World Wide Fund for Nature and Practical Action, albeit on a smaller scale. By 2009, over 1,885 mini-grid electrification schemes (mini- and micro-hydro and peltric sets[1]), amounting to an installed capacity of 26.85MW, had been commissioned and there was an approximate installed capacity of 3.09MW from SHS (Practical Action, 2009; AEPC/ESAP, 2008). Two-thirds of rural households that gained access to electricity between 2001 and 2005 were supplied by off-grid solutions (REP, 2009).

Peru

Peru's electricity sector underwent reforms during the 1990s aimed at privatising and liberalising the sector. As a result, there are currently many different institutions involved in rural electrification in Peru. First, there are the state institutions such as the Ministry for Energy and Mines (MEM), the Administrative Company for Electrical Infrastructure (ADINELSA), regional and local governments and the national regulator, OSINERGMIN. Second, there is the private sector that comprises the large distribution concessionary firms and small or medium-sized enterprises (which mainly provide stand-alone solar-based solutions to electrification). Third, there is the non-profit sector made up of NGOs such as Practical Action and some leading Peruvian universities. The introduction of a series of new rural electrification laws since 2002 has also begun to strengthen the sector's regulatory framework. Nevertheless, Peru is second from bottom among Latin American countries in rural electrification and still faces many physical, financial and institutional barriers (DEP, 2007). These include the remoteness and low

1 Peltric sets are a type of water turbine connected to an electric generator

population densities of some non-electrified communities, a lack of financing and credit arrangements, inadequate subsidy and planning structures, poor transparency in some state institutions, insufficient training and empowerment of local authorities and communities, and insufficient regulation for decentralised systems.

Rural electrification predominantly takes the form of grid extension and over 87 per cent of all investments described in the government's National Plan for Rural Electrification for 2009–2018 are grid based. The World Bank supported Revolving Fund (for new connections) and the Electrical Social Compensation Fund (a nationwide consumer internal crossover tariff subsidy) are also biased in favour of grid extensions. Energy planners (such as those in regional governments and staff of the National System for Public Investment) and distribution concessions tend to favour grid-based over off-grid proposals, owing to their greater familiarity with the technological, operational and management infrastructure involved. Government policy states that off-grid projects using renewable energy technologies (solar, wind, hydro) should only be considered for those villages where grid extensions would cost over USD 1,000/household; a recent Master Plan report, however, estimated that over 10 per cent of non-electrified households (33,700 villages or 361,800 households) will not gain access to the grid network given current technical and economic constraints and are therefore in need of off-grid electrification by way of solar or hydropower (JICA, 2008). Wind energy was not considered in the Master Plan, yet both the government and NGOs (such as Practical Action) have begun to install wind-based off-grid systems in rural areas. Although several actors are involved in the off-grid rural electrification sector (for example, MEM, ADINELSA, university research centres, Practical Action, Engineers Without Borders (Catalonia), Green Empowerment, Action Aid, Don Bosco, private enterprises and regional governments) their actions are much less integrated or systematic than in Nepal. It is hoped that this may improve following a Practical Action initiative to develop regional and district level Master Plans for Rural Electrification using (mainly off-grid) renewable energy systems at the request of, and in tandem with, the local authorities and other relevant local bodies.

Kenya

Kenya's power sector also underwent a process of unbundling as a result of the Electricity Power Act of 1997 and further reforms (including semi-privatisation and the creation of new institutions) followed the passing of the Energy Act in 2006. Kenya Electricity Generating Company (KenGen) now has principal responsibility for generation and owns approximately 75 per cent of total installed capacity (independent power producers can also sell power onto the grid and feed-in tariffs were introduced in 2008 to encourage more investment in renewable energy), Kenya Electricity Transmission Company Limited (Ketraco) is in charge of developing new transmission projects, Kenya Power and Lighting Company (KPLC) is responsible for existing transmission lines and all distribution over 3MW. The Rural Electrification Authority (REA), established in 2007 to accelerate the overly slow pace of the government's Rural Electrification Programme that had started in 1973, is tasked with increasing access to electricity in rural areas. Rural electrification under the REA predominantly takes the form of grid extension as 75 per cent of the country's population is concentrated in 10 per cent of its landmass. The Ministry of Energy's Rural Electrification Master Plan details its intention to electrify all public facilities (such as district administration headquarters, market centres, schools and health facilities) by 2012 and 40 per cent of rural households by 2020.

The former Rural Electrification Programme had invested in 13 off-grid power stations, all of which were diesel-powered. Ownership of all but two of these has now been passed to REA and KPLC is contracted to operate, maintain and manage the distribution side of the business. Despite the country's limited experience with off-grid power, the Rural Electrification Master Plan stipulates that off-grid systems (powered by wind, solar photovoltaic and dual-fuel diesel units) will be used to electrify 330 public facilities and serve 66,000 connections in approximately 200 localities. REA will also run a small number of pilot demonstration projects involving other types of off-grid renewable energy: biogas for cooking and electricity generation in schools, biomass gasification for electrification of off-grid communities and community micro-hydro plants. However, the majority of off-grid power generation has been deployed by the private sector and other independent groups. The solar photovoltaic (PV) market is private sector-led and has created one of the largest markets for SHS in the world; there are an estimated 300,000 SHS in use in Kenya and solar lanterns are increasingly being used. Telecommunication companies have started to install hybrid wind-solar-diesel generation systems for their off-grid base stations, often providing a charging point for locals to recharge their mobile telephones free of charge. Two Global Environment Facility initiatives (Greening the Tea Industry in East Africa and Cogeneration for Africa) will include an off-grid rural electrification element to their renewable energy tea and sugar industry power generation programmes. NGOs, United Nations institutions, research institutions and local community groups have also conducted decentralised renewable energy schemes although their activities are few and far between.

3 Case studies

Although only able to provide analytic (and not statistical) generalisation, case study research can help to decipher 'complex social phenomena' by retaining the contextual conditions and the 'holistic and meaningful characteristics of real-life events' (Yin, 2003). This chapter provides a description of the main case studies examined in this report, along with the methodology used and sustainability assessment results. Its main findings are that:

- A holistic approach to sustainability – that is, consideration of its technical, economic, social, environmental and institutional dimensions – should be adopted in the project planning and implementation stages in order to create sustainable welfare benefits. Neglect of one or more dimension will detract not only from sustainability, but also development impact and resilience.
- The broader a project's remit (for example, not only focusing on electricity access but also introducing toilet-assisted biogas, raising awareness on environmental issues and improving the local gender balance), the greater its potential to improve a community's overall development.
- Project management can be made more efficient, transparent and effective when it is clearly separated from ownership and a formal system of checks and balances is established. Effective management can also improve resilience to internal and external shocks and stresses.
- Wherever possible, practitioners should aim to future-proof systems by including demand growth margins in the original project design. Project resilience can be enhanced if detailed risk analyses are conducted and contingency plans agreed by all the key stakeholders *a priori*.

Overview

As described in **Chapter 1**, the purpose of electrification is not access to electricity per se, rather the ability to benefit from the energy services it can provide. Therefore, it is important to assess the extent to which a project is able to generate sustainable welfare benefits for its intended beneficiaries, the rural poor. To do this, three main case studies of renewable energy mini-grids were conducted, one in each of Nepal, Peru and Kenya. The choice of cases from different countries affords the opportunity to compare and contrast examples of rural electrification projects implemented against a backdrop of different institutional and cultural contexts. Although cultural differences within a country cannot be ignored, the variety is likely to be greater across nations and continents, thus coverage of three continents provides an interesting (although still not comprehensive) wide-angle view of rural electrification practices and experiences worldwide. In order for the emergent hypotheses to lay claim to wider analytical generalisability and greater external validity, the three main case studies were triangulated against a series of less in-depth satellite case studies in each country and these results were included in the subsequent analysis (see **Chapter 4**). Nevertheless, this chapter will focus on the three main case studies conducted between May 2009 and October 2010.

Table 1
Key similarities and differences between cases

	POKHARI CHAURI (NEPAL)	TAMBORAPA PUEBLO (PERU)	THIBA (KENYA)
Technology	Micro-Hydro	Micro-Hydro	Mini-Hydro
Size	22kW	40kW	135kW
Year commissioned	2000	2000	2005
No. customers	239 households	218 households	180 households
Ownership	Community	Municipality	Community
Management	Cooperative	Micro-enterprise	Cooperative
Technical Operations	Local employees	Local employees	Local employees
% of capital costs paid by users	Labour and 7.5% (bank loan repaid over 2 years)	Labour only	Labour and 50% approx
% of operating costs paid by users	100%	100%	100%
Productive Uses	Some	Lots	None
Non-energy related activities promoted	Yes	No	No

Summarised in **Table 1**, the three electrification projects all relied on the same technology (micro- or mini-hydro mini-grids),[2] served approximately the same number of customers (around 210 households) and were commissioned in approximately the same timeframe (5–10 years prior to fieldwork). However, although all projects were independently managed and operated from within the community, the type of management model employed (cooperative or micro-enterprise) was deliberately chosen to vary. Projects that involved a more holistic approach from the implementing agent (reflected in the promotion of non-energy related activities as part of the overall project) were also contrasted with more narrowly focused electricity projects. Finally, although none of the projects required

2 Hydro mini-grids were chosen as they have a longer history of use than other low carbon mini-grid technologies and a thorough sustainability assessment requires the technology to have been installed several years before the assessment takes place. Moreover, hydro mini-grids have often reached cost parity with (or are sometimes already cheaper than) diesel powered mini-grids on a levelised cost basis (ESMAP, 2007).

external financial assistance to meet their running costs, the third community (Thiba) contributed substantially more towards the capital costs.

Different data collection techniques were employed during the field visits. These included transect walks, semi-structured interviews with users and managers, observations and photographic evidence. Villagers' perspectives (those of households/users, system managers, community leaders, school teachers, health workers, and so forth) were triangulated against the results of semi-structured interviews held with the implementing agencies, enabling different levels of analysis to be embedded in each case study (Yin, 2003) and improving both construct and internal validity (Leonard-Barton, 1990).

Pokhari Chauri, Nepal

Approximate position of Pokhari Chauri in Nepal

Pokhari Chauri is a rural settlement of 239 households in Kavre district, central Nepal. The area had had no access to electricity and households relied on candles and kerosene lamps for their basic lighting needs. However, in July 2000 a 22kW run-of-river hydro plant was installed by the United Nations Development Programme-led Rural Energy Development Programme (REDP). The project was mainly funded by the REDP, national and local government subsidies, but the community contributed money (via a bank loan equivalent to 7.5 per cent of total capital costs) and unpaid labour. Households have been fitted with a 100W mini-circuit breaker. Those with larger machinery (for example carpentry tools or mills) have had meters installed. Electricity is supplied every day between 4am and 4pm and again from 6pm until 11pm. Two community members have been trained as system operators and one as manager, thereby improving local skill sets and providing additional employment. User electricity tariffs are used to maintain the system and to provide members with micro-loans; these are normally repayable within six months and are often used to establish small cottage industries or build toilet-assisted biogas plants. Following a community consensus, approximately 2 per cent of the households are provided with electricity free of charge due to their lower economic status. The system rarely needs to be shut down, other than to conduct repairs or during heavy storms (this occurs approximately five times a year). Interviewed households expressed satisfaction with the service provided, attesting that repairs, when necessary, were carried out quickly and to a high standard.

The community have greatly benefited from the arrival of affordable electricity. Schoolchildren now study for an average of 1–2 hours more per day and teachers believe them to be better informed from increased radio and television access at home. At school, electricity is mainly used for cassette players and listening exercises in language classes, though it is sometimes used for lighting if the day is particularly overcast or rainy. Electric light aids the local health worker when conducting examinations (particularly ear, nose and throat examinations) and during night-time births. Both the school and health post now receive their electricity free of charge, thereby saving precious funds. Household savings from the displaced cost of kerosene and batteries vary between approximately 0.7 and USD 12/month depending on their family size, disposable income and number of children in education. Migration away from the community

Assortment of mills in Pokhari Chauri.

is relatively low, other than of children continuing their studies to tertiary level.

Traditional agro-processing techniques have also improved following the installation of three rice mills, one flour mill and an oil grinder, all purchased by the community. The use of such machinery especially benefits the local women as it used to be their job to grind the produce and it would cause hand pain. Whereas previously grinding used to be done at home, the communal space created to house the community-owned mills provides an additional point of social interaction for the women and girls. Moreover, approximately 25 per cent of interviewed households reported that the time and effort saved by these mills allow them to process extra crops and sell them in the markets, giving their family an additional seasonal income of approximately USD 135–270/month. New private businesses have also emerged, for example three carpentry workshops and a milk chilling unit that provides other local farmers with the ability to store and maintain the quality of their milk prior to its sale in Kathmandu.

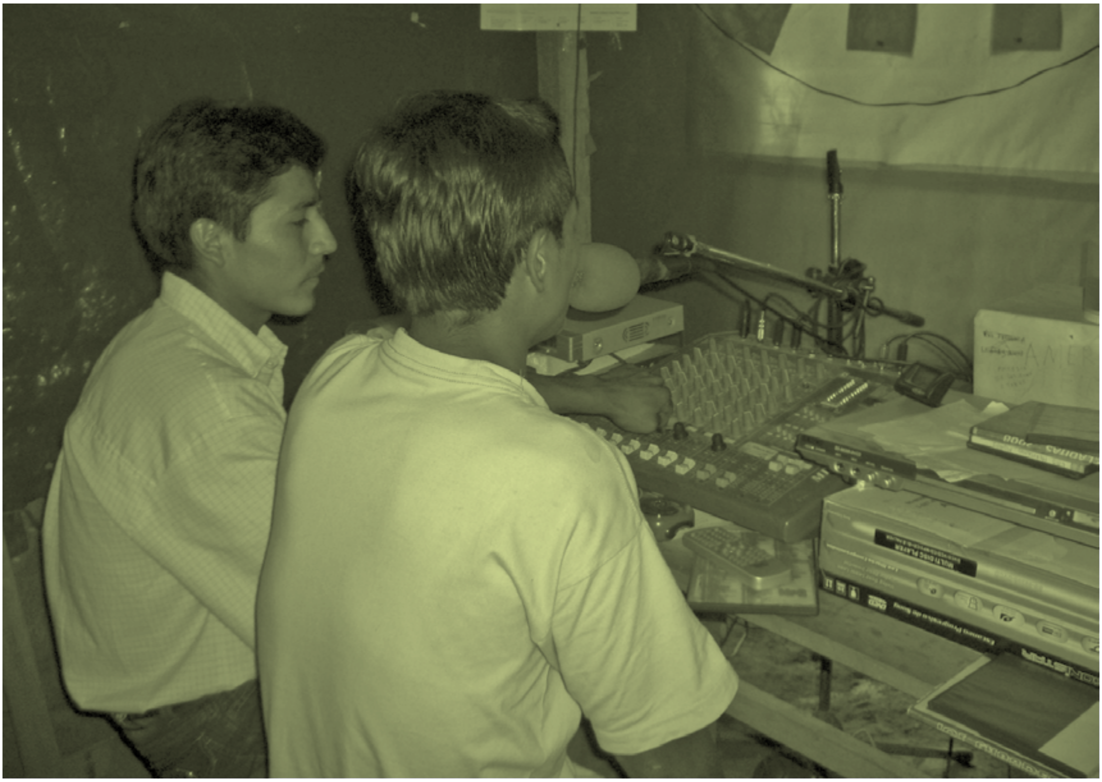
In 2002, the community formed a cooperative – the Chauri Khola Micro-Hydro Cooperative Ltd. – to manage the electricity system and the income it generates. All members meet on a yearly basis, when the seven-member executive committee (which meets monthly and is elected every three years) informs them of the cooperative's finances and plans for the following year. To keep members informed and involved in a wide range of community development activities throughout the year, 22 community organisations were formed – 11 male and 11 female (gender segregation was found to boost female participation) – by the REDP (all community members belong to one of these groups). A representative from each of these 22 groups attends the executive committee's monthly meetings, reports back and participates in one or two of the five subcommittees, organised according to different thematic interests (loans, education, legal, community mobilisation and advisory). The REDP also facilitates other trainings (for example in incense and soap-making, off-season vegetables, poultry farming, bee keeping, forest nursery and the environment, and the building of pit latrines, permanent toilets and garbage pits) so that interested members can diversify their income streams and contribute to the development of the community. Community members are now more aware and proactive about environmental issues, and the local surroundings are better kept as a result.

Tamborapa Pueblo, Peru

Approximate position of Tamborapa Pueblo in Peru

In the year 2000, a 40kW micro-hydro mini-grid was installed in Tamborapa Pueblo, northern Peru (then a community of 160 households) by the Peruvian branch of Practical Action (*Soluciones Prácticas*) as part of the Inter American Bank's Fund for the Promotion of Micro-Hydro Power Stations. All capital costs were met by various national and local government bodies, with the community contributing in kind by way of unpaid labour. A 24-hour electricity service is provided and all households have metered connections, allowing them to pay according to usage. Housholds are forbidden to use non-energy saving light bulbs in order to improve system efficiency. As the development of productive uses was deemed important by both the managers and the implementing agency, a block tariff system was introduced with the intention of favouring those who aspired to use electricity for income-generating activities (the unit cost of electricity decreases in stages as consumption increases). The cost of managing and maintaining the system is met by the income generated through the collection of this tariff and users are fined 1 per cent of the outstanding amount per month if their payments are late; their service is suspended if three months pass without payment. This is a rare occurrence and users are given at least one day's notice before planned suspensions of service. There have been few problems with the system; nevertheless, when they are needed, repairs are conducted relatively quickly due to the availability of funds (collected tariff payments) in the bank account.

Electricity is used for a wide range of productive and non-productive uses. Street lighting improves the security of the area and makes women feel more comfortable when visiting their neighbours at night. The lighting of a local sports field creates an additional source of evening recreation for the local youth. There have been improvements to the health service and the following electrical equipment is now in use: two refrigerators, a radio transmitter, a freezer, a steriliser, a suction machine, three computers, lamps, a centrifuge (for laboratory work), a



The radio station at Tamborapa Pueblo

Doppler machine (powered by re-chargeable batteries) and a stereo (used during prenatal classes). Women no longer need to travel 5 hours by minibus to receive check-ups when pregnant, making it much more likely that they will see a specialist and thereby lowering the risk for both mother and baby. Teachers believe that the quality of education has improved and homework is of a higher standard due to electric lighting in homes. Children have access to six computers (there is an additional machine for administrative purposes), a photocopier, five microscopes, two televisions with DVD, two printers and a stereo (used for dances). Pupils are now benefiting from the use of educational videos and CD-ROMs such as Encarta. Moreover, since August 2007, an external businessman has established a computing school in Tamborapa Pueblo offering three-month courses on basic computing skills. There are a total of 120 people enrolled on the courses and the centre has eight computers and two teachers. A secondary school teacher remarked that access to these new teaching aids has stimulated pupils' interest in continuing their studies – around 20 per cent of pupils now enter tertiary education, against the previous figure of around 2 per cent.

Communications and entertainment have also improved. As well as domestic use of electricity to power televisions, radios and mobile telephones, the village now has the services of a local radio station whose transmitter is powered by the electricity produced by the micro-hydro plant. The radio station functions as a private micro-enterprise, employing five people and charging listeners to post advertisements or personal messages. Although its principal use is to provide entertainment, it also acts as a source of information and on occasion is used to post important announcements (such as notifications of the suspension of the electrical service). Other uses of the electricity include mills and coffee processing machines, lighting, videos and music during church services, and the domestic use of refrigerators, irons and food blenders. Several hundred people have migrated to the area since the micro-hydro plant was installed, seeking to improve their living standards: the local population effectively tripled in size between 2000 and 2009 when it reached 490 households. This population rise has created surplus demand for the electricity service; not all households who seek it can be connected (only 218 households are) and workshop owners are prohibited from using electrical machinery after 6pm.

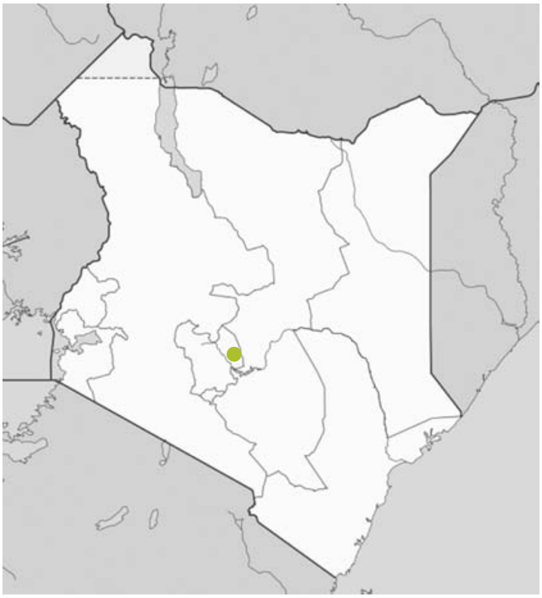
Remarkably, since the electricity service began in 2000, 55 businesses have been established in Tamborapa Pueblo and over 42 per cent of their owners consider the availability of electricity to be important, if not essential, to their enterprise. The enterprises include a computer school, 26 shops (two with public telephones, one that sells DVDs, one that provides photocopying services and one pharmacy), 12 restaurants (one with a public telephone), 9 carpentry workshops, 3 mechanic's workshops, 1 electronics workshop, 1 radio station, 3 bakeries, 2 battery charging providers, 2 fuel dispensers, 2 hostels and 4 kiosks that are only run at weekends. For the vast majority of these business owners, their profits only supplement basic living costs, although their children's education is the second most frequent use of the income, specifically mentioned by 25 per cent of the entrepreneurs. The businesses are often run (or at least jointly run) by female members of the household; many of these women mentioned that they considered it a welcome respite from the hard manual labour of farm work.

Initially, as official owners and guarantors, the municipality had wanted to manage the micro-hydro plant. However, the villagers resisted, believing that the municipality would reallocate the funds collected from the tariff payments into other projects and not set aside enough with which to maintain the system in times of need. Thus, with the help of Practical Action, a local micro-enterprise was established to maintain and manage the system and an operator-administrator team was chosen and trained (they are paid for their work from the user tariffs). Although the project has not been problem-free (one of the administrators allegedly misused the system's maintenance funds), a formal accountability mechanism (an auditing committee composed of users and municipality staff that evaluate the micro-enterprise's performance every two years to decide whether or not to renew its contract) identified this problem and the administrator was replaced. The experience shows that the necessary regulatory and legal structures were in place to ensure that a fair system would prevail.

Thiba, Kenya

The community of Thiba initiated their own mini-hydro project. KPLC had started extending the grid nearby as early as 2002, but no transformers were being installed within 600 metres of Thiba; it would have cost each household over USD 1,500 to be connected. This was prohibitively high – the average annual salary of local tea farmers. The community chairman had the idea of generating power for the community via their local hydro resources but he did not have the technical expertise to execute the project. He therefore approached GPower, a local non-governmental organisation working in electrification, for technical assistance.

There are 800 members in the Thiba project and all were expected to contribute approximately USD 150, unskilled labour and two poles (from local Eucalyptus trees) for the distribution system. In return, they would receive shares in



Approximate position of Thiba in Kenya

the project and would be paid dividends once the system started generating a profit. Five hundred members are fully paid and some members paid more than the required USD 150 (for example, up to 500 USD), thereby entitling them to more shares. GPower installed the generation system (a 135kW modified Kaplan turbine) and trained four local men to look after the operation and maintenance of the system. These men had to pass the Certificate in Electrical Engineering exams in Nairobi. However, following a dispute, in 2005 the chairman broke off the relationship with GPower after the NGO had only installed part of the distribution system and connected only 10 households to the network.

Currently, the mini-hydro system distributes electricity to 180 households within a 1.6km radius of the generation equipment and operates from 6am to 8pm every day. One hundred and seventy of these households are members and 10 are member clients (member clients have to pay approximately USD 200 over four months for connection; however, as they had been unwilling to contribute at the beginning of the project they are therefore not entitled to shares). All users pay a flat tariff of approximately USD 3/month (to pay for repairs and the technicians' salaries) and their connections are not metered. In comparison, KPLC charges rural households approximately USD 7/month for their metered usage. There is surplus energy on the system (peak demand is around 100kW) and therefore, for the time being, households can even use electric cookers or irons. No step-up or step-down transformers were installed in the distribution system so the majority of households (particularly those further away from the point of generation) experience regular voltage drops (brown-outs) that damage their appliances. Electricity is not provided to institutions such as schools or health centres.

There have been problems with the turbine since inception: its shaft becomes bent and bearings are worn down on a regular basis (once or twice a month) causing blackouts. There is a lack of funds to do rigorous repairs or purchase higher quality components. The constant need to replace the bearings and seals and reshape the shaft is consuming all the revenue accumulated from the tariffs. Connected households experience three to four days of blackouts a month as each problem generally takes one or two days for the technicians to fix (including the time required to buy the replacement parts). The regularity of the blackouts frustrates customers. The system can barely sustain itself financially at present. This self-reinforcing relationship between the lack of funds and ongoing technical problems is a major hindrance to the project's sustainability.

The Thiba project is managed by a 17 member committee. Elections are held every three years but people have so far retained all those who were originally elected. Once elected onto the committee, the committee members decide among themselves who will be the chairman, vice chairman, treasurer and secretary. In reality, these positions often go to those who financially contributed the most towards the building of the project. In addition to the four technicians, the committee also employs a female project member to collect the monthly tariff payments. There is a general meeting every three or four months to outline how the committee has been spending these payments. Although the committee claims to be making an effort to be as transparent and accountable to its members as possible, it is unclear how well the project is being managed, particularly as GPower believes that internal corruption caused the disintegration of their partnership.

Despite its numerous difficulties, the community of Thiba – as was also the case with Pokhari Chauri and Tamborapa Pueblo – are proud of their mini-hydro plant and pleased that people from different communities (and even countries) visit them out of a desire to replicate the project. They are particularly proud of progressing so far with relatively little external financial assistance (although they did receive some loans and grants, Thiba contributed approximately 50 per cent of total capital costs in addition to unpaid labour). The community are now looking for external financing to improve the system (through turbine replacement, the installation of transformers and improvements to the distribution network) and hope one day to generate excess power that they can feed into the national grid in return for feed-in tariffs (the grid network has now reached the edges of the community).

Application of assessment methodology

A series of 43 Sustainability Indicators was developed with which to assess the projects' ability to generate sustainable welfare benefits for their intended beneficiaries. Sustainability was defined in its holistic sense of technical, economic, social, environmental and institutional (or organisational) sustainability, as proposed by Ilskog (2008). The indicators were originally based on a smaller set of indicators developed by Ilskog (2008) and were then adapted to meet the research's specific needs, drawing on the author's prior experiences in the field. The full list of indicators can be found in **Table 2**. As far as possible, indicators were chosen that would reflect the wide-ranging concerns of different stakeholders involved within a given project. An absolute value of one point was awarded each time the indicator was met within a case, 0.5 was awarded if the indicator was only partially met and none where the indicator was not met. The greater the score for a particular dimension of sustainability, the more sustainable welfare benefits produced.

Table 3 and **Figure 1** present the results of the sustainability assessment. A more detailed breakdown (including explanations as to why fewer points were awarded for certain indicators) can be found in **Appendix 1**. Effort was made to make the process as objective and transparent as possible, however the author's choice of indicators was ultimately subjective, as was her assessment of the case studies with the corresponding allocation of points. Similarly, although each indicator receives an equal weighting (Environmental Indicator 6 is the exception), certain issues are given greater emphasis through the assignation of multiple indicators (for example, Social Indicators 1 and 2 both relate to improvements to education).

Key findings and assessment of resilience

The results show that micro- or mini-hydro mini-grids can produce sustainable welfare benefits provided all dimensions of sustainability are considered in the planning and implementation stages. Whereas the systems in Pokhari Chauri and Tamborapa Pueblo both scored relatively highly, Thiba's low scores were largely the product of insufficient financing, which prevented the technicians from investing in higher cost components and conducting better quality repairs. This prevented the electricity service from having a greater development impact (which particularly limited the range of socio-economic benefits) and detracted from the system's overall sustainability. Nevertheless, its

Table 2
Sustainability Indicators used in the research

	Sustainable Development		
	TECHNICAL DEVELOPMENT	**ECONOMIC DEVELOPMENT**	**SOCIAL/ETHICAL DEVELOPMENT**
Key Variables	Operation and Maintenance Technical Client-Relation	Financial Productive Uses Employment Generation	Improved Service Availability Credit Facilities Equal Distribution
Indicators	1. Service is reliable, disruptions are minimal 2. Service meets demand capacity requirements 3. System is efficient and technical losses are minimised 4. System is compatible with future grid service 5. Support infrastructure (expertise, supply parts) is readily available 6. System is well maintained 7. Advance notice about planned service disruptions is given to users 8. Service is safe to use and operate	1. Service is affordable for users 2. System breaks even (O&M costs are met) 3. System is profitable, excl. capital costs 4. System is profitable, incl. capital costs 5. A share of the profits is re-invested in the electricity service 6. Electricity is used by local industries 7. Electricity is used by a broad range of micro-enterprises 8. Electricity is used to improve agricultural activities (irrigation, food processing, refrigeration of goods) 9. Local employment opportunities have increased due to electricity 10. Profits from micro-enterprises or livelihoods have increased due to electricity	1. Electricity is used in schools 2. Education has improved due to electricity 3. Electricity is used in health centre 4. Healthcare has improved due to electricity 5. Electricity is used in community centre 6. Existence of street lights 7. Telecommunications have improved due to electricity 8. Women's burdens have reduced due to electricity 9. Micro-credit (or alternative) possibilities are available for electricity services connection and tariff payment where necessary 10. All households who want it have access to electricity service

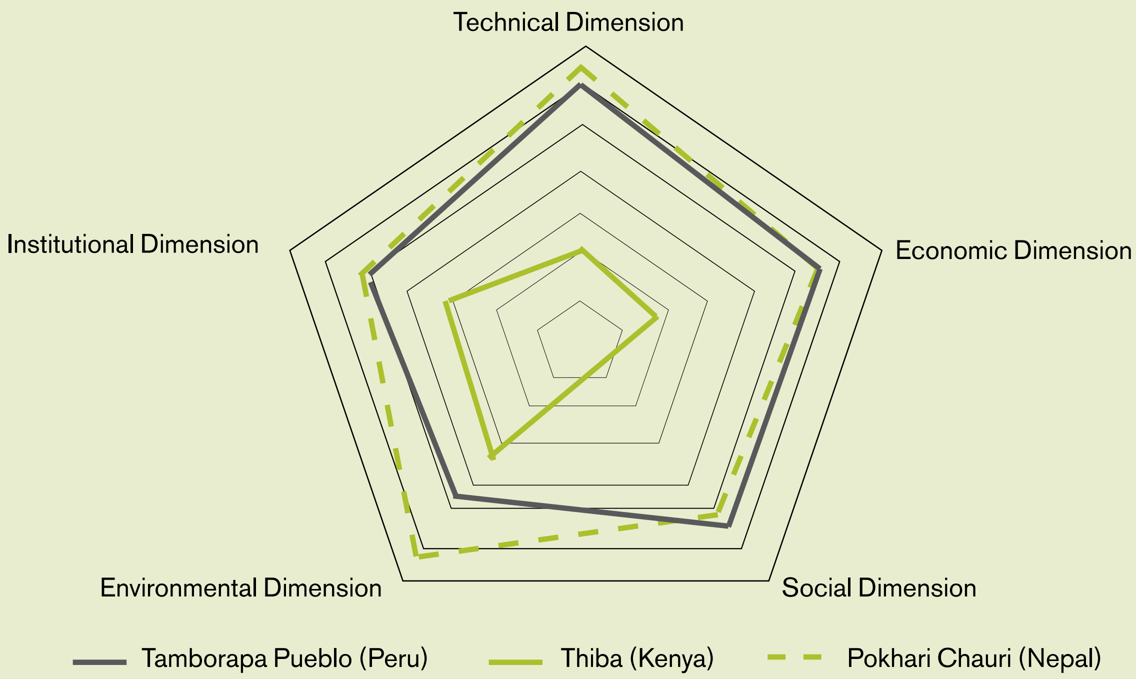
ENVIRONMENTAL DEVELOPMENT	ORGANISATIONAL/ INSTITUTIONAL DEVELOPMENT
Global Impact Local Impact	Capacity Strengthening Client-Relation Stakeholder Participation
1. Electricity is generated from a low carbon source 2. Electricity has replaced other 'dirty'energy sources for lighting (e.g. kerosene) 3. 'Dirty' energy sources for cooking (e.g. firewood) have been replaced or improved 4. Electricity has displaced actual or potential 'dirty' energy sources for powering equipment (e.g. diesel) 5. No adverse local environmental impacts have occurred 6. Adverse local environmental impacts occurred but have been fully rectified 7. Community awareness of environmental issues and environmental surroundings have improved	1. Electricity service management organisation is efficient and effective 2. Local capacity for organisation and management has improved due to electricity 3. High sense of responsibility for system by managers 4. High degree of stakeholder participation in the system if desired 5. Greater empowerment for women through involvement in the electricity system 6. Low level of non-technical losses or payment defaults 7. Users are satisfied with the electricity service 8.Transparent financial accounts are kept 9. There is an effective channel through which complaints about the service can be made

Notes
1. These indicators were designed by the author but were influenced by Ilskog (2008) and Fenner et al. (2006).
2. Economic Development: Indicators 2 – 4 can be obtained cumulatively.
3. Environmental Development: Where Indicator 5 is obtained, Indicator 6 should be omitted and total points should be normalised out of 6. Indicator 6 carries a maximum of 0.5 points (that is, 5.5/7 is the maximum score for this dimension if Indicator 6 is obtained).

Table 3
Sustainability assessment results

	POKHARI CHAURI (NEPAL)	TAMBORAPA PUEBLO (PERU)	THIBA (KENYA)
Technical Dimension (max. 8)	7.5	7	2.5
Economic Dimension (max. 10)	8	8	2.5
Social Dimension (max. 10)	7.5	8	1
Environmental Dimension (max. 6)	5.5	4	3
Institutional Dimension (max. 9)	6.5	6.5	4

Figure 1
Spatial representation of the indicator scores



technicians displayed great resourcefulness to keep the system in operation. The community in Thiba had also shown great leadership and initiative to bring about the hydro plant's construction in the first place.

Although their scores were broadly similar, the REDP's holistic approach (including the creation of separate male and female community organisations, the introduction of toilet-assisted biogas and awareness-raising on environmental issues) gave Pokhari Chauri marginally higher scores than Tamborapa Pueblo. Moreover, migration to Tamborapa Pueblo dramatically increased following the introduction of an electricity service (a testament to the high demand for electricity in rural areas), which placed a heavy strain on system capacity and negatively impacted upon its score. Not all new households could be connected to the electricity service and businesses using electrical machinery (such as carpentry workshops and welders) were not allowed to use their machines after 6pm. Nevertheless, the most efficient and effective management system was the micro-enterprise in Tamborapa Pueblo; this was the only case in which detailed financial accounts were kept. Thiba's management was the least transparent and potentially the most vulnerable

The micro-enterprise electricity service company at Tamborapa Pueblo.

to manipulation and corruption. The separation of management and ownership has arguably improved the effectiveness of the management system in Tamborapa Pueblo as a formal system of checks and balances were in place.

In addition to the sustainability indicators, the case studies were qualitatively analysed with respect to their systems' proven or expected resilience to external shocks and long-term stresses. Resilience is defined as 'the amount of change a system can undergo while maintaining its core properties' (Leach, 2008) and therefore demands that an intervention place due focus on 'adaptive capacity/capability, institutional flexibility and diversity of responses' (Scoones, 2009). In so doing, the intervention becomes less vulnerable to external global and local events such as climatic change, rising oil prices or a power change in local government. Neither Pokhari Chauri nor Tamborapa Pueblo were considered particularly at threat from these events, or from internal corruption. However, the lack of transparency in Thiba's management committee exposed it to a greater risk of internal corruption. The system at Tamborapa Pueblo could be considered slightly more resilient than that at Pokhari Chauri as the management of the former had a greater number of formal ongoing checks on its performance (every two years). But even Tamborapa Pueblo's system is not entirely exempt from potential internal manipulation in the future.

Certain existing trends within the cases also provide cause for concern with respect to the projects' resilience. Notably, the low cost repair works that were being carried out in Thiba not only affected service provision for existing customers (including restricting the amount and breadth of end uses that could be developed), but also limited the speed at which the distribution network could be extended to connect more of the project's shareholders in the future. All existing tariff revenues were being used to conduct repairs and could not be set aside into a reserve fund to ensure that a high quality maintenance service will be conducted or the service expanded in subsequent years. The high level of (ongoing) migration in Tamborapa Pueblo also casts doubt over the system's ability to sustain a high quality of operations and a satisfied, yet inclusive, customer base in future years. Wherever possible, a growth in electricity demand needs to be accounted for in the original project design, particularly if surrounding villages are likely to remain without power as people often migrate to locations that can offer higher living standards. In this case, the scale of the influx to Tamborapa Pueblo would have been difficult to predict. However, wherever possible rural electrification practitioners should aim to future-proof their systems by including demand growth margins. Project resilience is likely to be considerably enhanced if detailed risk analyses are conducted and contingency plans agreed by all the key stakeholders *a priori*.

4
The impact of different delivery models

The concept of project delivery models is used variously by different agents and a consistent definition has yet to be established. Nevertheless, a Department for International Development funded project has defined a project's delivery as 'the way that a project design or a business plan aims to overcome the barriers to scale up and sustainability in energy access and development projects' (Practical Action Website, 2010). This report further expands that definition by explicitly incorporating the intervention's technology choice, implementation process and surrounding support infrastructure (its enabling environment). Several different variables are contained within a delivery model: the assessment of community needs, desires and availability of local resources; management models; productive end uses; the implementing agency's approach; ownership and governance; local skills and training; local job creation; financing; dissemination strategies; and the project's interaction with hardware suppliers and the various financing, regulatory, legal and political institutions and policies that form its enabling environment (see **Figure 2**).

This chapter examines which elements of a project's delivery model are particularly important for the creation of sustainable welfare benefits. Given the greater amount of existing research on pre-implementation assessment and technology selection methodologies, focus was placed on a project's implementation process and interaction with the enabling environment. Findings are based on the data generated by the three main and several less in-depth satellite case studies, 67 expert interviews and a review of existing literature. A full list of interviewees is provided in **Appendix 2**. Wherever possible, the interviews were recorded and transcribed. In accordance with the categorisation used during the coding process, the results will be discussed under the following sub-sections: ownership, management, productive uses, training and job

Figure 2
Variables pertaining to project delivery

Technology Choice
Assessment of Community Needs, Desires & Availability of Local Resources

Implementation Process
Management models, Productive End Uses, Implementing Agency Approach, Ownership and Governance, Local Skills and Training, Local Job Creation, Financing Issues, Dissemination Strategies

Enabling Environment
Financing, Regulation, Legality, Suppliers, Governments & Institutions

creation, implementing approach, dissemination and scaling-up, enabling environment and financing. This chapter describes the key points relevant for each of these areas and provides examples from the field and secondary literature.

Ownership

It is important to engender a strong sense of local ownership to obtain local support and buy-in for the project, and for users to take responsibility for a system's maintenance (where required). This was stressed repeatedly in all countries of research. Communities need to 'accept, internalise and adopt a new project as their own'; without this, they may continue to see the intervention as external and take less interest in its development (pers. comm. Odada, 2010). Communities that have a strong sense of ownership for the project have been known to support the implementing agency and put pressure on local politicians to provide planning approval (*ibid.*).

It can help if users participate in the planning and decision-making process and contribute their own funds towards the initial set-up costs. A renewable energy rural electrification toolkit reports, 'Participation from beneficiaries during all stages of the project cycle is important in encouraging a sense of ownership and increasing their understanding of the technology' (PAC, 2010). Close coordination between planners, project coordinators and villagers should be established, including villagers' participation in the implementation stage, in order to avoid 'a situation whereby the villagers would see the project as introduced from outside' and subsequently not feel responsible for its maintenance (Kivaisi, 2000). Remarkably, during the Nepali civil war (1996–2006), where communities had a strong sense of ownership, their systems withstood attempted destruction by Maoist forces. In some REDP communities, people are said to have challenged rebels to kill them first: the micro-hydro plant belonged to them, not the government (pers. comm. Neupane, 2009).

Obtaining community consensus during the planning stage could strengthen a community's ability to resolve disputes in future, as well as increase local buy-in. In Nepal, it is recommended that full consensus should be sought as a priority even where this may cause delays in the planning and implementation stages (pers. comm. Subedi, 2009). This is to ensure that everyone in the community (including the disadvantaged groups) feels involved and responsible for the project. Addressing concerns and achieving full consensus during the implementation stage should increase community buy-in, improve local organisational capacity and put the community in a better position to settle disputes by itself after the project facilitator has left (Yadoo and Cruickshank, 2010b; Yadoo *et al.*, 2011a).

External facilitation may be required to ensure that decisions are taken on the basis of well-informed judgements. Practitioners warn that without appropriate guidance, communities may take decisions based on friendships or neighbourly alliances rather than on the basis of well-informed judgements (pers. comm. Escobar, 2009). A similar trend has also been noted for rural water supply projects where there is a need to balance 'participation and ownership with good decision making' (Taylor, 2009).

If communities are too poor to provide an initial payment, they could be asked to provide unskilled labour or 'sweat equity'; this does not necessarily detract from sustainability. A study performed by the Judge Business School (albeit on a limited data set) found little correlation between the amount of financial contribution provided by the community for a project and whether or not it operated successfully (Harley *et al.*, 2011a). Other factors, such as the community's initial level of proactiveness, better reflected its willingness to ensure that the project functioned in a sustainable fashion (*ibid.*).

Ownership is only important if a community's sense of responsibility for the system increases; thus, perceived ownership is often more important than legal ownership. In Tamborapa Pueblo, legal ownership for the system remained with the municipality, however, the community still felt responsible for its upkeep as they felt it to be theirs. This distinction between perceived (a sense of) ownership and actual (legal) ownership was field-tested by Harley *et al.* (2011b) who corroborated that the former is of greater import than the latter. Khennas and Barnett (2000) comment that 'Ownership is less important for sustainability than business-like management'.

It can be advisable to spread ownership over a wider set of stakeholders to improve the accountability of the management board. According to the experience of the GIZ Private Sector Participation in Micro-Hydro Programme in Rwanda, faced with internal corruption or mismanagement, enterprises are more resilient when their investment group is composed of a diverse set of stakeholders, including socially motivated equity investors ('business angels') (pers. comm. Pigaht, 2011).

Management

Effective management is essential for project sustainability and welfare impact. This was voiced particularly strongly by Practical Action in Peru and the REDP in Nepal, yet it was also commented upon in the literature, 'Management plays a major role in deciding the success of a micro-hydro plant' (ITDG, 1999). ESMAP (2001) found that it is often the system's management, rather than the technology, which may ultimately cause a project to fail and this has been reiterated in several other studies (ESD, 2003; Krishnaswamy, 2010; Miranda, 2006; Zerriffi, 2007).

In the long term, more formalised management (such as cooperatives or micro-enterprises) is generally better than looser forms of management such as CBOs as greater transparency and accountability can be enforced. In Nepal, greater formalisation can help to improve the transparency, accountability and overall organisational strength of the management board as it can now be penalised if found breaching its codes of conduct. This is also true in Peru, where micro-enterprises and cooperatives are considered more robust than CBOs (pers. comm. Escobar, 2009). A study performed by Practical Action in Nepal has shown that community managed systems 'appear extremely tricky to administer and are unlikely to succeed unless the community is homogenous' largely due to 'inadequate management and operational capacity', advocating instead that a 'corporate structure' with business enterprise models and 'institutionalised operational practices' (including improved documentation and recording practices) should be adopted (Practical Action, 2006).

Only properly trained community members should be assigned the responsibility of managing or operating an electrical system and this responsibility should not be rotated within the community without the training being repeated in full. Although rotation potentially widens participation in the project, it dilutes the chains of accountability and makes it difficult to hold the operators responsible if something goes wrong. The annual or biannual rotation of administrators at the PV battery charging stations in Huancho Lima (Peru) resulted in poor administrative and technical management in later years: the passing of technical knowledge by word of mouth from one administrator to the next was inadequate and community control over collected funds was weak.

It can be more difficult to scale-up and replicate community-led projects than privately led ones. Harley *et al.* (2011b) demonstrated this for the case of Nepal, but the same has been noted for rural solar projects in India (Miller, 2010) and other electrification technologies across the world (Hystra and Ashoka, 2009).

Management by a local cooperative can be an effective way to conduct the less profitable task of rural electricity distribution. There are several examples of cooperative managed rural electrification systems around the world, including in the United States of America, Bangladesh, Costa Rica, the Philippines and Nepal (Yadoo and Cruickshank, 2010a; Yadoo *et al.*, 2011b, *under review*). Cooperative management can effectively deliver electricity services to rural areas, achieving greater operational efficiency and improving customer service, as exemplified in the above-cited cases (*ibid.*; Foley, 2007; Waddle, 2007; Wolman, 2007). The South Lalitpur Rural Electricity Cooperative in Nepal reinvests system profits into the community, shares out dividends and offers micro-loans to members (Yadoo and Cruickshank, 2010a; Yadoo *et al.*, 2011a). Furthermore, non-technical losses (electricity theft) can be considerably lowered when cooperatives take over local distribution networks from public utilities (Pandey, 2005): in Mugling, Nepal, non-technical losses reportedly dropped from 35 per cent to 15 per cent following this shift in management (pers. comm. Dixit, 2009; pers. comm. K.C., 2009).

However, the success of a cooperative management structure depends on a number of factors. A robust community mobilisation process needs to have been conducted prior to project implementation (Neupane, 2009), there needs to have been a precedent of successful cooperatives working in other arenas within the country, and the community should be united with a pre-existing culture of cooperation (pers. comm. Dixit, 2009; Foley, 2007). Cooperatives should also strictly adhere to the principle of full cost recovery and other commercial practices (Foley, 2007; Foley and Logarta, 2007; Waddle, 2007) and adopt rigorous reporting routines to facilitate ongoing national level monitoring and regulation (Waddle, 2007).

Cooperatives could work in tandem with medium- or large-sized private companies (such as tea factories and telecommunications operators) that generate their own electricity from mini-grids in order to extend electricity access to rural households. Local cooperatives such as Kenyan tea farmer associations (for example, the EPK-Outgrowers's Association of Kipchoria) are willing to distribute power to rural customers (including health centres, grain mills and schools) after buying electricity in bulk from the local tea farm (pers. comm. Shrestha, 2010). However, the tea farmers generally require a degree of grant financing, technical and business capacity support from external facilitators such as NGOs before they are able to engage in distribution (*ibid.*).

Rural electricity systems managed by micro-enterprises are often more sustainable than CBO (and even some cooperative) managed systems. There are several examples of micro-enterprise managed rural electricity systems worldwide, including Practical Action's model in Peru (as shown in the Tamborapa Pueblo case study), Dream Power in Bangladesh, Saran Renewable Energy in India, solar charging station franchises in Laos and numerous micro-enterprises that sell solar lanterns and solar home systems. Entrepreneurs have often invested their own money and are keen to see a return, strictly enforcing tariff payment and encouraging productive uses of electricity in order to boost daytime (off-peak) load and system revenues (pers. comm. Adhikari, 2009; Gyawali *et al.*, 2004). This can have a knock-on incremental benefit to the community through a greater array of electrical end uses on offer (ropeways, mills, bakeries, and so forth). Cost-reflective tariffs are charged and this improves the overall sustainability of the system (conversely, the priority in many CBOs is to keep tariffs as low as possible, sometimes even to the detriment of a system's financial sustainability) (pers. comm. Adhikari, 2009; pers. comm. Valenci, 2009). Entrepreneurs may also find it easier than CBOs or cooperatives to suspend services to those clients not paying their bills on time, as testified in the fieldwork conducted in Nepal and Peru and from the reported experience in other countries (Raats, 2009).

However, in some cultures establishing an individual-led for-profit rural business may be stigmatised. Moreover, profit margins are usually slim and it may be difficult to find motivated and talented entrepreneurs willing to invest in rural electrification. The success of micro-enterprise managed electricity systems can depend on local cultural norms and their resultant social acceptability. In Nepal, even small private enterprises can be negatively viewed as profit seeking and are assumed to be more interested in personal gain than the community's welfare (pers. comm. Adhikari, 2009). Together with slim (or non-existent) profit margins, this detracts from the appeal of starting a rural electric business (*ibid.*). Due to low profit forecasts, in Mali, Morocco and South Africa only the more socially orientated community members were interested in becoming shareholders in Electricité de France's Decentralised Services Societies (Massé, 2008).

The high cost (and low profit) nature of rural electricity distribution often dissuades urban-based utilities and distribution companies from investing. The service that they provide in rural areas may also be inferior to that of locally managed systems. Distribution concessions are dissuaded from investing in rural off-grid electrification (even where subsidies are available) as they perceive them to be much more complicated and costly to manage than grid extensions, given their current organisational structure (pers. comm. Zolezzi, 2009). Managers should maintain regular contact with the communities in order to ensure that people pay on time and this can be costly if they are not locally based (pers. comm. Janampa, 2009). In Quishuarcancha, Peru, external management by ADINELSA provided an inferior quality of service: there were long delays to replace faulty equipment and users' complaints were not heeded as it was too difficult for them to reach the national regulator's offices.

Pre-payment technologies can significantly improve the efficiency and effectiveness of centrally managed systems. Pre-pay meters are used by centralised utilities in countries such as Peru, Brazil and South Africa (Bekker *et al.*, 2008). In Peru, ADINELSA has found that using pre-pay meters lowers management costs by about 66 per cent as it is otherwise expensive to administer tariff collections (and disconnect households who do not comply) from a central hub (pers. comm. Zuñiga, 2009). Other techniques include payment cluster groups (whereby smaller groups of users are made jointly responsible for the non-payment of individual households within their group) (Foley and Logarta, 2007), integrated micro-processor chips that allow a manager to remotely disable a system (such as in the case of Sunlabob's rented solar home systems (Gaillard and Schroeter, 2008) or E.quinox's battery boxes (pers. comm. Hamayun and Baker-Brian, 2011)), and the use of local committees, shop keepers or community members to collect payments on the external agent's behalf (Tuntivate and Barnes, 2007). However, although such payment methods can lower costs for utilities, their acceptance 'may depend on existing community trust and social networks' (Wilson and Garside, 2011).

Entrepreneurs are likely to require substantial subsidies, equity or debt financing and an 'anchor load' if they are to invest in larger-scale electrification infrastructure such as mini-grids. Generally speaking, private sector companies prefer to work with solar lanterns, solar home systems or charging stations combined with battery or solar PV rental schemes as the initial capital outlay can often be lower than for mini-grids and their business can be more easily grown in a modular fashion as income becomes available (for example, E.quinox's charging stations in Rwanda, Egg Energy's charging stations in Tanzania and the various solar lantern and solar home system private sector distributors in Kenya). Nevertheless, GIZ's Private Sector Participation in Micro-Hydro Development Project in Rwanda has shown that local investors will invest in micro-hydro projects provided they receive a 50 per cent grant subsidy and debt financing from commercial banks (pers. comm. Pigaht, 2011). The presence of an 'anchor load' such as a factory or grid link is also often pivotal for a system's financial sustainability (*ibid.*; Mulder and Tembe, 2008).

Productive uses

Productive uses of electricity can make a significant contribution to a project's sustainability. An entrepreneur in Barpak, Nepal, found that he had to promote the development of productive uses (milling industry, carpentry workshops, grinding mills, bakery and a ropeway) during off-peak hours in order for his micro-hydro plant to be financially sustainable (Gyawali *et al.*, 2004). Productive uses also increase welfare benefits, 'Productive energy end uses are highly desirable to realise increased benefits from the project' (PAC, 2010). Similar to findings from biogas projects where 'Saving in monetary terms translates into much less of a gain in the eyes of the recipient' (Alwis, 2002), new income streams generated from productive uses are more valued by beneficiaries than cost savings from displaced expenditure on traditional electricity substitutes (pers. comm. Kelly, 2011). The ability to generate additional income will also improve purchasing power, enabling the purchase of more electrical items whose use can further increase the perceived value of electricity as well as generate additional revenue for the managing agency.

Productive uses will not necessarily develop organically and active promotion by way of awareness-raising, training, seed capital and tariff discounts may be required. Some programmes (for example, the REDP) provide training and grants to help a community invest in electrical machinery such as grain mills, rice de-huskers and oil grinders. In Peru, Don Bosco invests in a wide range of productive activities for the benefit of local people and to create a steady baseload demand for the electricity service. EILHICHA (an electrical company formed by Don Bosco) and Practical Action's micro-enterprises have devised special tariffs to incentivise the use of electricity for productive ends. EILHICHA offers a discount for business users during off-peak hours whereas Practical Action has devised a tariff system based on declining blocks whereby the unit cost reduces as more electricity is consumed (Sanchez, 2007). It is important to tailor the design of productive activities to a community's existing livelihoods and socio-cultural idiosyncrasies (pers. comm. Gamio, 2009; PAC, 2010) and care should be taken to avoid over-saturating local markets (pers. comm. Pruneri, 2009).

Complementary investments may need to be made in roads, transport, communications and other infrastructure before economic benefits are realised. As seen in Pokhari Chauri and reflected in the literature elsewhere, it may also be necessary for the government or an external donor agency to invest in other development areas (for example, improving the communications, roads and transportation facilities to local markets) before local income will be raised, 'Without such complementary programs, the full socioeconomic effect of electrification probably will not be realised' (Barnes, 2007).

Training and job creation

It can be beneficial to train local people to operate and carry out the maintenance of their electricity system as fully trained mechanical or electrical engineers do not often live within easy reach. Engaging the services of fully trained engineers may be time-consuming and expensive (pers. comm. Escobar, 2009), therefore 'Ensuring local capacity for continued operation and maintenance is essential for every project' (PAC, 2010). Urban centres often offer Certificates in Electrical Engineering and these could be made an integral part of a local technician's training. The United Nations Industrial Development Organisation (UNIDO) has been criticised for providing inadequate training for users of their Community Power Centres, effectively dumping the technologies without undertaking sufficient community engagement (UNIDO, 2010). As seen during fieldwork at the centrally managed project in Quishuarcancha, it can be better to train and fund local representatives so as to reduce reliance on the frequently absent service manager.

The creation of well-functioning technical support networks can also improve sustainability. Studies advocate 'institutional linkage, monitoring and backstopping at the district and local level' to create project support networks and provide ongoing advice from agencies and donors for technical and other points of concern (Practical Action, 2006). These technical support networks were also commended by interviewees as they would allow users to access assistance and spare parts when they are needed (pers. comm. Gamio, 2009). The Solar Energy Foundation (SEF) places considerable emphasis on establishing sustainable technical support infrastructure for solar PV in Ethiopia, setting up the International Solar Energy School to provide a six-month training course for electrical engineers. To date, 57 technicians have been trained as rural solar energy technicians and are now employed in the 10 SEF solar centres set up as solar maintenance hubs across the country (SEF, 2011; Ashden Awards, 2009).

The installation of a new electricity system can often create jobs. The number of new jobs that are created as a result of electrification varies, depending on the type of management elected (executive members of CBOs and cooperative boards tend to work on a voluntary basis). However, paid positions are normally created for the operators of the electrical plant and the administrator who collects tariff payments and keeps the accounts. Wilson and Garside (2011) recommend the creation of jobs as part of a holistic poverty reduction strategy: 'The more value that local people can capture across the value chain, the more likely that access-to-energy interventions will reduce poverty'. Jobs may also be created where productive uses of electricity are developed, for example, as community mill operators or in micro-enterprises such as bakeries, carpentry workshops and mechanical workshops.

Training may be required to raise knowledge about renewable energy off-grid options among communities, governments, potential financiers and entrepreneurs. There is a strong need to train communities, local and regional governments about renewable energy technologies (pers. comm. Escobar, 2009; Clemens *et al.*, 2010). Human capacity needs to be developed (for example through the training of technicians) if more projects are to be implemented at a faster pace and for the systems to be sustainable. Several E+Co entrepreneurs testified that there is still a grave lack of qualified technicians and trained business people whom they can hire when they wish to scale-up their business (pers. comm. Skuler, 2011). Practical Action Kenya took steps to train locals in operating, maintaining and administering their systems as it was fully acknowledged that the projects' 'continued success depends on good management, particularly with regard to rectifying technical problems, tariff collection, ensuring that the generator does not become overloaded (for example by consumers bypassing their load limiter), and diplomatic resolution of disputes' (Maher *et al*., 2003).

Communities may require managerial as well as technical training. In Peru it was noted that well-organised communities were likely to manage a system well after a project leader or team leaves. Therefore, the community either need to be closely knit with a proven track record of effective community-based groups, or they must receive rigorous training. Working in the sphere of rural sanitation, Bongartz and Chambers (2009) argue that appropriate community facilitation (such as training) will enhance the level of organisation and leadership evident within a community. The technician closest to the project in Huancho Lima believes that the project would have greatly improved had the community received more rigorous training on the administrative and technical aspects of management (pers. comm. Huaraco, 2009).

Implementing approach

Systematic and national level approaches tend to be far more effective in creating sustainable, scalable systems and improving the institutional environment. ESAP in Nepal adopts a sector-wide approach and is involved in national level policy advocacy and institutional development, including the formulation and administration of a subsidy policy for decentralised renewable energy projects (pers. comm. Adhikari, 2009). Similarly, the REDP in Nepal strengthens the country's institutional framework by selecting technical staff to be integrated in the local development planning offices throughout the country (within the District Energy and Environment Section of the District Development Committees). In this way, two or three technical members of staff are employed in every district, ensuring that the awareness and capacities of local planning authorities are raised (pers. comm. Tiwari, 2009).

Awareness of renewable energy off-grid electrification options may need to be raised among national and regional energy planners. Regional and district level off-grid electrification master plans can raise awareness and improve planning systems. In Peru, Practical Action is working to improve the awareness of off-grid renewable energy options and to encourage regional planners to focus on rural areas rather than merely on improving conditions in urban areas where the majority of their voters are based. Creating regional and district Master Plans for Rural Electrification using renewable energy (at the request of and in tandem with the relevant regional authority) endorses a more systematic appraisal of the needs and options available (pers. comm. Escobar, 2009). The REDP also adopts a systematic approach to its project planning. Upon entering a new district, a District Energy Situation Report is written to assess all sites for potential micro-hydro installations in that region. The REDP works on four of these sites at a time only leaving a district when all of them have been fully electrified and all the hydropower potential has been fulfilled (pers. comm. Subedi, 2009).

Local buy-in could be increased if communities play an active role in the planning of their electricity system; however, care should be taken to ensure that participation is inclusive. Practical Action Peru demands a high level of local participation in the decision-making and monitoring of a plant's operation, maintenance and administrative management so that the community take responsibility for the system and recognise the rights and obligations of the various stakeholders (Sanchez, 2007). Given that 'needs are perceived differently by women and men, young and elderly, and by groups of different status within a community' (Wilson and Garside, 2011), one should account for the power inequities of different groups to ensure that decisions are representative of the community as a whole (Yadoo and Cruickshank, 2010b). Subdividing the community into smaller groups during planning sessions (for example, segregating according to gender), is thought to raise the confidence of traditionally under-represented groups and encourage them to subsequently voice their desires and concerns in broader community settings (pers. comm. Subedi, 2009).

Energy planning should be transparent and non-partisan; where relevant, representatives from different political parties could be consulted during planning. Practical Action attempts to engage all local political parties during the planning and decision-making process so as to improve the ongoing sustainability of the model by obtaining consensus across the different political groups that could later take over the administration of local government (and become owners of the electrification system under the Practical Action management model). This non-partisan and transparent approach has also been recommended by others in the field (pers. comm. Gamio, 2009; Foley and Logarta, 2007).

Detailed and realistic work-plans should be drawn and community expectations managed so as to prevent a subsequent loss of trust. Plans should be tailored to a community's specific desires and requirements. A work plan needs to be developed to which all stakeholders (including the community) can agree and it is important to be realistic with objectives so as not to build false hopes (pers. comm. Gamio, 2009.). Unmet expectations can shatter communities' trust in the implementing organisation (pers. comm. Gamio, 2009; pers. comm. Muriithi, 2010). This emphasis on trust building and user expectation management has also been underlined in literature on the experience with solar home systems (Nieuwenhout *et al.*, 2001) and biogas digesters, erroneously high expectations 'will never be met after installation of the plant; product dissatisfaction by the user will prevail, even if the plant is kept in operation' (SNV, 2009).

Projects should be demand-led although a community mobiliser can often assist in increasing local motivation to instigate a project and drive it forward. Few communities contain the strong leadership and proactivity required to see their project through from conception to completion without any external assistance. It is vital that enough interest for the electricity system is generated within the community in order that they desire to keep the system running to a high standard post-installation, 'Social acceptance can make or break adoption of – and payment for – new energy technologies and services' (Wilson and Garside, 2011). This task is thought to be considerably easier if the electricity system is helping to generate additional income for the community as a whole or for a large number of individuals within it (pers. comm. Kelly, 2011). Some organisations (for example ESAP in Nepal) choose to simply inform communities about the potential of renewable energy electrification technologies and then wait until they apply to a regional office for assistance to develop such a project. This approach can generate good results, yet it requires strong leadership and proactiveness within a community themselves, often taking the form of a particularly motivated individual as seen in the case of Thiba. However, such individuals can be difficult to find (Massé, 2008) and a competent community mobiliser or facilitator can substantially enhance the process (Yadoo and Cruickshank, 2010b; Bongartz and Chambers, 2009). A community do not need to have instigated a project as long as they trust the external mobiliser, take on responsibility for the project and are able to appreciate its value (pers. comm. Odada, 2010).

Community mobilisation is essential for instilling a sense of responsibility for the system within the community and it can also be used to stimulate benefits in other development spheres. Community mobilisation was highlighted as an essential component – perhaps the core component – in a successful delivery model in all three countries and the proactivity of a community mobiliser is central to a project's later success (pers. comm. Escobar, 2009; pers. comm. Neupane, 2009). In REDP's approach, the mobilisation process is also used as a gateway to engendering development on a range of other spheres such as women's empowerment, savings groups, water and sanitation improvements, natural resource management, improved cooking stoves and the use of biogas. In this way, the micro-hydro plant becomes the 'interpoint for total development of community' (pers. comm. Subedi, 2009) and the mobiliser's agenda is much more holistic.

Dissemination and scaling-up

The use of pilot projects and demonstration sites can boost awareness (and reduce scepticism) of off-grid technologies. Greater familiarity can encourage others to install an off-grid electrification system. Where communities are proud of their electricity system they often disseminate their knowledge to neighbouring villages and other external contacts, using their project as a demonstration site (pers. comm. Odada, 2010). Prodia's experience in Peru showed that at first only a few families put themselves forward for a SHS as others were unsure of the technology (pers. comm. Ojeda, 2009). After installation, the sceptics' curiosity was satisfied and many more families wanted to participate (*ibid.*). Practical Action and Engineers without Borders Catalonia have established Cedecap, a learning centre in Cajamarca (northern Peru) where technicians and communities can familiarise themselves with different technologies and electricity systems.

Showcasing their system can give a community pride and strengthen their sense of responsibility for its upkeep. Evidence for this was found during fieldwork in Bamabamarca, Peru, Pokhari Chauri, Nepal, and Thiba, Kenya. Implementers should strive to not only make their projects as beneficial to the local community as possible, but also spread information about the work, liaising with the communities to seek permission to use their systems to showcase to others (the communities may be able to earn extra income through this activity, as in the case of Prodia's communities who showcase their Healthy Homes to tourists and government observers for a fee).

Enabling environment

Supportive institutional infrastructure and regulation is required for projects or programmes to be sustainable, scalable and replicable. A World Bank report suggests adopting 'light handed and simplified regulation', whereby the 'national or regional regulator should be allowed (or required) to "contract out" or delegate, either temporarily or permanently, regulatory tasks to other government or nongovernment entities' (Reiche *et al.,* 2006). For example, if the government does not have the capacity to monitor and enforce regulation, competent donor agencies can propel programmes forward and monitor activities. Flexibility is advised to allow regulation to be varied depending on the entity being regulated and 'Quality-of-service standards must be realistic, affordable, monitorable and enforceable' (*ibid.*).

An enabling government can be one that is non-interventionist during the implementation stage, yet consistent and transparent in terms of policies and regulations. Nepal has a supportive institutional framework for decentralised rural electrification (the result of previous work by organisations such as ESAP, the REDP and the Nepali government). The AEPC facilitates, providing guidance and subsidies but does not intervene in the implementation stage. Elsewhere, civil servants could be set stringent targets so that work is propelled forward and does not stall in anticipation of bribes or simply out of laziness and a lack of consequences (pers. comm. Hankins, 2010; pers. comm. Ngeno, 2010). However, if a government is to be non-interventionist in the implementation stage there needs to be a committed and well-regulated private sector (donors or businesses) to conduct rural electrification activities.

Financing

A mixture of loans, investment and subsidies is often required to develop off-grid electricity systems yet it can be difficult for local entrepreneurs and rural communities to gain access to commercial financing. Several organisations are working to improve the lending terms offered by financial institutions by raising their awareness of off-grid renewable energy technologies and business models. They are also helping lending institutions develop innovative loan products and identify high quality products and trustworthy developers with sound business models in whom to invest. Micro-financing institutions (MFIs) are gradually becoming more willing to lend for renewable energy in Kenya and can accept household items as collateral, which simplifies access to financing (pers. comm. Kariuki, 2010). Elsewhere, microfinance has been shown to work 'when carefully structured to suit local situations', Energética in Bolivia lowers loan default rates by allowing 'loan payments to be rescheduled to match agricultural production cycles' (Wilson and Garside, 2011.). However, 'loan shark type behaviour' and 'high lending rates' have dissuaded customers from borrowing from commercial MFIs in India (*ibid.*). In Kenya, commercial banks were not interested in lending to micro-entrepreneurs as the transaction costs would be too high. However, the more decentralised their decision-making processes, the easier it was for them to agree to lend for renewable energy technologies (pers. comm. Kariuki, 2010.).

Partial loan guarantees or access to longer term credit lines may be required to raise the amount banks or MFIs are willing to lend and to facilitate loan repayments. This need is recognised by the World Bank and mentioned in its operational guidelines (Terrado *et al.*, 2008). In Kenya, communities might take out loans for micro-hydro plants but still not raise enough money with which to complete the installation works as the amount financial institutions are willing to lend is too low or the repayment schedule too short (pers. comm. Kariuki, 2010; fieldwork in Kariegi, Kenya, 2010). In Nepal, the political turbulence created an underlying expectation that the government might waive rural debts and many have not been maintaining steady repayments as a consequence (pers. comm. Aryal, 2009). Therefore, Nepali banks have been reluctant to embark upon new lending in this sector without the assistance of partial loan guarantees.

Social investors have provided loan or equity financing for rural energy businesses, yet the investment process can be slow and arduous, particularly as due diligence cannot rely on standard assessment procedures in the absence of credit histories. Socially-motivated financing organisations such as E+Co and ERM Foundation are working to improve access to finance through the direct provision of loans, technical and business support to aspiring entrepreneurs in developing countries. A country's regulatory environment is fundamental: where a country has effective regulation (such as in Asia), it makes it far easier to invest in entrepreneurs and achieve results than in other countries in Africa, or parts of Latin America (pers. comm. Skuler, 2011). Loans are typically offered only after a rigorous due diligence process has taken place – entrepreneurs are given support to improve their business plans and it may take two or three years before it is considered ready for investment. During this time a relationship is built with the entrepreneur and their reliability is tested. Moreover, E+Co only conducts 'serial investing' – the first loan is typically made for a relatively low amount for an initial four or five year period. Further investments may be made for larger amounts if an entrepreneur is able to prove their effectiveness and commitment.

It is extremely difficult to make carbon financing economically viable for rural electrification projects. Applying the concept of suppressed demand (based on the assumption that power will one day reach the community) can raise the baseline level of carbon and therefore provide greater emission reductions. However, most rural electrification projects remain economically unviable as project transaction costs (writing the project design document and conducting annual monitoring) are high (pers. comm. Stevens, 2011). The use of recently formulated Programme of Activity templates should help reduce transaction costs in the future (*ibid.*).

5
Reflections and lessons learned

This chapter reflects upon the research findings that were described in **Chapters 3 and 4**. Three cross-cutting themes are identified as well as strategies for scaling-up and replication. A sample hybrid business model for mini-grid development and a decision support tree for practitioners are provided. The following core recommendations are suggested for the benefit of practitioners and institutions involved in the provision and implementation of rural electrification projects in developing countries:

- During a project's planning and implementation stages, overriding focus should be placed on generating a sense of local responsibility for the electricity system and its upkeep across all key stakeholders, growing local desire for the electricity services provided and stimulating providers to expand their business, and extending the scope of the project across different development arenas to create maximum welfare impact.
- A number of concrete steps can be taken to achieve this, many of which fall under the categories of ownership, management, productive uses, training and job creation, financing and implementing approach (see Figure 3).
- Rather than focusing exclusively on a project's micro level, attempt to influence and build the institutional framework and environment in which the project takes place (raising awareness of renewable energy off-grid technologies, training technicians, improving access to finance, establishing regulation and national support policies). In so doing, the ability for a project's benefits to be scaled-up and replicated should increase.
- Try to engage the private sector through more innovative partnerships and hybrid business models, provided a supportive institutional and financial environment is already in place. If successful, private sector involvement should help accelerate scaling-up and replication.
- Be aware that there is no one-size-fits-all solution. Take care to tailor the rural electrification system to cater for the specific needs, desires and cultural specificities of different communities. This will be particularly relevant with regard to the choice of management model.

Cross-cutting themes

The research set out to assess which elements of a project's delivery model are particularly important for the creation of sustainable welfare benefits. Analysis of the case study research conducted in rural Nepal, Peru and Kenya, 67 expert interviews and a wide-ranging literature review identified the three most salient cross-cutting themes to be those of Responsibility, Impetus and Scope. The key components of each theme are presented in **Figure 3**; however, their boundaries are not entirely discrete and elements of all three may at times overlap.

Responsibility refers to the extent to which a sense of duty for the off-grid electricity system among users, managers and local support staff (such as implementing agencies, governments, manufacturers or financiers) has been created and it is arguably the most important factor that will influence the likely sustainability of a project or programme. **Impetus** denotes the need for incentives that will encourage users, managers and investors to provide ongoing support for the

Figure 3
Summary of research findings

Responsibility

- Perception of ownership can increase reponsibility and be more important than legal ownership
- Financial contributions, 'sweat equity', project showcasing, and local participation in planning and decision-making can create sense of ownership and responsibility for users, while responsibility in management can be instilled through rigorous training, selection tests ongoing monitoring and community mobilisation
- Community mobiliser can provide guidance and external objectivity
- More formalised management (and a wider group of owner-stakeholders) can improve transparency and accountability

Impetus

- Users do not have to be particularly proactive in the first instance provided that their interest in the project can be aroused through facilitation (for example, by a community mobiliser)
- If the electricity system meets users' needs and desires, generates additional welfare benefits, income and local employment, users are likely to have a strong impetus to keep it going
- Managers and technicians should be paid an appropriate wage for their services to maintain their motivation
- Sustainable business models should be developed to incentivise private sector involvement

Scope

- A broad range of welfare impacts, income generating uses of electricity and local employment opportunities should be created
- Awareness raising, training, seed capital and investment in surrounding infrastructure may be needed to develop productive uses and increase their ability to alleviate poverty
- Adoption of a holistic approach with energy at the heart of broader developments is recommended
- Enabling environment can be improved by increasing access to financing and technical support networks, conducting awareness-raising and effective monitoring, and working alongside national governments to improve policies and institutions

Sustainable Welfare Benefits

electricity system, as well as to scale-up and replicate the project's activities. **Scope** describes the extent to which holistic development benefits are achieved and a project's institutional environment is strengthened so as to create a sustainable sector and increase a project's chances to be sustained, scaled-up and replicated.

Scaling-up and replication

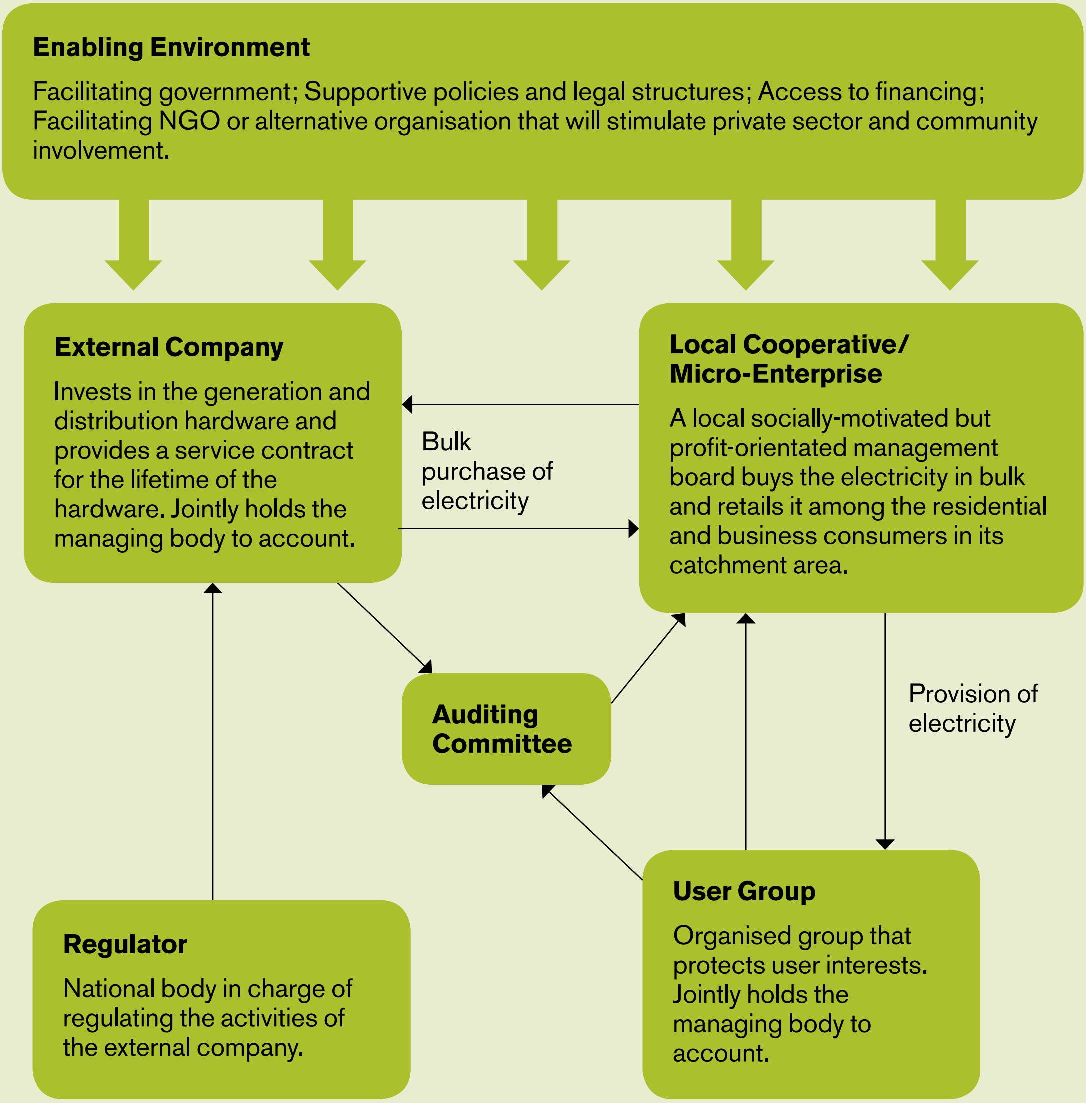
The creation of sustainable welfare benefits can also be maximised through the scaling-up and replication of successful interventions. However, the ability for a project to be scaled-up or replicated largely depends on the supporting conditions: in this respect, an enabling environment can play a pivotal role.

First, there needs to be widespread awareness of the range of off-grid electrification options and their respective advantages and disadvantages. Not only potential users, but local planning and financing agencies could also benefit from demonstrations and training in this regard. The current knowledge gap is limiting grass-root demand, planning and financing capacity for renewable energy off-grid projects in rural areas. Using well-implemented projects as demonstration sites can create an additional flow of income for the host community and significantly improve the ability for projects to be replicated across the country or region. Designated renewable energy learning centres can also help increase awareness and familiarity with such technologies, as well as establish a network of technicians capable of surveying, designing, installing and maintaining renewable energy electrification systems. Some of these technicians could be integrated into the local and regional level development planning commissions to boost capacity and technical understanding in the relevant public sector bodies.

Second, national and regional level coordination is required to achieve a more systematic approach to electrification and facilitate scaling-up and replication. National, regional and municipal governments can play a pivotal role in this regard. Moreover, transparent, streamlined and consistent policies supportive of rural electrification and renewable energy technologies need to be formed by the national government and followed by well-regulated independent implementing agencies.

In addition to an enabling environment, private sector approaches to rural electrification could be sought to more rapidly scale-up and broaden the reach of successful projects (Hystra and Ashoka, 2009; Gradl and Knobloch, 2011). However, as with other examples of rural electrification, there is often little incentive for profit-motivated companies as profit margins tend to be slim (this is particularly true for mini-grid-based infrastructure as capital costs can be relatively high (ESMAP, 2007; Yadoo and Cruickshank, 2010a). To date, private sector companies have generally concentrated on lower unit cost over-the-counter electrification products such as solar home systems, solar lanterns or battery charging businesses, which can be more easily scaled-up and disseminated (for example, ToughStuff International, D.Light, Tecnosol Nicaragua, E.quinox, Egg Energy, and so forth). But such products are limited in capacity and unable to provide as many welfare benefits or productive uses as larger capacity mini-grids (Yadoo and Cruickshank, 2012). Moreover, as this research has shown, local community-managed projects can contribute several advantages with regard to the distribution side of an electrification business (for example, lowered instances of theft, improved tariff collection and speedier repairs). Similarly, a recent policy paper urges practitioners to consider 'local people not only as consumers but also as producers or distributors, and as co-designers of products and business models' (Wilson and Garside, 2011). To this end, hybrid business models could be sought (see **Figure 4**) in order to exploit the different comparative advantages offered by a range of stakeholders.

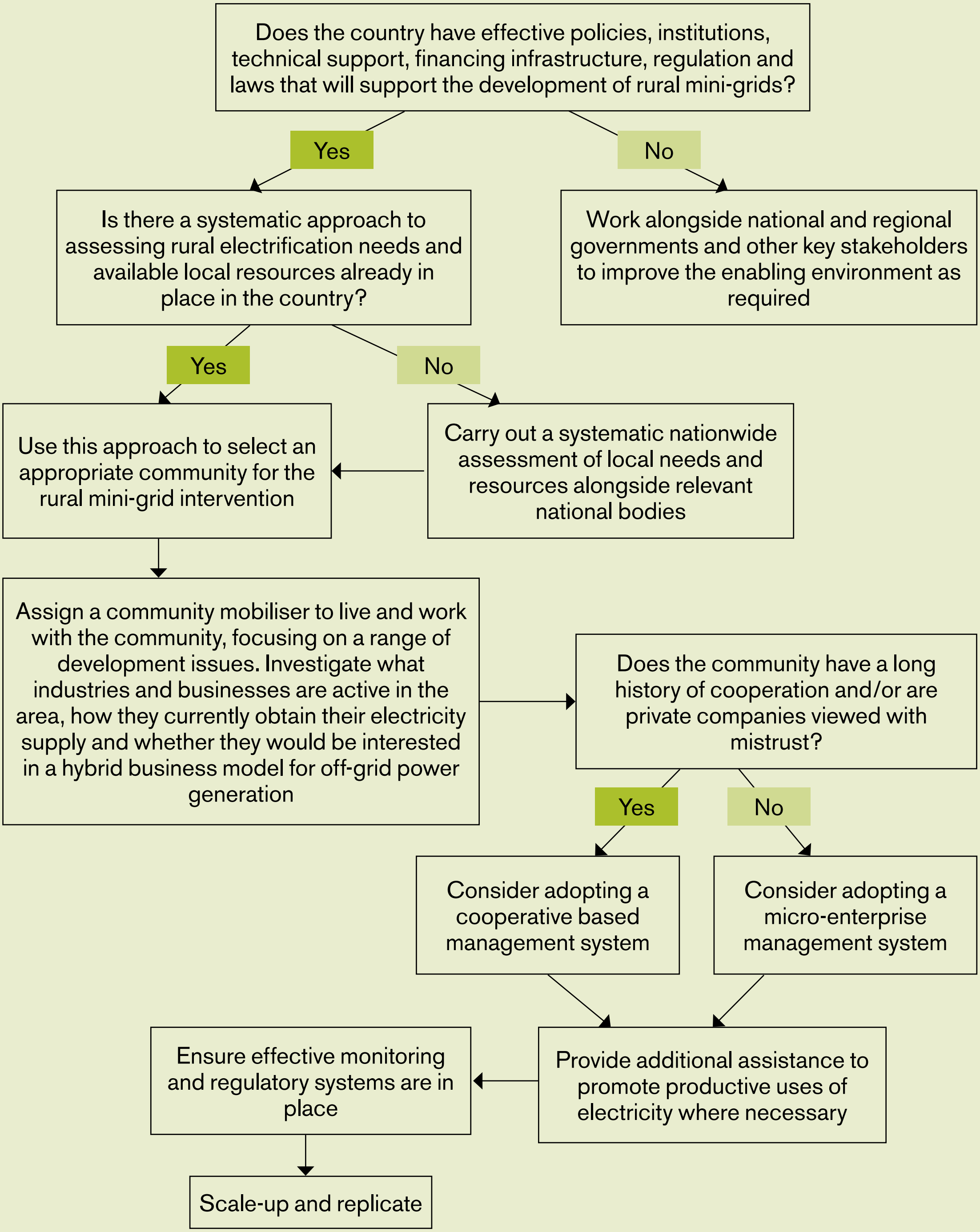
Figure 4
Sample hybrid business model for mini-grid development



Distribution grid and street lighting in Tamborapa Pueblo

An external company is likely to have greater access than a community-based project development team to the financing and technical skills required for the installation and continued maintenance of a mini-grid's generation and distribution hardware. However, as shown through the experience of the Groupe Spécial Mobile Association and Greening the Tea Industry in East Africa (these have been promoting the building of household distribution grids in association with large anchor loads such as that of a telecommunications base station or tea factory), private sector companies are reluctant to become involved in the distribution of electricity to residential customers, perceiving it to be costly, risky and complex (pers. comm. Gubbi, 2010; pers. comm. Shrestha, 2010). Moreover, even external companies (such as distribution concessions) that have been specifically tasked with extending rural electricity access can show reluctance to engage in electricity distribution in rural areas (pers. comm. Valencia, 2009; pers. comm. Mamani, 2009). But as a community's comparative advantage is distribution management, one potential option would be for a private company to finance and service rural electrification infrastructure (or subcontract a qualified firm to do so), and for a local management committee such as a cooperative or local micro-enterprise to buy their energy in bulk and manage the distribution to local residents. The private company could be a designated energy services provider or a nearby telecommunications operator or factory that requires off-grid electrification for its own use.

Figure 5
Decision support tree for practitioners



A similar precedent has been set to good effect in countries such as the United States of America, Bangladesh, Costa Rica, the Philippines and Nepal, where local cooperatives manage the distribution of grid electricity in rural areas (Yadoo and Cruickshank, 2010a; Yadoo *et al.*, 2011b, *under review*). For remote off-grid projects (which are normally too costly to connect to the grid, precluding feed-in tariffs), the presence of a commercial end user (such as a factory) as an anchor load should improve financial sustainability (Mulder and Tembe, 2008). However, adequate institutional and financial support is likely to be required before a private company will be interested in the business venture. Moreover, the government should ensure that effective regulation is in place to monitor its activities. Likewise, an auditing body – composed of the user group and the external company investing in the generation equipment – should be established to improve the effectiveness of the local management committee. Finally, the rights and obligations of each party (the external company, local management team and users) should be transparent, formalised and enforceable by law.

Adjusting for contextual factors

The majority of this research's conclusions were not found to be country specific, despite the deliberate selection of case studies from three continents to reflect different physical, institutional, economic and socio-cultural domains. This having been said, the enabling environments in the three countries did vary considerably and this impacted upon the types of projects encountered, their sustainability and potential to be scaled-up and replicated. At the community level, the largest difference between countries related to the choice of management model employed: micro-enterprises found it more difficult to gain traction in Nepal than in Kenya or Peru, as they were regarded with some distrust. Conversely, due to a strong tradition of cooperation and more closely-knitted communities, cooperatives were generally considered more effective in Nepal than in Peru or Kenya where such traditions were not as predominant.

In spite of the relatively minor inter-country differences at the community level, different delivery models did appear to work better than others depending on a project's specific contextual factors. A decision support tree has been designed (**Figure 5**) to incorporate the results of this research for the benefit of rural electrification practitioners worldwide.

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Appendix 1
Indicator results

Technical dimension indicator results

	POKHARI CHAURI (NEPAL)	TAMBORAPA PUEBLO (PERU)	THIBA (KENYA)
1. Service is reliable, disruptions are minimal	Yes	Yes	No (frequent blackouts and brownouts)
2. Service meets demand capacity requirements	Yes	No (unmet demand due to pop. rise)	Yes
3. System is efficient and technical losses are minimised	Partly (energy efficient bulbs not used)	Yes	No (no transformers or meters have been installed, high inefficiencies)
4. System is compatible with future grid service	Yes	Yes	No (problems with turbine, poorly constructed distribution grid)
5. Support infrastructure (expertise, supply parts) is readily available	Yes	Yes	Partly (operators have been trained but quality repairs too costly)
6. System is well maintained	Yes	Yes	No (low quality components leading to equipment failure)
7. Advance notice about planned service disruptions is given to users	Yes	Yes	No (users complain of poor info.)
8. Service is safe to use and operate	Yes	Yes	Yes
Total (max. 8) Key: Yes = 1, Partly = 0.5, No = 0	7.5	7	2.5

Economic dimension indicator results

	POKHARI CHAURI (NEPAL)	TAMBORAPA PUEBLO (PERU)	THIBA (KENYA)
1. Service is affordable for users	Yes	Yes	Yes
2. System breaks even (O&M costs are met)	Yes	Yes	Partly (in operation but funds are insufficient for optimal maintenance work)
3. System is profitable, excl. capital costs	Yes	Yes	No (no profits generated)
4. System is profitable, incl. capital costs	No (initial costs too high to recoup through tariffs)	No (initial costs too high to recoup through tariffs)	No (initial costs too high to recoup through tariffs)
5. A share of the profits is re-invested in the electricity service	Yes	Yes	No (no profits generated)
6. Electricity is used by local industries	No (there are none)	No (there are none)	No (power not supplied)
7. Electricity is used by a broad range of micro-enterprises	Yes	Yes	No (poor service quality restricts development)
8. Electricity is used to improve agricultural activities (irrigation, food processing, refrigeration of goods)	Yes	Yes	No (poor service quality restricts development)
9. Local employment opportunities have increased due to electricity	Yes	Yes	Yes
10. Profits from micro-enterprises or livelihoods have increased due to electricity	Yes	Yes	No (poor service quality restricts development)
Total (max. 10) Key: Yes = 1, Partly = 0.5, No = 0	8	8	2.5

Social/Ethical dimension indicator results

	POKHARI CHAURI (NEPAL)	TAMBORAPA PUEBLO (PERU)	THIBA (KENYA)
1. Electricity is used in schools	Yes	Yes	No (school is not connected)
2. Education has improved due to electricity	Yes	Yes	No (no improvement)
3. Electricity is used in health centre	Yes	Yes	No (health centre not connected to system)
4. Healthcare has improved due to electricity	Yes	Yes	No (no improvement)
5. Electricity is used in community centre	No (not used)	Yes (in church)	No (not used in the churches)
6. Existence of street lights	No (no street lights)	Yes	No (no street lights)
7. Telecommunications have improved due to electricity	Yes	Yes	No (no improvement)
8. Women's burdens have reduced due to electricity	Yes	Yes	Yes
9. Micro-credit (or alternative) possibilities are available for electricity services connection and tariff payment where necessary	Partly (saving groups provide loans to poorest)	No (no provision)	No (no provision)
10. All households who want it have access to electricity service	Yes	No (unmet demand)	No (unmet demand)
Total (max. 10) Key: Yes = 1, Partly = 0.5, No = 0	7.5	8	1

Environmental dimension indicator results

	POKHARI CHAURI (NEPAL)	TAMBORAPA PUEBLO (PERU)	THIBA (KENYA)
1. Electricity is generated from a low carbon source	Yes	Yes	Yes
2. Electricity has replaced other "dirty" energy sources for lighting (e.g. kerosene)	Yes	Yes	Partly (only when there is no blackout)
3. "Dirty" energy sources for cooking (e.g. firewood) have been replaced or improved	Partly (some ICS and TABs are used)	No (cooking unaffected)	Partly (only for some families)
4. Electricity has displaced actual or potential "dirty" energy sources for powering equipment (e.g. diesel)	Yes	Yes	No (poor quality service prevents electricity being used to power equipment)
5. No adverse local environmental impacts have occurred	Yes	Yes	Yes
6. Adverse local environmental impacts occurred but have been fully rectified	n/A	n/A	n/A
7. Community awareness of environmental issues and environmental surroundings have improved	Yes	No (no noticeable improvement)	No (no noticeable improvement)
Total (max. 6) Key: Yes = 1, Partly = 0.5, No = 0	5.5	4	3

Institutional/Organisational dimension indicator results

	POKHARI CHAURI (NEPAL)	TAMBORAPA PUEBLO (PERU)	THIBA (KENYA)
1. Electricity service management organisation is efficient and effective	Partly (improvements required)	Yes	No (potentially vulnerable to corruption)
2. Local capacity for organisation and management has improved due to electricity	Yes	Yes	Partly (committee formed but does not seem robust)
3. High sense of responsibility for system by managers	Yes	Yes	Yes
4. High degree of stakeholder participation in the system if desired	Yes	Yes	Yes
5. Greater empowerment for women through involvement in the electricity system	Yes	No (no gender specific approach adopted)	Partly (token role for women on committee)
6. Low level of non-technical losses or payment defaults	No (there are still some payment defaults)	No (there are still some payment defaults)	Yes
7. Users are satisfied with the electricity service	Yes	Partly (some complain of over-stretched capacity)	No (frequent blackouts and brownouts)
8.Transparent financial accounts are kept	No (not kept)	Yes	No (not kept)
9. There is an effective channel through which complaints about the service can be made	Yes	Yes	No (no effective channel)
Total (max. 9) Key: Yes = 1, Partly = 0.5, No = 0	6.5	6.5	4

Appendix 2
Interviews conducted

DATE OF INTERVIEW	INTERVIEWEE (JOB TITLE AT TIME OF INTERVIEW)	LOCATION OF INTERVIEW
15 Aug. 2008	Teodoro Sanchez (Practical Action) – Energy Technology and Policy Advisor	Rugby, UK
9 Dec. 2008	Mike Enskat (GIZ) – Project Leader, Energy for Sustainable Development	Telephone
16 Feb. 2009	Nicolas Lambert (EuropeAid, European Commission) – Head of the Energy Facility	Brussels, Belgium
16 Feb. 2009	Stefan Zens (EuropeAid, European Commission) – Head of Energy Infrastructure	Brussels, Belgium
17 Feb. 2009	Kjell Larsson (DG Development, European Commission) – Head of Energy	Brussels, Belgium
9 March 2009	Kavita Rai (Global Village Energy Partnership International) – Programme Manager	London, UK
21 June 2010	Sagar Gubbi (Development Fund, Groupe Speciale Mobile Association) – Consultant, Community Power	Email Exchange
3 Aug. 2010	David Sogan (Live Energy) – Director	London, UK
6 Jan. 2011	Srinivas Krishnaswamy (Vasudha Foundation) – Director	Skype
7 April 2011	Mansoor Hamayun and Christopher Baker-Brian (E. quinox, BBOXX) – Founding Directors, Partners	Skype
21 April 2011	Jo Kelly (Renewable World) – Programmes Development Director	Cambridge, UK
28 April 2011	Mario Merchan Andres (formerly GIZ) – former Project Manager for PSP Hydro in Rwanda	Email Exchange
10 May 2011	Maurice Pigaht (Renewable Energy Consultant, formerly GIZ) – former Project Manager for PSP Hydro in Rwanda	Skype
24 June 2011	Robert Stevens (ClimateCare) – Vice President	Skype
27 June 2011	Leehe Skuler (E+Co) – Strategic Business Development	Skype
	NEPAL	
4 May 2009	Dilli Ghimire (National Association of Community Electricity Users in Nepal) – President	Kathmandu, Nepal

5 May 2009	Prem Sagar Subedi (Rural Energy Development Programme) – Livelihoods Promotion Advisor	Kathmandu, Nepal
5 May 2009	Devendra Adhikari (Energy Sector Assistance Programme) – Component Manager, Mini-Grid Rural Electrification Component	Kathmandu, Nepal
5 May 2009	Mahendra Neupane (Rural Energy Development Programme) – Human Resource Development Advisor	Kathmandu, Nepal
7 May 2009	Ram Prasaat Tiwari (Rural Energy Development Programme) – Energy Development Officer	Dhulikhel, Nepal
8 May 2009	Manu Binod Aryal (Rural Energy Fund) – Programme Officer	Kathmandu, Nepal
21 May 2009	Abhimanyu KC (Renewable Energy Project) – Technical, Monitoring and Evaluation Coordinator	Kathmandu, Nepal
26 May 2009	Ugan Manandhar (World Wide Fund for Nature Nepal) – Senior Alternative Energy Officer	Kathmandu, Nepal
27 May 2009	Jun Hada (Practical Action Nepal) – Head of Access to Infrastructure	Kathmandu, Nepal
28 May 2009	Ajaya Dixit (Nepal Water Conservation Foundation)	Kathmandu, Nepal
28 May 2009	Dipak Gyawali (former Minister for Water Resources)	Kathmandu, Nepal
	PERU	
24 Oct. 2009	Lino Pruneri (EILHICHA) – Head of Operations	Lima, Peru
24 Oct. 2009	Felix Jan (EILHICHA) – Coordinator and Electrical Engineer	Lima, Peru
26 Oct. 2009	Pedro Gamio Alta (Global Village Energy Partnerships Latin America) – Regional Manager Latin America and former Vice Minister for Energy	Lima, Peru
27 Oct. 2009	Carlos Centeno (Ministry of Energy and Mines) – Chief Evaluator	Lima, Peru
29 Oct. 2009	Hugo Sulca (Ministry of Energy and Mines) – Head of Planning in the Department of Rural Electrification	Lima, Peru
29 Oct. 2009	Ciro Zuñiga (ADINELSA) – Head of Commercialisation and Systems	Lima, Peru

2 Nov. 2009	Eduardo Janampa (ADINELSA) – Regional Project Coordinator in Pasco, Junin and Ayacucho	Lima, Peru
2 Nov. 2009	Wilfredo Herrera (ADINELSA) – Regional Project Coordinator in Cajamarca	Lima, Peru
2 Nov. 2009	Jorge Velasquez (ADINELSA) – Commercial Supervisor in the Department of Non-Conventional Energy	Lima, Peru
2 Nov. 2009	Manfred Horn (Centre for Renewable Energy, National University of Engineering) – Professor	Lima, Peru
5 Nov. 2009	Miguel Ramos (Department for Renewable Energy)	Puno, Peru
5 Nov. 2009	Jorge Huaraco (Private entrepreneur with solar energy business)	Puno, Peru
5 Nov. 2009	Edgar Mina (Centre for Renewable Energy, National University of Engineering) – Technical team member	Puno, Peru
7 Nov. 2009	Cesar Rivasplata (Eurosolar) – Evaluator	Puno, Peru
9 Nov. 2009	Luis Mamani (Electropuno) – Head of Operations and Maintenance	Puno, Peru
10 Nov. 2009	Luis Acosta (Practical Action Peru) – Sicuani Project Worker	Lima, Peru
10 Nov. 2009	Rafael Escobar (Practical Action Peru) – Head of the Regional Office in Cajamarca	Lima, Peru
13 Nov. 2009	Rosalinda Pastor (Regional government of Loreto)	Lima, Peru
14 Nov. 2009	Pedro Sanchez (Solartec) – Director	Lima, Peru
16 Nov. 2009	Anna Garwood (Green Empowerment) – Executive Director	Cajamarca, Peru
16 Nov. 2009	Benito Ramirez (Practical Action Peru) – Sociologist	Cajamarca, Peru
17 Nov. 2009	Jose Delgado (Technosol) – Director (Entrepreneur)	Cajamarca, Peru
18 Nov. 2009	Jorge Valencia (Hidrandina) – Director	Cajamarca, Peru
20 Nov. 2009	Mariela Ojeda (Prodia) – Project Worker	Skype
20 Nov. 2009	Roseles Machuca (Regional government of Cajamarca) – Head of Economic Development	Cajamarca, Peru
15 Dec. 2009	Eduardo Zolezzi (World Bank) – Consultant	Lima, Peru
16 Dec. 2009	Oliver Marcelo (Practical Action Peru) – Acting Head of Energy Programme	Lima, Peru

	KENYA	
7 Aug. 2010	Robert Mutsaers (GPower) – Co-Director	Skype
26 Aug. 2010	Eric Odada (University of Nairobi) – Professor and Director of ACCESS	Nairobi, Kenya
27 Aug. 2010	Eric Muga (Powergen Technologies) – Engineer	Nairobi, Kenya
27 Aug. 2010	Joseph Nganga (Renewable Energy Ventures) – Chief Executive Officer	Nairobi, Kenya
27 Aug. 2010	Leo Blyth (Lighting Africa) – Technical Advisor	Nairobi, Kenya
1 Sept. 2010	Henry Gichungi (Kenya Power and Lighting Company) – Deputy Manager, Off-grid Power Stations	Nairobi, Kenya
2 Sept. 2010	Daniel Macharia (Global Village Energy Partnerships Kenya) – Regional Programme Manager	Nairobi, Kenya
3 Sept. 2010	Mark Hankins (Renewable Energy Consultant)	Nairobi, Kenya
4 Sept. 2010	Anthony Ngeno (Winafrique) – Managing Director	Nairobi, Kenya
6 Sept. 2010	James Muriithi (Rural Electrification Authority) – Senior Engineer, Renewable Energy Generation	Nairobi, Kenya
7 Sept. 2010	Samwel Kinoti (Sky Link Innovators) – Co-Director	Nairobi, Kenya
13 Sept. 2010	Phyllis Kariuki (Global Village Energy Partnerships Kenya) – Financial Institution Support and Liaison Specialist	Nairobi, Kenya
15 Sept. 2010	John Kapolon (Practical Action Kenya) – Project Officer	Nairobi, Kenya
23 Sept. 2010	Bhola Shrestha (Greening the Tea Industry in East Africa) – Project Manager	Skype

Access to affordable, reliable and clean energy is fundamental for poverty reduction and sustainable development; without it, the Millennium Development Goals cannot be achieved. Electrification, along with access to modern cooking fuels and mechanical power, is a catalyst for improvements in the fields of poverty reduction, food security, health, education and gender equality. Nevertheless, 1.3 billion people still lack access to electricity, of which over 95 percent live in sub-Saharan Africa or developing Asia and 84 per cent are in rural areas.

The purpose of this report is to analyse the impact of delivery models on the creation of sustainable welfare benefits. Three case studies are selected, comprising one renewable energy mini-grid project or programme from Nepal, Peru and Kenya. Although rural electrification poses a great challenge to all three countries (only 32 per cent of rural Nepalese, 23 per cent of rural Peruvians and 10 per cent of rural Kenyans have access to electricity in their homes), their different physical, institutional, economic and socio-cultural contexts have led to different approaches to rural electrification.

The majority of the report's conclusions are not country-specific, despite the deliberate selection of case studies from three continents to reflect different physical, institutional, economic and socio-cultural domains. The enabling environments in the three countries vary considerably, impacting upon the types of projects encountered, their sustainability and potential to be scaled-up and replicated. The report presents core recommendations for the benefit of practitioners and institutions involved in the provision and implementation of rural electrification projects in developing countries.

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ISBN 978-1-84369-868-5