SMART VILLAGES

New thinking for off-grid communities worldwide

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Smart Villages: New thinking for off-grid communities worldwide

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Published in 2015 by Banson, 27 Devonshire Road, Cambridge CB1 2BH

ISBN: 978-0-9932932-0-7 (paperback); 978-0-9932932-1-4 (hardback)

Citation: Heap, R.B. (ed) 2015. *Smart Villages: New Thinking for Off-Grid Communities Worldwide*. Banson/Smart Villages Initiative.

This publication was made possible through the support of grants from the Templeton World Charity Foundation and the Cambridge Malaysian Education and Development Trust.

Copy editor: Helen de Mattos
Design and layout: Banson
Printed in the UK by Lavenham Press

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For forty years the development challenge has been a rich world of one billion people facing a poor world of five billion people.

Paul Collier, The Bottom Billion, 2008

The basic truth is that for less than a percent of the income of the rich world nobody has to die of poverty on the planet. That's really a powerful truth.

Jeffery Sachs, UN General Assembly, 2006

Millions can be lifted out of poverty without ruining the planet with the help of clean sustainable energy.

Practical Action (formerly ITDG),

Power to the People, 2002

Energy is the golden thread that connects economic growth, increased social equity, and an environment that allows the world to thrive.

UN Secretary-General Ban Ki-moon,

Sustainable Energy for All initiative, 2011

Food security and energy security are closely related, but they need the underpinning of environmental security and sustainability.

M.S. Swaminathan, 2015

Like slavery and apartheid, poverty is not natural. It is man-made and it can be overcome and eradicated by the actions of human beings.

Nelson Mandela, 2005

The greatest thing on Earth is to have the love of God in your heart, and the next greatest thing is to have electricity in your house.

Tennessee farmer,1930s

The extent of physical hardship imposed on poor women in acquiring and using energy for the most basic survival needs is an enslavement that denies them vital opportunities to escape their state of deprivation.

K.V. Ramani, Energy as an Instrument of Women's Economic Empowerment, 2002

Foreword

I warmly welcome the publication of this important collection of expert essays following the launch of the Smart Villages Initiative on 27 January 2015, hosted by the University of Malaysia Sarawak (UNIMAS – Universiti Malaysia Sarawak) in Kuching, Sarawak, Malaysia. The launch was attended by the Honourable Datuk Dr Erwin Ebin, Minister of Science, Technology and Innovation, Sarawak; Tan Sri Dr Ahmad Tajuddin Ali, President of the Malaysian Academy of Sciences (Akademi Sains Malaysia); the Honourable Datuk Haji Talib Zulpilip, Chairman of Sarawak Economic Development Corporation; and Professor Dato' Dr Mohamad Kadim Suaidi, Vice-Chancellor of UNIMAS.

A highly successful workshop followed the launch, in which the Malaysian Academy of Sciences played a key role. The Kuching workshop attracted participants from a wide range of countries, including Cambodia, Indonesia, India, Myanmar, the Philippines, Singapore and Thailand, as well as Canada and several countries in Africa and Europe. It also coincided with Malaysia's 2015 chairmanship of ASEAN, the Association of Southeast Asian Nations.

Malaysia has been in the vanguard of rural electrification, and today's high-tech smart villages under construction are improving the lives of numerous rural families, while promoting environmental sustainability. Estimates show that today, only 1.3 per cent of the rural population of Malaysia is without electricity.

Early steps towards electrification were taken shortly after the Second World War, as pointed out by Tan Sri Ir Ahmad Zaidee Laidin, chair of the organising committee of the workshop, in his essay. Building blocks of the Government Transformation Programme were introduced in 2010, providing a roadmap towards achieving the status of developed country by 2020.

Strong links exist between Malaysia and the United Kingdom, sustained by the many highly talented students from Malaysia who have studied at British universities, Cambridge among them.

I am particularly delighted to note that the Cambridge Malaysian Education and Development Trust (CMEDT), which was founded in 2010 under the chairmanship of the Honourable Dato' Sri Mohamad Najib bin Tun Abdul Razak, Prime Minister of Malaysia, has played a formative part in enabling this new Smart Villages Initiative to get off the ground, together with the Malaysian Commonwealth Studies Centre at Cambridge (MCSC), founded by the Honourable Tun Dr Mahathir bin Mohamad, formerly Prime Minister of Malaysia.

I commend these essays to everyone concerned about energy for development, and in particular to policy makers and decision takers as we seek to lift the disadvantaged in our communities out of the bottom billion.

Tun Ahmad Sarji bin Abdul Hamid
Chairman, Executive Committee,
Cambridge Malaysian Education and Development Trust
Joint-Chairman, Executive Committee,
Malaysian Commonwealth Studies Centre at Cambridge

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Preface

The significance of international development as we know it today was anticipated in President Truman's inaugural address in 1949 – "a bold new program for making the benefits of scientific advances and industrial progress available for the improvement and growth of underdeveloped areas". Six decades later, the argument continues about the contribution that techno-utopian views – commonplace in today's high-tech world – can make towards international development. Yes, real reductions in poverty and hunger have been achieved in pursuit of the Millennium Development Goals, but there is still a long way to go.

The aim of these essays is to explore access to energy as an entry point for rural development. On the supply side, what are the scientific and technological advances of today and tomorrow that could transform the way that energy, particularly electricity, could be made more readily available for rural transformation? On the demand side, what are the enabling factors that make energy access a catalyst for sustainable development in off-grid villages? What framework conditions need to be put in place so that local entrepreneurs can establish enterprises to deliver and make productive use of energy in remote villages, the home of some 1.3 billion poor and underserved (Holmes and van Gevelt)?

New technologies emerge from basic science, but innovation to bring those technologies to rural markets and in associated financing and business models is essential. Energy derived from modern technologies promises to make the transition from fossil fuels to renewable sources of energy more realistic, though how market volatility will influence their sustainability in developing countries remains to be seen. In remote parts there may be little choice in terms of the technologies available, but a range of new possibilities is being investigated (Kammen, Bahaj, Kumar).

Notwithstanding its dynamic growth and changes in investment strategy over the past 40 years, Malaysia has pioneered an early form of smart villages as analogues of smart cities (Zaidee). The potential also exists in smart villages to change lives, whether through improved health and nutrition (Soboyejo, Swaminathan and Kesavan), or democratic empowerment (Banerjee). Clearly, rural education could become one of the greatest beneficiaries of information and communication technology (ICT) if electricity from renewable resources becomes available in remote areas (González).

Public-private sector involvement and entrepreneurship are a requisite for universal energy access in remote villages. Will resources from the public and private sectors be adequate for the necessary capital investment and the required infrastructure, and will there be proper governance and appropriate regulation (Sovacool, Mnzava, Schmidt)?

Sir Paul Collier at the University of Oxford argues that no country anywhere has developed without urbanisation because of the way that a good city is able to harness economies of scale and specialisation[1]. What is the role of smart villages in this transition and might they help redress the balance of opportunities between cities and villages? This will depend greatly on the quality of life created in smart villages (Ssali, Thorpe), and on the provision of sustainable employment (Barasa). The essays conclude, therefore, with an urgent plea to focus attention on employment as the key step towards the economics of escaping the rural poverty trap, showing how interrelated are energy provision and the capacity to create jobs and sustain employment (Nayyar).

We are deeply indebted to all the distinguished experts who have contributed to this eclectic collection of essays. They have readily turned their expertise to the task of writing about the concept of smart villages in accessible and concise ways that fit well with the United Nations Sustainable Energy for All initiative (se4all.org) and the new Sustainable Development Goals, post-September 2015.

We publish these essays with policy makers and decision takers in mind – planners of sustainable off-grid well-being faced with the demanding challenges of lifting the bottom billion out of the poverty trap.

Professor Sir Brian Heap
Senior Adviser for Smart Villages
Research Associate of the Centre of Development Studies,
University of Cambridge

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Energy for development – the concept

John Holmes and Terry van Gevelt

Worldwide, 1.3 billion people remain without access to electricity and 2.7 billion are still cooking on harmful and inefficient stoves[1]. Many live in remote rural village communities, and until they have access to energy services, little progress can be made to develop and improve their lives[2]. As United Nations Secretary-General Ban Ki-moon has stated, “energy is the golden thread that connects economic growth, increased social equity, and an environment that allows the planet to thrive”[3].

Improving the lives of rural communities by developing smart villages is a concept analogous to the more familiar smart cities. The vision for smart villages is that modern energy access can act as a catalyst for development – in education, health, food security, productive enterprise, clean water and sanitation, environmental sustainability and participatory democracy – which in turn supports further improvements in access to energy. Integrating energy access with other development initiatives, harnessing and developing local entrepreneurial capacities, and technological advances in the supply and use of sustainable energy are making such transformative change possible.

Overview

Smart villages capture many of the benefits of urban living while retaining valued aspects of rural life and ensuring balanced development at the national level. This enables villagers to attain healthy and fulfilling lives, achieve their development potential, earn a viable living and be connected to the wider world, giving them a real choice between the traditional route of migration to a city, or life in a smart village.

The key enablers of development in smart villages are sustainable access to electricity and clean and efficient cooking appliances

Smart villages will be connected to towns and cities through information and communication technologies (ICT) enabled by access to energy. Such technologies will enhance education and health services by providing links

M-health initiatives will enable mobile health diagnostic solutions requiring relatively low levels of local medical skill and provide access to specialist health care

to the world's knowledge base and opportunities for distance learning, as well as supporting initiatives in m-health (mobile health, also known as telemedicine). Connectivity will also open up participation in governance processes at local, regional and national levels.

Smart villages will serve as complementary engines of economic growth to smart cities, producing goods and services for local rural markets as well as high-value-added agricultural and rural industry products for both national and international markets. And they will act as stewards for the environment as well as, in some cases, functioning as ecotourism hubs.

Key enablers of these development benefits in smart villages are sustainable electricity supplies and the availability of clean and efficient appliances for cooking. Productive enterprises and facilities with higher energy demands will tend to be located in hub villages supplied by the national grid if sufficiently close or – for the many remoter communities – by local mini-grids driven by renewable energy sources, possibly in hybrid form with diesel generators in some cases. The more dispersed communities around the hub villages will typically use pico-power and stand-alone home systems to provide more basic levels of electricity supply until distribution networks can be extended to them (see Box 1)[4,5,6].

Smart Villages Initiative

This initiative is evaluating how to deliver energy access to rural communities so as to make smart villages a reality. Through a three-year programme of engagement activities in Africa, Asia and Latin America, it will help to ensure that policies and development initiatives are better informed on the realities, challenges and opportunities of rural energy provision for development in key sectors. The following paragraphs elaborate on some of the characteristics of smart villages that will be explored by the initiative.

Education

Smart villages aim to increase the time available for students to study and will address prevalent factors that negatively affect the ability of students to acquire the knowledge and skills necessary to achieve economic goals and improve labour productivity. These include eliminating the need to spend time collecting traditional biomass, reducing respiratory illness caused by indoor air pollution, and ensuring that lighting is both safe and of sufficient quality.

ICT-equipped schools will provide a good level of access to the internet and consequently the world's knowledge base, ending the information isolation experienced by many rural communities. New opportunities will be generated for distance and adaptive learning, reducing the need to move to towns or cities to achieve higher levels of education. In

Box 1 Electrification technology options for smart villages[7, 8]

Technology	Generation capacity (kW)	Energy sources	Services available	Estimated economic cost
Pico-power systems	0.001–0.01	Solar PV	Lighting, radio communication reception, two-way mobile communication	US$ 10–100
Stand-alone home systems	0.01–1	Solar PV	Same as above plus additional lighting and communication, television, fans, limited motive and heat power	US$ 75–1,000
Micro/mini-grids	1–1,000	Hydro, wind, solar PV, biomass, diesel, hybrid combinations	Same as above plus enhanced motive and heat power, and ability to power community-based services	Medium-large capital cost, low marginal cost to end-user
Regional grid connection	1,000–1,000,000	Fossil fuel, hydro, wind, solar PV, biomass, geothermal	Assuming high quality of connection, same as above up to a full range of electric power appliances, commercial and industrial applications	Medium-large capital cost, low marginal cost to end-user


Samrat35/Dreamstime.com

Small-scale solar is ideally suited to the low energy requirements of modern communication technologies.

addition, ICT and internet access also have a "pull factor", providing incentives for school attendance and for attracting and retaining good teachers.

Health

At the most basic level, households in smart villages will be able to consume potable water and a more nutritious diet due to the reduced cost of boiling water and cooking food, and enhanced agricultural productivity arising from associated development initiatives and reduced wastage. Furthermore, modern technologies and cleaner fuel sources will replace the traditional biomass cook stoves that currently result in harmful indoor pollution.

ICT-enabled m-health initiatives such as the Swasthya Slate (www.swasthyaslate.org) will enable mobile health diagnostic solutions, requiring relatively low levels of local medical skill and providing access to specialist health-care services based in urban communities where necessary. Epidemiological data will be gathered, providing the opportunity for more effective interventions and early warning capability in case of outbreaks of contagious diseases such as cholera and Ebola.

Food security

Approximately one in every seven people in the developing world is food insecure, unable to consume sufficient food to sustain a healthy and active life. Energy provision together with ICT can help smart villages become more food secure as farmers take advantage of improvements in irrigation systems, weather forecasting, cold-storage infrastructure, and agronomic and market information, and become fully informed of cognate environmental issues. Consequently, smart villages will be in a better position to gain from the benefits of agricultural modernisation, reduce waste and capture more of the agricultural value chain.

Productive enterprise

Productive enterprise in rural areas generally consists of small and medium-sized enterprises such as agro-processing, textiles, furniture, chemicals, electronics and machinery. Energy access promises participation in knowledge-based activities ranging from handicraft shops to factories, operated informally or organised as a formal business, and using traditional production processes or even employing cutting-edge modern technology. Participation in primary manufacturing, however, will be limited in off-grid villages by the scale of energy required relative to that available from local sources.

Smart villages, through the provision of modern energy access, will bolster rural industry through a variety of channels, including the ability to use mechanical power, the availability of a more skilled workforce through ICT-enabled education, and extended working hours through high-quality lighting. ICT will provide access to mobile financial services and up-to-date market information to enable integration with more complex value chains, and to carve out niches in international markets through identifying and transacting directly with previously unreached customer bases.

Where appropriate, smart villages will host clusters of rural enterprises in strategic areas of dynamic competitive advantage. Clusters will be underpinned by modern energy access as well as other hard and soft infrastructure, and supporting institutions. This will allow rural

Smart villages will be stewards of the environment, monitoring forest health, water quality, soil conditions and changes to the landscape

Smart villages will allow communities to become more aware of their rights, engage in governance processes and hold policy makers to account

enterprises to further benefit from economies of scale and agglomeration.

Environment

Smart villages will be stewards of the environment aided by technologies to monitor key environmental indicators such as forest health, water quality, soil conditions and changes to the landscape. They will also reduce pressure on deforestation through the use of efficient cook stoves to decrease the need for traditional biomass energy sources such as charcoal, a key driver of unsustainable forest use.

Smart villages will host community-run recycling facilities ranging from those equipped to recycle wastewater and organic waste from agro-processing, to next-generation facilities for the recycling of e-waste including energy-storage and generation technologies such as batteries and solar panels. Depending on geographical endowments, some smart villages will be able to operate as regional ecotourism hubs, an activity that can improve the welfare and connectivity of rural and urban communities.

Participatory democracy

Rural communities tend to be politically disenfranchised due to their relative remoteness. Consequently, they lack information on societal issues and have difficulty becoming actively involved in debates about how to address them. Smart villages, through ICT, will allow rural communities to become more aware of their social, economic and political rights, engage in governance processes at all levels and hold policy makers to account.

Quality of life

Through the provision of modern energy, smart villages will have a transformative impact on villagers by alleviating the drudgery of repetitive tasks that is pervasive in many lives in rural communities. This will save time and effort, and villagers will be able to enjoy entertainment through radio, television and the internet. Public lighting at night will mean that people, particularly women, can enjoy social interaction without fear of danger.

Conclusion

Achieving the Millennium Development Goals, the post-2015 development agenda and the United Nations target of energy access for all by 2030 requires a concerted effort focused on rural areas, where approximately 70 per cent of the world's poor live[9]. Drawing on the success of smart cities, the smart villages vision offers an ambitious and unifying framework that is sufficiently flexible to allow for different development pathways for different rural communities, while leading to significantly improved lives for villagers and village communities, and contributing to balanced national and international growth.

There are many areas within the smart villages vision that will be sharpened and refined through a series of workshops to be held around the world under the current Smart Villages Initiative. What is clear, however, is that the smart villages vision, with the immense potential benefits that it can bring to rural communities, is not just aspirational but can be realised with the engagement and wholehearted commitment of all stakeholders, from the inventors of new energy-provision technologies to indispensable village leaders as role models.

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For more information on the Smart Villages Initiative, see www.e4sv.org.

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Energy innovation for smart villages

Daniel M. Kammen

Two critically important and linked challenges face the global community in the 21st century: the persistence of widespread energy poverty and the resulting loss of economic opportunity; and intensifying human-driven climate disruption. These crises are inexorably linked through the energy technology systems that have so far provided the vast majority of our energy: fossil fuels. Both the equity and energy service crisis and the climate crisis have become increasingly serious over past decades, even though we have seen with greater clarity the individual and social benefits that energy technology systems have brought to humanity.

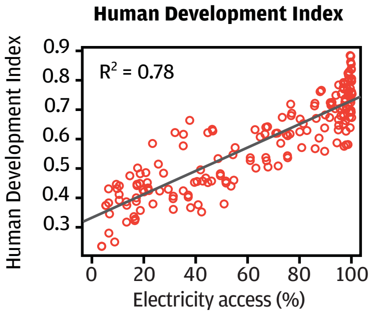
The correlation between access to electricity and a wide range of social goods is overwhelming. Access to improved energy services alone does not, however, provide a surefire pathway to economic opportunity and an improved quality of life. In Figure 1 we show the correlation between electricity access across nations and a variety of quality-of-life indicators such as the Human Development Index, a measure of well-being based in equal thirds on gross national income, life expectancy and educational attainment. Other indicators studied include gender equality in educational opportunity and the percentage of students who reach educational milestones. All of these indices improve significantly and roughly linearly with access to electricity. As just one example, both the percentage of people below the poverty line and childhood mortality decline with increasing access to energy[1].

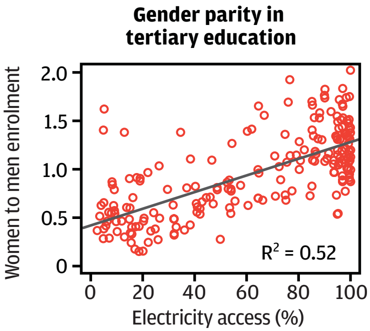
Today, some 1.3 billion people – approximately 17 per cent of the global population – are without access to electricity, relying instead on kerosene and traditional biomass including dung and agricultural residues. This access gap has persisted as grid expansion programmes and population have grown.

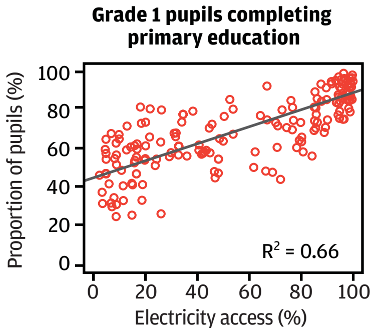
Access to energy services alone is not sufficient, but it is a vital resource for improved economic opportunity and quality of life

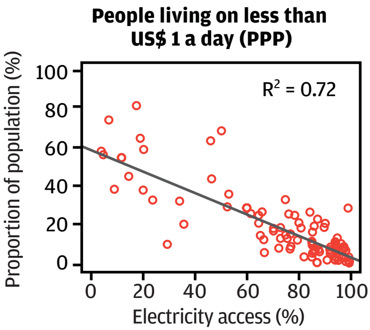
Figure 1 Indicators for quality of life

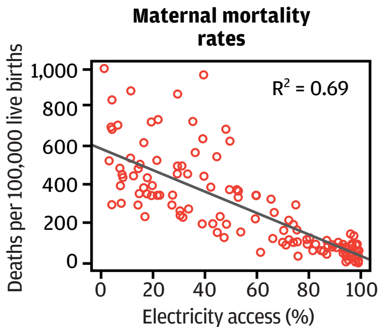
The Human Development Index (HDI) and various additional metrics of quality of life are plotted against the percentage of the population with access to electricity. Each data point represents country-level data at a specific point in time. For additional data, see Alstone *et al.*[1]











Grid expansion over the last century has roughly kept pace with the increase in the global population. According to 2013 data, about 1.4 billion people are completely off-grid, and many ostensibly connected people in the developing world experience significant outages that range from 20 to 200 or more days a year. The majority of the off-grid population is in rural and underserved peri-urban areas. Current forecasts predict that this number will remain roughly unchanged until 2030, which would relegate a significant portion of the population and the economies of many of the neediest countries and regions on Earth to fragile, underproductive lives with fewer options than they might otherwise have. Traditional grid extension will be slowest to reach these communities. Unless the advances in both the energy and the information systems that have occurred over the past decade are more widely adopted, there will be little if any chance to alter this trend.

Advances in off-grid systems

We have recently seen the emergence of off-grid electricity systems that do not require the same supporting networks as traditional forms of centralised power generation. These technological innovations are as much based on information systems as they are directly about energy technology. While traditional electricity grids can gradually pay off (amortise) the high costs of generation, transmission and distribution equipment across many customers and many decades, a new business model is needed to rapidly bring energy services to the rural and urban poor. Mini-grids and products for individual user end-use, such as solar home systems (pay-as-you-go), have benefited from dramatic price reductions and advances in the performance of solid state electronics, cellular communications technologies and electronic banking, and from the dramatic decrease in solar energy costs[2]. This mix of technological and market innovation has contributed to a vibrant new energy services sector that in many nations has outpaced traditional grid expansion.

The comparison between the traditional utility model of central-station energy systems and this new wave of distributed energy providers is instructive. Traditional dynamo generators and arc lighting perform best at large scale, and they became the mainstay of large-scale electric utilities. But the classic utility model of a one-way flow of energy from power plant to consumer is now rapidly changing. The combination of low-cost solar, micro-hydro and other generation technologies coupled

Off-grid electricity systems are as much based on information systems as they are directly about energy technology

Daniel M. Kammen

A village micro-grid system in Sabah, Malaysian Borneo. The system serves a community of 200 and provides household energy services, telecoms and satellite (dish shown), and water pumping for fishponds (seen at centre) and refrigeration. The supply includes micro-hydro and solar generation – one small panel is shown here and others are distributed on building rooftops.

with the electronics needed to manage small-scale power and to communicate with control devices and remote billing systems has changed village energy. High-performance, low-cost photovoltaic generation, paired with advanced batteries and controllers, provides scalable systems across much larger power ranges than central generation, from megawatts down to fractions of a watt.

The rapid and continuing improvements in end-use efficiency for solid-state lighting, direct-current televisions, refrigeration, fans, and information and communication technology (ICT) have resulted in a super-efficiency trend. This progress has enabled decentralised power and appliance systems to compete with conventional equipment for basic household needs.

These rapid technological advances in supporting clean energy both on and off the grid are furthermore predicted to continue, a process that has been particularly important at the individual device and household (solar home system) level, and for the emerging world of village mini-grids[3].

Diverse technology options expand village energy services

With these technological cornerstones, aid organisations, governments, academia and the private sector are developing and supporting a wide range of approaches to serve the needs of the poor, including pico-lighting devices – often very small 1–2 watt solar panels charging lithium-ion batteries which in turn power low-cost/high-efficiency light-emitting diode (LED) lamps, solar home systems and community-scale micro- and mini-grids. Decentralised systems are clearly not complete substitutes for a reliable grid connection, but they represent an important level of access until a reliable grid is available and feasible, and a platform from which to develop more distributed energy services. By overcoming access barriers, often through market-based structures, these systems provide entirely new ways of bringing energy services to poor and formerly un-connected people.

Meeting people's basic lighting and communication needs is an important first step on the modern electricity service ladder[4]. Eliminating kerosene lighting from a household improves health and safety while providing significantly higher quality and quantities of light. Fuel-based lighting is a US$ 20 billion industry in Africa alone, and tremendous opportunities exist both to reduce energy costs for the poor and to improve the quality of service. Charging a rural or village cell phone can cost US$ 5–10 per kilowatt hour at a pay-for-service charging station, but less than US$ 0.5 via an off-grid product or on a mini-grid.

This investment frees income and also tends to lead to higher rates of use for mobile phones and other small devices. Overall, the first few watts of power mediated through efficient end uses lead to benefits in household health and education as well as a reduction in poverty. Beyond basic needs, there can be a wide range of important and highly valued services from decentralised power – such as television, refrigeration, fans, heating, ventilation and air-conditioning, or motor-driven applications – depending on the power level and its quality along with demand-side efficiency.

Meeting people's basic lighting and communication needs is an important first step on the modern electricity service ladder

Experience with off-grid under-served people confirms the exceptional value derived from the first increment of energy service – equivalent to 0.2–1 watt hour per day for mobile phone charging or the first 100 lumen-hours of light. Given the cost and service level that fuel-based lighting and fee-based mobile phone charging provide as a baseline, simply shifting this expenditure to a range of modern energy technology solutions could provide a much better service, or significant cost savings over the lifetime of a lighting product – typically three to five years.

Box 1 Roadmap to clean energy in a smart village

- **Establish clear goals at the local level.** Universal energy access by 2030 is the global goal[7], but establishing near-term goals that embody meaningful steps from the present situation will show what is possible and at what level of effort. Cities and villages have begun with audits of energy services and costs, and environmental impacts. A number of tools are often cited as excellent starting points, including climate footprint assessment tools such as http://coolclimate.berkeley.edu, and the HOMER software package http://www.homerenergy.com, used by many groups both to design local mini-grids and to plan and cost off-grid energy options.

- **Empower villages as both designers and consumers of localised power.** Village solutions necessarily vary greatly, but clean energy resource assessments, evaluation of the requisite infrastructure investment, and – most often neglected but most important – identifying the social structures that enable training, are required to make the village energy system a success. In a pilot programme in rural Nicaragua, once the assessment was complete[8], movement from evaluation to implementation quickly became a goal of both the community and a local commercial plant.

- **Make equity a central design consideration.** Community energy solutions have the potential to liberate women entrepreneurs and disadvantaged ethnic minorities by tailoring user materials and energy plans to meet the cultural and linguistic needs of these communities. National programmes often ignore business skills, culturally appropriate cooking requirements and other home energy needs. Thinking explicitly about this is good business and makes the solutions much more likely to be adopted.

Mirroring the early development of electric utilities, improvements in underlying technology systems for decentralised power are also being combined with new business models, institutional and regulatory support, and ICT systems[5,6]. Historically, the non-technical barriers to adoption have been impediments to widespread access to off-grid electricity, and in some cases they still are. A lack of appropriate investment capital also hampers the establishment and expansion of private-sector initiatives. Furthermore, complex and often perverse policy environments impair entry for clean technologies and entrench incumbent systems. Subsidies for liquid lighting fuels can reduce the incentive to adopt electric lighting. In addition, the prevalence of imperfect or inaccurate information about quality can lead to market spoiling[4], and is also manifested by a lack of consumer understanding and awareness of alternatives to their existing lighting technology.

Testing laboratories that rate the quality of the lighting products and disseminate the results are an invaluable step in increasing the quality and competitiveness of new entrants into the off-grid and mini-grid energy services space. The Lighting Global programme (https://www.lightingglobal.org) is one example of an effort that began as an industry watchdog, but has now become an important platform that provides market insights, steers quality assurance frameworks for modern off-grid lighting devices and systems, and promotes sustainability through a partnership with industry.

An action agenda for smart villages

The diversity of new energy service products now available, alongside rapidly increasing demand for information and communication services, water, health and entertainment in villages worldwide, has built a very large demand for reliable and low-cost energy[7]. Combining this demand with the drive for clean energy brings together two important objectives that were for many years seen as in direct competition: clean energy and the provision of village energy services. To enable and expand this process, an emerging range of design principles can form a roadmap to clean energy economies.

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Transforming rural communities through mini-grids

AbuBakr Bahaj

Access to energy, especially for rural communities, represents a central pillar of development. For the more than a billion people in the world without reliable access, the provision of electricity will have a huge impact on their livelihoods as it is crucial for human well-being and development.

Without a reliable energy supply it is difficult to escape a subsistence lifestyle and poverty. However, in many developing countries, the upfront investment required to link villages to the electrical distribution network is and will likely remain prohibitively expensive in terms of construction and community affordability. This is the case across most of Sub-Saharan Africa and some areas of South Asia. Previously agreed United Nations development criteria were embedded in the Millennium Development Goals (MDGs)[1], and now energy provision is established as one of the new Sustainable Development Goals[2], which replace the MDGs.

In Africa, renewable energy derived from vast hydropower resources and solar energy potential could satisfy much of the continent's growing need for power. However, power capacity from these sources will have to increase exponentially to provide the necessary access. The United Nations Sustainable Energy for All (SE4All) initiative has responded to the global energy development challenges by setting three linked goals for 2030:

- universal access to modern energy;
- doubling the rate of improvement in energy efficiency globally; and
- doubling the share of renewables in the global energy mix.

To achieve the 2030 target for universal access to electrical power alone, the current global capacity will need to increase by 45 per cent, and this will be in the form of mini-grids[3]. In Sub-Saharan Africa, with 13 per cent of the world's population, only 290

In Africa, renewable energy derived from vast hydropower resources and solar energy potential could satisfy much of the growing need for power

million of the 915 million people have access to an electricity network. The estimated cost of universal access is approximately US$ 470 billion for Sub-Saharan Africa alone, compared to US$ 1 trillion globally[4].

These numbers highlight the mammoth task ahead. The challenge for the global community is to address the development and implementation of sustainable energy supply projects in rural communities in Africa and Asia. Solutions should embrace social, technical, economic and environmental aspects, building on cultural understanding and local needs. Such approaches will allow appropriate knowledge generation based on mini-grid projects replicated at scale. In my view, we need to establish joint learning entities or project exemplars between national and international institutions. These will be beacons to show what can be achieved in smart villages, lending much-needed confidence in the scoping and implementation carried out by rural electrification authorities involved in projects of this kind, as well as capturing the valuable knowledge of what has worked and what has not. What follows is a discussion of two exemplary case studies.

Mini-grid case studies

Renewable off-grid energy supply based on mini-grids can be developed and designed to provide essential access to electricity in rural areas. Due to the remoteness of the locations such solutions, using appropriate business models, represent a cheaper option than extending the national grid. Such models will need to have income generation at their core, governed through an energy supply company and supported by a community cooperative or other suitable business venture.

An on-going action-research approach aimed at addressing energy provision in rural communities in East Africa is the grant-funded Energy for Development (e4D) concept. This aims to establish and implement replicable and sustainable off-grid electricity generation to promote development and well-being[5].

The challenge for the global community is to address the development and implementation of sustainable energy supply projects in rural communities

The e4D concept has people at its core, engaging effectively with communities to determine their energy needs and develop appropriate community structures and renewable electrical power supply systems, focusing on long-term project sustainability. A major aim

Figure 1 Community power

A bird's-eye view of the Kitonyoni village trading centre, solar PV canopy and water tank. Two containers underneath the canopy hold the batteries and the system's switch gear and protection. One of the containers is used as the community cooperative office.

of e4D is to invigorate communities and their village centres, providing support for self-governance, finance and entrepreneurship.

Our first intervention in Kenya, in 2012, created a community-based cooperative and a solar photovoltaic (PV)-driven mini-grid providing electricity to the remote Kitonyoni village trading centre, Makueni county, some 130 kilometres from Nairobi. The site was chosen for its remoteness, level of community poverty and grid proximity, with a monitored control village about 30 kilometres from Kitonyoni forming part of the project. The solar project is designed to support around 3,000 very poor inhabitants by providing grid-standard alternating-current power directly to all buildings – shops, cafes, schools, health centres, places of worship and so on, which in turn provide a range of services to customers from the surrounding area. These services include refrigeration and charging of appliances such as light-emitting diode (LED) lanterns and mobile phones. The infrastructure houses the plant equipment and provides office and meeting facilities for the community and its committees, acting as a village focus (Figure 1)[5]. Together, e4D engineers, local contractors and villagers were able to assemble the containerised 13.5 kilowatt-peak (kWp) PV solar plant, battery storage and canopy, and install the locally supplied mini-grid within one week. The premise of the modular project design is to make it easy to replicate and resize to suit villages of various sizes and energy requirements[5].

The e4D team worked closely with villagers to determine their needs, aspirations and goals with respect to electrification. We established an economically sustainable approach

Strong and growing interest in adopting the e4D approach has emerged among governments and the private sector as well as international funding agencies

whereby the community contributes to the project and is responsible for the operation and maintenance of the plant. Through the energy supply company ESCO, income for the cooperative is generated via membership fees, local sales of electricity and share ownership. Such income covers all the running and replacement costs of project components and management, provides micro-financing for the community and contributes to the recovery of the capital cost of the project.

The school, health centre, churches and more than 40 businesses in Kitonyoni have a 24-hour, stable and reliable source of electricity, allowing them to extend their working hours and to provide additional services to 3,000 local people; services include information technology training, tailoring and hair-dressing, as well as the electrical charging facilities mentioned earlier. Moreover, the solar canopy of the PV system was designed to serve as a rain collector feeding tanks with capacity for 20,000 litres, enabling water to be stored and sold by the cooperative to the community throughout the year.

The transformation of the trading centre is very clear – land prices have more than doubled, benefiting the local community through land sales. At least 10 new buildings have been completed since the project's inception, new businesses have started, business income has more than doubled in most cases and, importantly, a newly donated maternity ward has been electrified and is now operational. Over the 24 months of operation, the e4D project has transformed the trading centre and the lives of the villagers, providing electrical services more reliably than the national grid. The project has given the research team data on system performance, energy demand at the trading centre, and comparative developmental analysis with the control village. It has also allowed the Kenyan Rural Electrification Authority (REA) to learn from the experience, developing capacity that has now expanded, with three additional solar PV projects based on the e4D concept.

The e4D concept was applied to another project developed and installed by the team, this time in a small community in Bambouti, rural Cameroon. This project was designed to test the growth and expansion of the concept of implementing a PV power plant – only this time it was initially without a mini-grid. It has a 6 kWp PV array and battery storage system that supplies the local dispensary with electricity and provides power to a community-based charging station for batteries and other appliances. The health centre is clearly improving and, according to the community 2014 annual report, the child mortality rate has fallen. Entrepreneurial activities such as a tool-sharpening business and a barber's shop have mushroomed since the arrival of electricity from the plant. The purpose is to enable the community to expand the project by their own means; currently the income from electricity sales and membership fees contributes to the establishment of a micro-grid to supply power to buildings at the centre of the village[5].

Conclusions

The scope for implementing the technologies needed to deliver access to electricity in rural communities is complex. I have highlighted some possible ways forward in delivering these services at scale through optimised modular designs, community structures, and partnerships between communities and energy authorities, creating projects that generate income and pay back the capital cost over an appropriate period of time. However, the challenge is now to reduce capital costs and embed the concepts and models in replication projects. This is currently being undertaken in four further partnership projects in Kenya and Uganda. In addition, strong and growing interest in adopting the e4D approach has emerged among governments and the private sector as well as international funding agencies, pointing to substantial funding to support the concept at scale.

Access to electrical power is fundamental to development and there are many global activities endeavouring to achieve this goal. However, there is huge inertia in the establishment of projects such as electrical mini-grids to support the development of rural communities[6]. Some of the reasons could be attributed to:

- failure to understand the technological and economic issues surrounding mini-grids;
- regional contexts of project implementation;
- lack of capacity in the delivery institutions;
- insufficient understanding of affordability (ability to pay) and the value of electricity from mini-grids compared to an unreliable utility grid; and
- lack of proper dissemination of the results of previous mini-grid projects, resulting in lessons not being learned for the future.

International initiatives will need to take these issues into account so that sustainable projects can be delivered to rural and poor communities at scale.

Acknowledgement

The programme e4D – a five-year project entitled Replication of Rural Decentralised off-grid Electricity Generation through Technology and Business Innovation, or Energy for Development (e4D) for short – is a multi-institutional research programme funded by the Research Councils UK and the UK Government's Department for International Development (DfID). The project consortium comprises the University of Southampton and Imperial College, London. More details about the project and partners may be found at: www.energy.soton.ac.uk and www.energyfordevelopment.net.

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Leapfrogging to sustainable power

R. Vasant Kumar

As the global population is still rising – albeit at a decreasing rate – we can expect an additional billion or more people in the next 10 years and yet another billion by 2040[1]. Simple mathematical calculations would suggest that the number of off-grid global poor will nearly double within a decade. And the world is also urbanising quite rapidly, thus a considerable proportion of the marginal poor can be expected to relocate to densely populated near-urban off-grid areas.

Successful off-grid energy solutions, however, can promote migration into developing rural communities, thereby giving them semi-urban characteristics. The growth of a semi-urban sector should not, however, be a cause for concern: in fact it can act as a buffer against the unsustainable growth of mega-cities with expanding slums, and point towards more sustainable models. In addition, the availability of off-grid electrical power for decent lighting, pumping, refrigeration, sanitation, education, communication, audio-visual and entertainment facilities, will enhance rural life and development[2].

Current position

The off-grid energy paradigm for electrification and development of the global rural population must be closely associated with the evolution of clean, green and low-carbon power. It is heartening to note the many ongoing and forward-looking rural projects such as Lighting Africa, the Pico-PV Programme, Husk Power Systems, the Jawaharlal Nehru National Solar Mission and Lighting India, to name just a few. Millions of poor people in the countryside now have access to electricity from photovoltaic (PV) modules alongside storage batteries that can generate 12, 48 or even higher voltages to run household and community appliances.

Photovoltaic systems are favourable options for meeting low energy demand – of less than 5 kilowatt hours per day – at steady loads in remote locations that regularly receive good solar flux. Solar lighting based on light-emitting diode (LED) lamps and solar lanterns are not

The growth of a semi-urban sector can act as a buffer against the unsustainable growth of mega-cities and point towards more sustainable models

There is a great opportunity to skip highly polluting forms of energy and move straight to cleaner sources such as solar power

only clean, efficient and reliable, but are cost effective in competition with kerosene lamps. There are also examples of rural electrification where engine-generators – diesel-driven gensets – are used for heavier loads along with PV systems in hybrid configurations.

An excellent model of micro-grid development is Mera Gao Power, an enterprise operating in partnership with USAID, which is able to build, own and operate micro-grids in rural communities in India for costs reported to be below US$ 1,000 per village. In each village setting they provide a centrally located solar panel combined with a bank of lead-acid batteries for storing and then delivering energy when solar flux is not available[3]. Within a period of two years, Mera Gao has been able to provide electricity to 500 off-grid villages, providing 65,000 people with lighting and mobile-phone charging facilities.

Hydropower in mini-grids has been implemented in a few rural locations with access to flowing water. Small wind turbines dependent on regular wind speeds higher than 15 kilometres per hour have been installed in some locations for charging batteries, and turbines can also lend themselves to larger infrastructure such as community-level local grids. However, as renewable sources such as solar and wind power tend to be intermittent, energy availability can be sporadic without the use of battery packs.

While biomass – mainly wood – has been an important source of energy for cooking in rural communities for centuries, the new opportunity to generate combined heat and power using generators has become a growing reality[4]. Several gasifiers have been made available within rural communities, where they are run on locally available biomass such as rice husks, wood chips, lentil or cotton stalks and other agro-residues including animal and kitchen wastes. These gasifiers can power generators to provide heat and power for a community or hamlet of typically 1,000–2,000 people. In another pioneering example in Uganda, it is reported that maize mill owners produce and sell power to households via mini-grids or battery charging.

New opportunities

Solar energy is expected to contribute more than 10 per cent of the energy mix in large developing countries and regions by 2022, driven by the goal of providing electricity to the hundreds of millions of rural people who do not have it now. There is a great opportunity to skip highly polluting forms of energy and move straight to cleaner sources such as solar power. Leapfrogging in this way will avoid the large costs of transmission lines while benefiting the environment and the health of the people. Off-grid electrification is an innovation that should be harnessed for entrepreneurship and gainful employment. In addition, the very villages that are expected to be the subject of this e-transformation are also the source of a demographic dividend arising from a youthful population.

Energy storage

Renewable energy technologies are not stand-alone solutions in the sense that solar PV and wind-based systems require batteries for storage along with inverters to convert direct current to alternating current, and battery chargers; gensets require a regular supply and storage of diesel or petrol; and hydropower, while relatively economic to operate, is dependent on the availability of fast-moving water throughout the year.

Technologies have evolved over many decades that allow us to convert the energy from sunlight into electricity through the PV cell, but this then needs to be stored in batteries and made available without interruption over a number of days. Battery packs based on lead-acid batteries are already used in rural off-grid electrification schemes for storing energy from renewable sources during peak production – and are also in demand in rural areas as a direct source of electricity for lighting or phone charging.

Lead-acid batteries currently provide the most economical electrical storage technology. Typically, these are designed for deep-discharge cycles that provide a small current for many hours between two charge cycles, using up most of the stored energy. Batteries store their energy as chemical energy in two separated electrodes. The separated chemicals can then be made to react via an electrolyte, feeding back the chemical energy as electrical energy.

Batteries can be charged and discharged over hundreds or even thousands of cycles, after which they become spent and cannot be used again. Given that the discharge of lead into the environment is not an option due to its toxicity, batteries must be recovered and recycled to

The very villages that are expected to be the subject of e-transformation are also the source of a demographic dividend arising from a youthful population

An environmentally sustainable process for recovering lead from batteries that can be operated on a small scale – but also a large one – is already in demand

make new ones. The good news is that lead is not difficult to recycle: in fact in developed economies and in the urban space of rapidly emerging economies, the infrastructure for collecting, dismantling and recycling batteries is very successful.

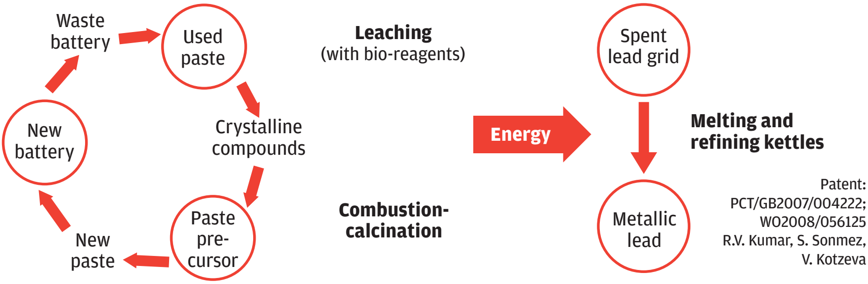
Recycling

Mature technology for recycling lead batteries is based on heavy investment in large high-temperature furnaces backed by environmental control of discharged dust, water and gases. Such relatively expensive and large-scale technologies are currently outside the practical realm of the rural sector. Nevertheless, there is a thriving – though often poorly regulated or even unauthorised – rural sector based on small-scale units and driven by the economic incentive of the resale value of lead. Unfortunately, however, small-scale units are unable to melt all of the lead compounds in the spent batteries, creating a massive potential health burden if unrecovered lead compounds make their way into the local environment.

Where growth in rural off-grid electrification through renewables is envisaged, as in smart villages, the demand for back-up storage batteries will intensify. A new technology for safely recovering lead from batteries in small-scale units has recently been developed at the University of Cambridge (Figure 1), precisely in anticipation of growth in battery usage spurred by rural electrification through renewables[5]. This battery technology can also be used in electric scooters, whose growth is anticipated as rural development progresses further. It is possible to imagine that, in the near future, more than 95 per cent of all lead – more than 20 million tonnes per year by 2022 – will be used in vehicle batteries and for back-up and emergency power supply, and most of this will be supplied by recovering lead from used batteries. An environmentally sustainable process that can be operated on a small scale – but also a large one – is already in demand and will further expand. The rural sector can lead this new technology.

Since economy of scale is not a limiting factor, such a technology will provide an opportunity for nucleating and retrofitting many rural, smaller-scale lead-battery industries in rapidly growing economies. This new green cottage industry will have a major positive economic impact for a large number of people dependent on lead batteries for their livelihood and for the development of their local economies.

Figure 1 Green battery recycling process[5]

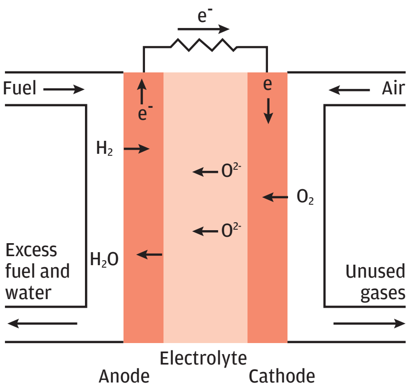


Residual battery paste is dissolved in an aqueous solution of carboxylic acids derived from plants (leaching) to produce lead organic material which is converted by combustion at high temperatures to lead monoxide and metallic lead for new battery paste preparation. The lead grids are refined separately using heat from the first process. The use of acids from plants results in a very low carbon footprint. Thus it is possible for rural users to send back to battery manufacturers value-added products for re-engineering.

Can fuel cells play a role in the future?

A fuel cell can generate electricity silently and without combustion. The fuel stream is fed into a compartment separated from a second compartment into which air is fed. The two streams never mix or burn, but still electricity is produced at efficiencies that can be more than 100 per cent higher than turbine-based power plants using the same fuel. In principle, the fuel cells are similar to batteries. The secret material in both cases is the separator – an electrolyte – which allows for silent but active communication between the fuel and the air (Figure 2).

Figure 2 A fuel cell



Fuel cells operating at high temperatures can also generate heat along with electricity, thus making them uniquely placed for heat-and-power solutions. A well designed combined heat-and-power unit can harness heat that would otherwise be wasted, transferring it to a heating fluid that can be used as a hot-water storage system.

An ideal fuel of the future is hydrogen, its main advantage being that the only waste product of using it for electricity generation is water. We are not ready for a local hydrogen economy as yet, and the storage and transportation of hydrogen is still a developing technology. But increasing use of the fuel cell as an off-grid technology will result in a short lead-time for adopting hydrogen fuel cells in the future.

If hydrogen is not an option for now, what will the fuel cell be in a rural setting? Biomass gasifiers using agricultural waste are already in use in the rural sector for generating power using conventional turbine technology. Fuels produced from biomass gasifiers contain hydrogen and carbon monoxide, which can be directly fed to the fuel cells and efficiently converted to electricity. The NonFerrous Materials Technology Development Centre (NFTDC) based in Hyderabad, India, in collaboration with the University of Cambridge, UK, is currently developing a low-cost fuel-cell stack suitable for rural application[6].

Both the gasifiers and the fuel-cell stacks lend themselves to micro-grid operation and provide incentives for community action, participation, employment and entrepreneurship. It is possible either to distribute the fuel to households with small fuel-cell stacks for individual electricity generation or to produce electricity at a community/hamlet level for distribution to households.

Biomass is a carbon-neutral source of power, as it embodies nature's living carbon within renewable stock and does not imperil the health of the carbon cycle – in contrast with the "dead carbon" in fossil fuels. A biomass-based fuel using local wastes for generating electricity through a fuel cell is a good model for moving up the energy ladder.

Conclusions

The fact that the electricity sector is quietly undergoing a globally disruptive transformation offers new opportunities for tackling electricity poverty. Rapid expansion of zero-emission solar power backed by energy storage in batteries is set to take off, both within the grid infrastructure and off the grid. Some estimates forecast 200 gigawatts of battery-backed solar power by 2025, a fourfold increase on 2015 – and a fortyfold increase on 2005. At the heart of this transformation is massive cost reduction in both solar cells and the rapidly advancing technology of lithium-ion batteries. Over the next five years, Tesla's new "gigafactory" in the USA is expected to double the world's lithium-ion battery supply for the stationary energy storage market, a vital enabling technology at the dawn of the upcoming solar age.

Off-grid electrification of the global rural community should catalyse the economic and social development of marginalised people. A number of available technologies as well as new opportunities on the near horizon are considered to be viable and environmentally sound, and will contribute to local economic development.

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Smart villages – the Malaysian approach

Ahmad Zaidee Laidin

Electricity first made its appearance in the region in 1894, when two prominent local Selangor-based Malayan entrepreneurs, Loke Yew and Thamboosamy Pillay, started to use electric pumps for tin mining. By the mid-1920s, several small generating plants had been established using a variety of fuels including low-grade coal, local wood, charcoal and bunker oil. A few hydro-electric power stations were also constructed, the biggest being the Chenderoh Dam (40.5 megawatts) in Perak and the smallest generating just 2–3 megawatts.

For rural Malaysia, the "let there be light" journey began about five decades ago. Several initiatives to upgrade the lives of the villagers in Malaya, as Peninsular Malaysia was then known – with both Sabah and Sarawak joining Malaysia later – were introduced by the British government. The health conditions of rural villages were studied as early as 1948, funded by the United Nations[1]. Cooperatives were encouraged among small traders and village industries such as sawmills and fishing products; the Cooperative College was established; and the Rural Industrial Development Authority (RIDA) was formed in 1951 with a programme to provide economic support and assistance to Malay farmers and rural inhabitants.

Rigorous studies of rural poverty by Royal Professor Ungku Aziz from the University of Malaya from 1952 to 1988 revealed that the per-person productivity of the region's agriculture lagged behind that of more developed nations due to a lack of technology and infrastructure, the vicious cycle of debt, and an exploitative marketing mechanism. By the 1950s, electricity was already available, but mainly in the larger towns and tin mines.

Malaysia has come a long way with rural development, aimed at developing physical infrastructure and providing extensive basic amenities to rural residents

After Independence in 1957, and the formation of Malaysia incorporating Sabah and Sarawak in 1963, the economic sectors of rubber plantations and tin mining were still largely owned and controlled by British and Chinese capital. The traditional agricultural sectors, on the other hand, were engaged by small-scale rice-growing farmers and smallholders including the Malays and other indigenous people. In 1957, out of a population of 6.5 million in the Peninsula, 73.4 per cent lived in rural areas, and Tunku Abdul Rahman, leader of the newly independent nation, assigned his Deputy Prime Minister Tun Abdul Razak to take charge of rural development.

Electricity and rural development

Malaysia has come a long way with rural development, aimed at developing physical infrastructure and providing extensive basic amenities to rural residents. Figure 1 summarises measures taken by Malaysia over the last six decades to bring rural society into line with the development of the country as a whole[2]. The Malayan Emergency was declared by the British Administration on 31 January 1948 and the newly independent Malayan government declared its end on 31 July 1960, triggered by the Malayan Communist Party who wanted to establish a communist government in Malaya.

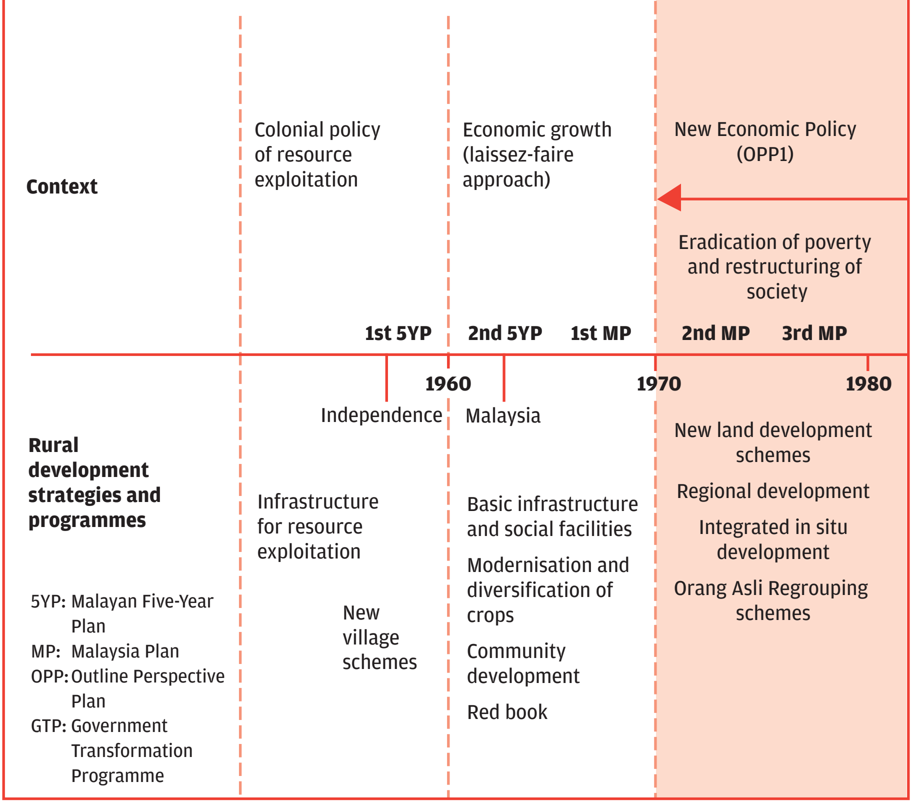
The Red Book Plan was launched in 1960 to be a parallel development programme for all rural areas. The people and leaders were involved not only in the implementation process of development but more importantly in the planning process itself. This transformational experience in rural development saw the village-level establishment of infrastructure such as electricity, water, radio and television, roads and transportation in tandem with other services such as health clinics, post services and police stations.

The constant monitoring of the numerous rural projects was not an easy task. The Malayan government adopted a special strategy called the Operations Room Technique (ORT), which focused on winning the hearts and minds of the rural people. It demanded almost military discipline in reporting on the progress of the various projects, and there was a clear chain-of-command structure. The Rural Development Committee comprised the “doers” and the “recipients”, with the direct involvement of officers from the relevant government departments. The Deputy Prime Minister himself made spot checks, especially on those villages that lagged behind.

The current Government Transformation Programme heralds an era of science, technology and innovation with the mindset of a developed country in rural areas

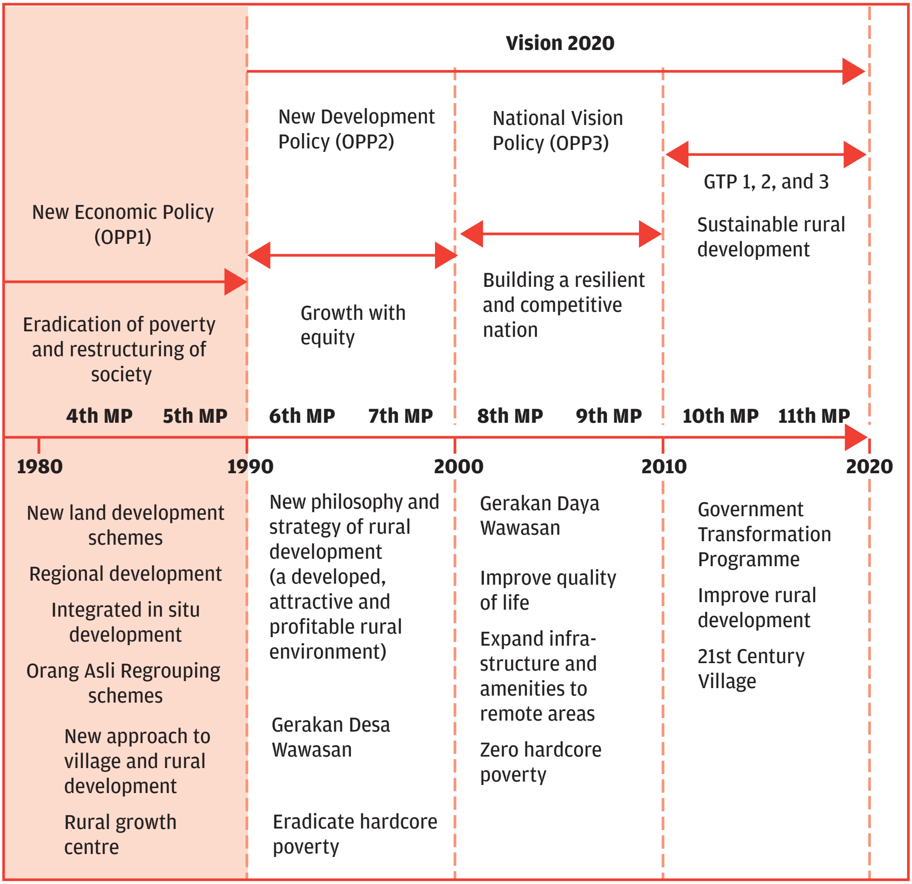
As a first step, off-grid generation using diesel gensets and providing a 12-hour supply from 6.00 pm to 6.00 am were installed in many parts of Malaya. The priority was to light up the domestic houses in the villages. This signalled that the government was bringing about a visible change to the lives of rural people. Before the advent of television, radio broadcasts were a very useful tool of psychological warfare against the communist terrorists, and the Malayan Film Unit, too, made numerous visits to the villages to educate the people

Figure 1 Malaysia's path to rural development[2]



regarding the various development objectives of the government. These tools were used for introducing rural electrification.

The rural electrification programme, mainly funded by the federal government, played a pivotal role in rural development. As the grid system continued to expand, the diesel sets were dismantled and the villages connected to a 24-hour supply. A review of rural



electrification was made in July 1978 for the Fourth Malaysia Plan. It was envisaged that rural electrification for Peninsular Malaysia would be completed by the year 2000. However, Sabah and Sarawak took a little while longer, primarily because the rural population was even less accessible than those in the peninsula.

In 1990, the National Electricity Board was directed by the then Prime Minister, Dato' Sri Dr Mahathir Mohammad, to look at mini-hydro plants as a source of off-grid electricity. Overall, the various attempts at rural electrification were peppered with more successes than failures, and it was noted that rural industries using electricity were somewhat limited. Realising this, the state governments, along with the federal level, organised various programmes and activities to further develop small and medium enterprises (SMEs) in rural areas by providing assistance in terms of production, product development, creating new products, management, funding, technology, promotion and marketing, and building business chains, to cite a few initiatives.

The Government Transformation Programme (2010–2020) for rural development

The building blocks of the Government Transformation Programme (GTP) introduced in 2010 were designed to provide a roadmap towards achieving the status of a developed country by 2020[3]. For rural development, GTP 1.0 (2010–2012) focused on implementing rural basic infrastructure (RBI) such as road improvement, access to clean water, 24-hour electricity and infrastructure maintenance. GTP 2.0 (2012–2015) targeted the more interior and remote sites. GTP 3.0 (2016–2020 and beyond) will herald the era of science, technology and innovation with the mindset of a developed country in rural areas.

In the context of electrification, considerable success has been achieved in both established and new villages. The International Energy Agency (IEA) estimated that in 2012, only 1.3 per cent of the Malaysian rural population remained without electricity[4]. Statistically, from 2013 to 2015, 47,840 rural houses would be connected to 24-hour supply[3]. The breakdown is as follows: Peninsular Malaysia 4,200 houses; Sabah 11,886 houses; Sarawak 31,754 houses.

Small projects involving rural people have demonstrated that basic IT skills can be acquired in a very short time, and enhance quality of life in many ways

Off-grid solar hybrid systems have been successfully installed in several parts of Malaysia, particularly on islands. However, the

The success of Malaysia's 21CV projects should convince implementers that a holistic approach should be taken with electricity as the underlying enabler

more remote villages – 0.5 per cent of the population in Peninsular Malaysia and 5.0 per cent in Sabah and Sarawak – present greater challenges, as bringing the indigenous population into the mainstream of development requires psychological and anthropological acumen and continuous education, besides funding and supporting infrastructure. Indubitably, electrification would open wider opportunities for learning and access to education and business.

21st century initiatives

A recent bold new initiative is the 21st Century Village (21CV) – a programme that encourages youth to remain in the villages (*kampungs*) and to work and start businesses *in situ*. The overall target was to create 132 new 21CVs, initially by 2015, and now extended to 2020 depending on the availability of funds. Activities in the 21CVs encompass a number of economic sub-sectors including agriculture, tourism, plantations and cottage industries. An estimated figure of about 37,800 households or 189,000 people are expected to benefit from this programme[3]. They are selected by the state government from identified rural poor as well as the unemployed.

The 21CVs have and will be developed using the following initiatives:

- 39 state-driven modern integrated farms;
- 15 private-sector-driven large-scale fruit and vegetable farms;
- 39 enhanced village cooperatives in tourism, plantation and cottage industries;
- 39 encouraging selected university, technical and vocational graduates as youth entrepreneurs.

The selection of the villages was based on those that have land available, those with successful cooperatives operating businesses, and those with potential or unique resources that can be developed into sustainable rural businesses. They will be evenly distributed between Peninsular Malaysia, Sabah and Sarawak, with funding from federal, state and private-sector sources. The government has spent MYR 145 million (US$ 39 million) on projects for the development of basic infrastructure in rural areas under GTP 2.0, of which MYR 137 million (US$ 37 million) was allocated for the 21CV and Desa Lestari (Sustainable Rural Area) programmes, while another MYR 8 million (US$ 2.2 million) is for large-scale farming programmes. The outcome is a jump-start to bring the rural areas into a suburban culture.

21st century remote villages

Remote villages need to be addressed differently. The Institute of Social Informatics and Technological Innovations at Universiti Malaysia Sarawak (UNIMAS) has applied a four-stage holistic approach. Social scientists are involved in community engagement and needs analysis in the first phase; followed by the involvement of technologists, economists and business academics in the planning and design process in the second; technology access and deployment in phase three; and finally evaluation and reflection involving all the disciplines in phase four[5].

An instructive example is given by a project in Bario, Sarawak (Figure 2). To reach it from Miri used to take a three-day boat journey followed by a four-week trek in dense tropical forest. Nowadays, you can reach it in an hour in a small plane or in 18 hours travelling along logging roads. In spite of considerable urban migration, the Kelabit, an indigenous people of the Sarawak/North Kalimantan highlands, numbering about 1,200 individuals, still live in long-houses and a number of smaller houses in 17 widely dispersed villages around Bario.

Figure 2 Improved livelihoods in isolated communities

A UNIMAS project bringing information technology to isolated communities in the rice-growing region around Bario has offered villagers opportunities for economic activities including handicrafts and ecotourism.

Box 1 Advantages brought about by electricity beyond lighting and basic comforts[5]

- **Education**, encompassing students, teachers and the community.
- **Preservation of culture, oral tradition and traditional knowledge**, including ease of documentation through ICT.
- **E-commerce**, including ecotourism, the offer of accommodation for home-stay, selling of handicrafts and the famous Bario rice.
- **Agricultural advances**, including gathering, classifying and sharing information regarding Bario rice.
- **E-health**, enabling medical information exchange between Bario, Miri and Kuching.
- **Empowerment of the community** through connection with the outside world.
- **ICT**, with satellite internet access enhancing the telephone and wireless network.

UNIMAS embarked on several projects in Bario. One was a research initiative to introduce information and communication technologies (ICT), VSATs (Very Small Aperture Terminals), telephones and internet access to villagers. A direct outcome of this technology is an increase in both domestic and international tourists to Bario. As a matter of fact, a National Ecotourism Plan for Malaysia was published in 2011[8]. Its implementation – by giving villagers the opportunity to provide modest but clean food and safe accommodation as well as guides and handicraft production – has boosted local incomes.

Another project that is worthy of note, entitled Ngerabit eLamai, was completed in 2012 at Long Lamai, Sarawak, where the population largely belongs to the Penan community[6]. These two projects should convince implementers that to make the necessary impact, a holistic approach should be taken with electricity as the underlying enabler (Box 1).

Although the state government had funded several renewable energy schemes such as micro-hydro and solar hybrid projects, the unmet demand opens up opportunities for non-governmental organisations (NGOs) to participate in the electrification effort through micro-hydro sets and the like. However, they face challenges from the authorities. Initial investment, although lower than when the government undertakes the projects, is still substantial and sustainability is a real issue. Nevertheless, the government may want to consider more engagement and strategic partnership with these NGOs to carry out some of the projects.

One such example is already taking place in Sabah. The Sabah Women Entrepreneurs and Professionals Association (SWEPA) selected a 40-year-old illiterate grandmother to go to the Barefoot College in Tilonia, India, for six months to learn how to install, repair and maintain solar-cell renewable energy equipment in her village, serving some 100 villagers[8]. In short, opportunities exist for experimenting with several alternatives, with a view to bringing down the cost and promoting the latent energy and voluntarism of NGOs. Nevertheless, electricity has its inherent dangers and safety cannot be compromised. Hence rules and regulations relating to competent operation and maintenance must be adhered to at all times.

Conclusion

While broad sweeps of economic development are covered by government transformation initiatives, truly meaningful and sustainable rural development also calls for creative ideas and innovative inputs from ecologists, scientists, anthropologists, psychologists, experts on arts and culture, tourism operators, engineers and geologists, apart from the traditional development economists and agriculturists. The UNIMAS model is worthy of serious consideration in this respect, not only in Malaysia but also in other developing countries.

Small projects involving rural people have already demonstrated that basic IT skills can be acquired in a very short time, and they have enhanced the quality of life in more ways than one. Ecotourism has been successfully enhanced albeit in a limited way. Information regarding diseases affecting humans, plants and animals could easily be made available through wider IT usage. Even teachers in remote villages can be trained through e-learning. For Malaysia, this is ideally the new horizon; this should be the most apt agenda for the GTP 3.0 for 2016–2020 and beyond. The smart village concept promises economic success in the rural landscape. However, the 21CV model is expensive and requires competent management. Consequently, other approaches have to be continuously investigated and piloted in parallel.

The eradication of poverty in rural areas is a multi-level and multi-faceted challenge. It is a never-ending pursuit. It demands dedication and attention at the very top of the administration. It dwells on education and training for the villagers; it promotes SMEs amongst them, using localised, available raw materials for development into marketable products; it also encourages ecotourism and agriculture, all the while leveraging on the progress of electrification in the country.

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Can energy access improve health?

Wole Soboyejo

In 2007, I was invited by a colleague to teach a global technology course to Princeton students at the Mpala Research Centre in Kenya. This is a wildlife research centre located in the Laikipia district of Kenya, which has a population of about 250,000 people in a land area about twice the size of Israel. It seemed like a perfect opportunity to explore ways of using technology to address the development challenges associated with energy access and waterborne disease. I therefore accepted the offer, with the hope that I would have the opportunity to trial some of the technologies that had been developed or tested in my lab[1,2,3].

Defining a need

On arrival in Mpala, I noticed that most of the Kenyan staff lived in two village communities with no access to electricity or potable water. In the absence of an electricity grid, most of the huts relied on kerosene lanterns, resulting in environmental pollution and about an 80 per cent incidence of pulmonary health problems, with most of the children in the village suffering from asthma. They also had waterborne diseases from drinking contaminated water from the local river, and there were serious concerns about the potential for bone deformities and the pitting of teeth that could occur due to the consumption of fluoride-contaminated water[4] from the local borehole.

Inspired by the challenges of life in Mpala village, I asked my Princeton students to talk to the villagers to learn more about the role that technology could play in addressing their basic needs. Somewhat surprisingly, the villagers identified electricity access as the most serious issue. Similarly, the Mpala clinic identified electricity access as their biggest hurdle in preserving much-needed vaccines and medicines necessary for the prevention of major diseases across the Laikipia district. We therefore decided to focus on ways of developing sustainable solutions to problems

The health impact of solar lanterns was much greater than anticipated, resulting in much lower levels of pulmonary health problems

of energy and water, using Mpala village as a model of a rural village in a developing country. This essay presents the results of our efforts and their implications for rural communities across the world.

There is a need to finance the initial acquisition of sustainable solutions when the initial costs of the products are greater than the consumers' available cash flow

In the case of access to electricity, our questionnaire studies revealed that the homes in the village had energy budgets of about US$ 4 per month, while the average income of individuals was between US$ 1 and US$ 2 per day. This meant that any alternative solutions had to cost about US$ 4 a month or less if they were to be competitive with the kerosene lanterns that had become part of the local culture.

Meeting the challenge

After some out-of-the-box thinking, we realised that a conventional system involving a 100-watt solar cell and a 12–24-volt battery with a cheap charge controller and inverter could offer no solution[2] because of its relatively high initial cost – approximately US$ 500–1,000 – when compared to the average monthly income of about US$ 60. We needed a system that cost no more than US$ 4 a month over 12 months.

To meet the US$ 4-a-month target, the solution was a solar-powered lantern with a 2-watt solar panel and a 6-volt motorcycle battery. Although many of the villagers wanted us to give this system to them for free, we realised that the lanterns would not be properly cared for unless they had been paid for, so every home in the village was given the option of financing a solar lantern over a period of 12 months. This resulted in the introduction of solar lanterns into all 200 homes of the village. The income from the lanterns was used to introduce ceramic water filters[3] that further improved the health and well-being of the people.

After a year, the health impact of the solar lanterns was much greater than we had anticipated. First, we found that they essentially eliminated the use of kerosene lanterns, resulting in much lower levels of pulmonary health problems. We also developed ways of converting old kerosene lanterns to solar power, enabling the local people to convert their lamps at a cost of about US$ 25 per lamp.

Encouraged by the success of the solar lanterns, we worked with the people of Mpala, the College of Art and Design in Pasadena and the Nomadic Peoples Trust to develop a solar-


W. Soboyejo

Introduction of a solar lantern to Mpala village.

powered refrigeration system that was mounted onto a bamboo frame on a camel. The system enabled the Nomadic Peoples Trust to use community-medicine approaches to provide refrigerated vaccines and medicines to the Laikipia community of about 250,000 people, and it is now being used in their monthly trips across Laikipia district.

Conclusion

The above examples show that villages such as Mpala can be provided with funds to develop demand-driven sustainable solutions to their energy needs, and they also show that the users value the solutions and are willing to take care of them when they are asked to pay for them.

There is, however, a need for funds to finance the initial acquisition of sustainable solutions when the initial costs of the products are greater than the available cash flow of the consumers. Such funds, which can be administered through local banks and/or cooperatives, can also be used to purchase water filters for removing the microbial pathogens that cause diseases such as dysentery, diarrhoea and typhoid, which kill up to 20 per cent of children in rural villages.

In addition, the combination of solar energy and refrigeration can be used to preserve vaccines in rural communities that cannot be reached by jeeps or landrovers. In such cases, rugged animals such as camels and donkeys can be used to transport the systems to the communities that need them. Further work is clearly needed to develop evidence-based strategies for scaling these approaches into policies that could improve the lives of the 1.3 billion people that live without access to electricity.

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Energy provision and food security in off-grid villages

M.S. Swaminathan and P.C. Kesavan

In spite of much technological progress, many countries as well as communities within countries suffer from food insecurity; one in seven people in the developing world remains food insecure.

Food security involves concurrent attention to availability, which is a function of production; access, which is a function of purchasing power; and absorption, which is a function of nutritional literacy, alongside attention to clean drinking water. Food security also involves steps to overcome protein hunger arising from the inadequate consumption of grain legumes, milk or animal products that are rich in protein content. In addition, there is the need to attend to micronutrient malnutrition caused by deficiency in the diet of iron, iodine, zinc, vitamin A and vitamin B12, among others. This is why, in programmes designed to ensure the health of the population, overcoming under- and malnutrition to ensure food security and the provision of non-food necessities like sanitation and primary health care need integrated attention. This is particularly so in off-grid villages where such provisions are sparse and agricultural activities are frequently at a subsistence level.

Food security is a concern for countries at low levels of economic development since a fall in food consumption may have serious irreversible nutritional consequences for both present and future generations. Off-grid villages are particularly vulnerable because the lack of electricity means a reduced capacity to run equipment such as machinery needed for cultivation and irrigation, and an inability to develop small-scale village industries locally[1]. However, an off-grid village does not really mean a no-energy village. For years, small-holder farmers in less developed countries, many living in off-grid villages, have relied on farm animals for draught purposes, supplemented with the labour of rural women and men belonging to family farms as well as

A fall in food consumption may have serious irreversible nutritional consequences for both present and future generations

landless families. This means that even today there is hardly a village in India without some form of energy, albeit limited. Villages in northeastern India have a shortage of energy for farm operations due to the insufficient number of farm animals. According to the Central Rice Research Institute, Cuttack, India, the yields of paddy in eastern India remain low due to inadequate bullock power. The situation can be remedied either by increasing animal power or by mechanisation. A smart village, therefore, would adopt and encompass some of the promising new renewable technologies that could lead to sustainable energy provision, increased food production and value-added outputs.

Modern agriculture

With modern agriculture, particularly after the green revolution era of the 1960s, a heavy dependence on energy has developed. There is a strong positive correlation between energy input and food output, and from the last century onwards productivity advance has been

Box 1 The dangers of excessive use of fossil-fuel-based inputs

Intensive cultivation of land without conservation of soil fertility and soil structure would lead ultimately to the springing up of deserts. Irrigation without arrangements for drainage would result in soils getting alkaline or saline. Indiscriminate use of pesticides, fungicides and herbicides could cause adverse changes in biological balance as well as lead to an increase in the incidence of cancer and other diseases, through the toxic residues present in the grains or other edible parts. Unscientific tapping of underground water would lead to the rapid exhaustion of this wonderful capital resource left to us through ages of natural farming. The rapid replacement of numerous locally adapted varieties with one or two high yielding strains in large contiguous areas would result in the spread of serious diseases capable of wiping out entire crops, as happened prior to the Irish potato famine of 1845 and the Bengal rice famine of 1942. Therefore, the initiation of exploitative agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture and without first building up a proper scientific and training base to sustain it, may only lead us into an era of agricultural disaster in the long run, rather than to an era of agricultural prosperity.

M.S. Swaminathan, Indian Science Congress, Varanasi, January 1968


Steve Allen/Dreamstime.com

Renewable and decentralised energy services could provide India's off-grid villages with the motive power required to supplement bullock pulling power and ensure a food-secure future.

related to the industrial production and consumption of mineral fertilisers and chemical pesticides. Agricultural mechanisation, post-harvest drying and processing, as well as groundwater pumping, make heavy demands on energy supply. According to estimates from the Food and Agriculture Organization of the United Nations, the dependence of agriculture on fossil energy means that the global average energy requirement to produce 1 tonne of cereal is about 85 kilograms of oil equivalent (kgoe); it can be as low as 20 kgoe per tonne in Africa through traditional methods, and as high as 116 kgoe per tonne in Western countries through industrialisation. A similar picture has been seen with maize grown in the USA or in Mexico[2].

The intensification and industrialisation of agriculture in developed countries has given rise to an increasing dependence on fossil fuels for providing nutrients for crops and also for groundwater extraction and irrigation. This has raised concerns about environmental issues and greenhouse gas emissions, as illustrated by predictions made in 1968 (Box 1).

Paradoxically, government agencies continue to promote the use of fossil energy in the tropics and sub-tropics, which are richly endowed with solar energy. So the vision of a smart village described in this collection of essays foresees an alternative scenario – renewable energy as a catalyst for development. It resonates with the idea of sustainable processes for rural development, a concept developed some years ago in the context of an evergreen revolution involving increases in productivity in perpetuity without the ecological harm referred to in Box 1[3].

Sustainable food production

Evergreen revolution technology involves integrated natural resources management and limited use of fossil-fuel-based energy. Smart villages for those who live off grid should, therefore, involve a low-carbon development pathway. For this we should promote the use of biomass for electrification, biogas, wind, solar power and ocean thermal energy (where oceans are nearby). In addition, increasing the productivity of crops through the efficient use of energy and advances in plant breeding should be associated with steps for feeding the crop in a sustainable manner. Breeding and feeding for high yield should go together.

The adoption of renewable and sustainable energy sources for food security needs to consider the impact on land and biodiversity. Recently, Brook and Bradshaw[4] evaluated the land-use, emissions, climate and cost implications of energy sources such as coal, gas, nuclear, biomass, hydro, wind and solar. The analyses showed that nuclear and wind energy had the highest benefit-to-cost ratio; the new-generation nuclear reactor technologies that are designed to fully recycle waste and incorporate passive safety systems seem quite dependable for generating sustainable clean and safe energy.

While nuclear energy is environmentally benign and can supply electricity to industries as well as households over long periods of time without also generating greenhouse gases, the impact of chronic doses of radiation on human health will continue to

Agricultural dependence on fossil energy means that the global average energy requirement to produce 1 tonne of cereal is about 85 kilograms of oil equivalent

demand careful study. Its use for agriculture, however, is limited, particularly for villages remote from the grid where, as mentioned previously, greater food security will depend on renewable bioenergy supplied by wind, solar, biomass and hydro, or relevant hybrid combinations. Nonetheless, coastal villages in India, with its extensive coastline of about 7,600 kilometres, could benefit from nuclear energy since the nuclear power plants are mostly located in the coastal regions – but this will depend on the adequacy of grid infrastructure.

Alternative means of providing nitrogen for plant growth have long been a dream of plant breeders, since they would reduce the need for energy-dependent chemical fertilisers. Leguminous crops like *Sesbania rostrata* have stem nodules that can enrich the soil by about 80 kilograms of nitrogen per hectare. The African tree *Faidherbia albida* is ideal to fix nitrogen in its leaves, which are subsequently incorporated into the soil. Uniquely, these "fertiliser factories in the field" do not compete with the crops for light, water and various soil nutrients other than nitrogen. Chinese and Japanese agricultural scientists have developed strategies to harness the organic matter in the soil, which contains microorganisms rich in phosphorus, potassium and several micronutrients, to enhance the productivity of crops with little in the way of energy-consuming chemical inputs[4,5]. Entrepreneurs who promote eco-agriculture and the evergreen revolution referred to previously provide livelihoods to the landless women in using their manual energy largely to produce vermicompost, green manure, biofertilisers and biopesticides.

Therefore, the vision for an off-grid smart village from an Indian perspective is one that achieves food security by using pathways of production that depend increasingly on biological rather than chemical inputs. In this way, renewable and decentralised energy services will provide the motive power required for machinery and irrigation, the development of cold-chain infrastructure to reduce waste, and the integration of communication technologies to help with pest management, soil health and improved market access. Entrepreneurial initiatives directed towards eco-agriculture will enhance food production in off-grid villages, whether by "fertiliser trees" and biogas plants, or water-harvesting structures such as Jal Kund, a simple and low-cost rainwater-harvesting structure which has been developed for storing rainwater in the upper terrace conditions of northeast India.

An off-grid smart village is one that achieves food security by using pathways of production that depend increasingly on biological rather than chemical inputs

Sustainable food security is a must, and we have to produce more and more food grains and other agricultural products from diminishing available per-person land and water resources alongside expanding biotic and abiotic stresses. The smart village keeps in mind the urgent need to foster the evergreen revolution pathway of ensuring food for all and forever. The strategy of renewable energy provision will be crucial for achieving these goals.

The smart village keeps in mind the urgent need to foster the evergreen revolution pathway of ensuring food for all and forever

To sum up, for a healthy and productive life we need physical and economic access to a balanced diet, clean drinking water, sanitation, primary health care and nutritional literacy. The concept of food security was in the past restricted to adequate calorie consumption, while nutrition security involved giving attention to all forms of hunger, namely calorie adequacy, clean drinking water, and avoiding a paucity of protein and other hidden hunger. Today, food security and energy security are even more closely related, but they need the underpinning of environmental security and sustainability, particularly as our attention turns towards those who live in off-grid villages and their need to achieve food security using appropriate modern technologies.

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Smart villages for smart voters

Mukulika Banerjee

The right to vote is generally considered a fundamental right of each citizen, underpinning all other basic rights – to food, education and security. And the world's most enthusiastic voters live in India's 650,000 villages. At the heart of India's democratic system have been regular elections that now see the participation of more than 100 political parties and the largest electorate in the world, currently numbering some 815 million people. The most dedicated voters are not the well-educated urban middle classes but the poorest, most discriminated against and least educated, mainly in villages and small towns, where turnout rates can be well over 80 per cent. Further, the more local the election, the higher the turnout, bucking global trends: in rural India, the turnout at neighbourhood elections is close to 100 per cent. Contrary to what many predicted in 1947, when India gained independence and chose to become a democratic republic granting universal suffrage to all its citizens, poverty and illiteracy have not hampered democracy.

At the most fundamental level, there is tremendous pressure not to waste a vote, as illustrated by a simple procedure carried out by the Electoral Commission of India. In all Indian elections, each voter has their left index finger marked with a short vertical line in indelible black ink. This procedure is carried out to prevent fraud, but it has also made it impossible to lie about *whether* one has voted. So it creates peer pressure to go and vote, particularly in the little world of the village, for not to do so results in suspicion about the abstention. Not losing face in small rural communities, whether among kin or party workers, is an important factor explaining high turnout rates.

Energy to vote

More recently, India's electronic voting machines have revolutionised the electoral process. Over the last two decades, a series of closely monitored pilot projects have taken the complex process of casting a vote away from a paper

Not losing face in small rural communities, whether among kin or party workers, is an important factor explaining India's high election turnout rates

India's voter power, as indelible as the ink on fingers.

ballot to very basic electronic machines, often powered by batteries, which the electorate of India has accepted and which have proved to be both fraud- and fool-proof. India is now a world leader in demonstrating how a simple but smart machine can revolutionise the running of a political system through accuracy and veracity, making it accessible to the illiterate, the innumerate and the disadvantaged.

At an informal workshop of the South Asian Association for Regional Cooperation (SAARC), held in Alleppey, Kerala, in 2011, Election Commissioners specifically devoted their discussions to the game-changing impact of electronic voting machines. India's neighbours – Bangladesh, Bhutan, Nepal, Pakistan and Sri Lanka – had all demonstrated their potential and the Commissioners agreed that this was the way forward. Now manufactured in India by two separate government-sponsored bodies, the machines are both affordable and scalable, with a million of them being used in each general election.

At another of the SAARC workshops, the Indian Election Commission underlined how they use local sources of electricity to power video cameras and to contact voters and parties in order better to regulate the elections, thereby making the rural electorate familiar with the uses, rather than abuses, of electrically powered devices as a means of ensuring the basic right from which all other rights in their society flow.

Change ignited

So why does rural India cast its votes so enthusiastically despite the sustained failure of the Indian state to improve the living standards of its poorest citizens? Is it because the poor are ignorant and don't know better? Are they gullible and vulnerable to vote buying and empty campaign promises? Or are they prey to bullying and violence? These are important questions and recent ethnographic research carried out nationally provides some insights.

One important reason why the rural electorate participates so enthusiastically in elections is because they hope their numbers and their votes for specific candidates and political parties will act as pressure for the delivery of these missing services. Sometimes this does bear fruit: a long-promised bridge materialises or a village finally gets its own primary health centre. But on the whole, such developments are often random and rely on serendipity rather than a concerted design for rural India. There is not, for instance, a concerted programme for smart villages to mirror the much-hyped smart city agenda. Democratically elected Panchayats have no coordinated action plan for delivery of services at the village level: at the most local level, there is not even administrative back-up for their budget allocation plans.

As a result, rural India has some of the worst infrastructure in the world, with access to basic services like water, electricity and roads a luxury for most villagers. In a community in West Bengal investigated in 2011, the electricity supply had reached fewer than half the homes, there was no piped water, only two households had a refrigerator, people were still dying of preventable diseases such as jaundice, and the roads both within the village and linking it to the outside world were all *kuchcha* (not macadamised). A combination of factors – no industry and few job opportunities, obstacles to paddy cultivation and bad connectivity – meant that there were only three main sources of income: sale of pilfered coal, mining sand from the nearby river bed and

> ***India is now a world leader in demonstrating how a simple but smart machine can revolutionise the running of a political system***

poppy cultivation, each of which was illegal. People said they did not want to break the law but had no other options for survival.

It is for this reason that elections have emerged as a moment when hope for a better life is reignited in the electorate, a moment when politicians have to account for their neglect of their constituencies and beg a second chance. During long and exhausting election campaigns in large and diverse constituencies – a parliamentary constituency in India is almost 20 times the size of one in the UK – the laundered clothes of rich politicians become sullied by journeys on dusty roads, their arrogant heads must bend to enter the modest huts of the poor, and their hands must fold in a plea for votes. Election campaigns therefore have a levelling effect, as the powerful are humbled and the ordinary voter finds a voice.

Duty

Unquestionably, research shows, most citizens in India are clear-eyed about the venality of politicians, the importance of their own role in the working of the democratic system and the effect their individual vote has in determining the composition of government. "The vote is our weapon" is a statement often used to explain this sense of empowerment. The electorate believes in the efficacy of multi-party democracy and regularly held elections because it is felt that only through these institutions can governments be forced to respond to popular pressure and be punished for bad performance. The fact that incumbent governments are frequently thrown out, or indeed rewarded with re-election, is proof of this. "Without us, the system is nothing," is how ordinary voters emphasise their role. Thus Indian voters see electoral participation as fundamental to their engagement with the state, and their presence on the voting list a rare but valued official acknowledgement of their existence. People often use the word "duty" while describing the importance of voting; a typical formulation states: "it is my right to vote and it is my duty to exercise this right. If I don't discharge this duty, it is meaningless to have this right".

Most citizens in India are clear-eyed about the venality of politicians and the importance of their own role in the working of the democratic system

Another factor is the visceral experience of actually voting. The culture of a polling station fosters order – disciplined queues, respect for the ordinary person of whatever social background, efficiency of process and trust in the system, all of which are rare commodities in Indian public life. In addition, here, the only relevant identity of a person is his electoral photo identity card, which carries nothing but the most basic information. As people arrive to vote, no preference is made on the basis of wealth, status or any other social marker, and officials treat everyone the same. In India, with its ubiquitous and daily practices of discrimination on grounds of caste, colour, class and religion – and those who live in India's villages experience these acutely – this extraordinary glimpse of egalitarianism is valued. Further, people have often pointed out that the knowledge that each vote is of equal value to any other heightens its importance even more.

Significance in "un-smart" places

So we can conclude that the rural voter in India's democracy is smart and politically savvy, even to the acceptance of new technology. It is clear that within 60 years voters have embraced electoral democracy, and electronic voting machines have helped to make it a meaningful participatory process through which people renew their own citizenship but also hope to hold the political class to account. Where this faith has been repeatedly thwarted by the non-performance of successive governments, Indian rural voters have displayed sophistication despite the distinctly "un-smart" surroundings of a large proportion of their villages. There is limited access to news, literacy, information – all of which severely hampers people's ability to make use of state schemes, opportunities, loans, programmes or other avenues that could make their lives better. Despite this, Indian voters have managed to maintain their enthusiasm for democracy and imbue it with significance. It is now time to deliver smart villages to these smart voters.

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Public policy targets for energy access

Benjamin K. Sovacool

If energy poverty and access is such a pressing social problem, why do we need to involve governments in addressing it at all? In other words, why won't the market devise solutions and innovative business models for expanding access to modern energy services? Or, why don't major institutions like the United Nations or the World Bank tackle the pesky issue once and for all as part of their donor agendas?

This essay demonstrates why. It argues that energy poverty arises from a market failure that only governments and public institutions are well-suited to engage. It then presents evidence that without strong public policy intervention geared towards expanding energy access, particularly in rural communities, hundreds of millions of people will remain mired in energy insecurity and human poverty for many decades to come.

Markets and intervention

It is useful briefly to delve into some basic theory about markets and government intervention. One quite fundamental problem is that markets only work for certain types of goods. They tend to be efficient at distributing private goods such as bicycles or hamburgers – where property rights can be completely defined and protected, where owners can exclude others from access, and where property rights can be transferred or sold – but less effective for common-pool goods or public goods that need agreed-upon rules or sanctions. Unfettered economic markets are almost completely ineffective at distributing public goods such as clean air or improved energy security, for instance.

Without strong public policy intervention, hundreds of millions of people will remain mired in energy insecurity for many decades to come

It is no surprise, then, that an extremely large number of people around the world do not receive modern energy services, especially through mini-grids or devices beyond solar home systems that lack business channels, because of a market failure to deliver them –

a situation in which neither private actors nor major donors expand energy networks to reach a socially desirable state. Instead, the very poor fall through the cracks and are too politically distant and economically costly to provide with energy services, even under many international programmes. Rural communities in off-grid villages often fall into this category, so that energy access becomes a higher development goal, not a lower one.

Energy security and reductions in energy poverty will happen only when more basic needs, such as the repayment of debt, financing of education and satisfaction of community responsibilities, are accomplished. In addition, many multilateral financial institutions such as the Asian Development Bank and the World Bank must demonstrate positive cost-benefit ratios for all of their projects, since they are indeed usually giving loans rather than grants, and many energy access projects have timelines that are too risky for these development partners. Making matters worse, rural communities are characterised by poverty and low population densities; with fewer households demanding less energy per household, utilities face much higher costs to supply each unit of electricity consumed. In contrast, in urban slums, where electricity theft is common, utilities struggle with how to bill informal settlements that often do not meet the legal requirements to become regular customers.

Disturbing trends

Projections from the International Energy Agency (IEA) subtly, but clearly, underscore that due to many of these factors, a large proportion of the poor are unlikely to reach the goals of the United Nations Sustainable Energy for All (SE4All) initiative anytime soon. In projecting the future in their 2012 *World Energy Outlook*, the IEA estimated that almost 1 billion people will still be without electricity by 2030 and that 2.6 billion people will still be without clean cooking facilities. That same year, the number of people without clean cooking technologies in India will amount to twice the population of the USA. Overall, the IEA forecast that 39 per cent of people in the Asia-Pacific region would lack access to modern cooking facilities.

Even the financing trends of the past few years confirm a trend away from universal access. The IEA projected that about US$ 76 billion would be required to achieve universal access to clean cooking by 2030, an average of US$ 3.8 billion a year, and that US$ 1 trillion would be needed for universal access to

By 2030, almost 1 billion people will still be without electricity and 2.6 billion people will still be without clean cooking facilities

Solar Sister's mission is to build an Africa-wide network of women solar entrepreneurs trained to introduce small-scale energy technologies to off-grid communities.

energy and electricity, an average of US$ 50 billion a year. As of 2013, however, only 3 per cent of this necessary annual investment had been committed.

Positive benefits

When energy access programmes are designed and structured according to sound principles, and when there is a productive use of energy, they can provide customers with a positive cost-benefit curve; that is, the benefits of energy access programmes will well exceed the programme's or technology's costs. In Nepal, evaluations of a rural energy programme involving micro-hydro units have specifically documented as much as US$ 8 in benefits per household for every US$ 1.40 in total expenditures; in Sri Lanka, roughly three times the budget of one energy access programme was invested in the market, suggesting it catalysed the involvement of the private sector[1]. In Sub-Saharan Africa, the United Nations reports[2] that every dollar invested in a Solar Sister entrepreneur – a woman selling solar lanterns – generates more than US$ 46 in economic benefits in the first year alone.

The returns for better cooking facilities can be even more significant. In Liberia, the return on investment for improved cook stoves is greater than 400 per cent while the return on investment for biogas stoves is greater than 100 per cent, meaning these systems both pay for themselves and produce net benefits[3]. In Kenya, rates of return for improved cook stoves are 429 per cent[4].

One scientific study simulated what it would cost to provide universal access to gaseous fuels for cooking and electricity for lighting in India by 2030, and found that programme benefits would far outweigh the expense. Improved living standards, greater livelihood opportunities and climate change mitigation – just three benefits – more than justified the cost of expanding energy access[5].

Another study looked at the benefit-cost ratio from 2005 to 2015 of switching away from fuelwood, dung and coal in 11 developing countries to cleaner forms such as improved cook stoves[6]. Such efforts would cost only US$ 650 million to achieve, but would produce US$ 105 billion in benefits each year. Of course, the dilemma with these returns is that they do not necessarily go to the parties making the investment: governments or vendors pay but it is households and communities that benefit through improved health or cleaner air[2].

Conclusions

In sum, the message from the market appears to be simple, yet blunt: the poorest households in the world are unlikely to be served by the activities of the private sector, government programmes or financial institutions as currently constituted. These are the energy-poor who – even through the IEA programmes – will not gain access to modern energy by 2030 under a business-as-usual scenario.

The lesson, however, is equally simple: if the energy access needs of these poorest of the poor are unlikely to be met, then actors need to implement policies and integrate them with targets to make certain that they are served. To ensure equal development and access for all, there is a need for specific interventions to reach the poorest at the bottom of the ladder, those who are not served by commercial energy providers or large-scale energy projects that demand

To ensure equal development and access for all, there is a need for specific interventions to reach the poorest at the bottom of the ladder

positive profit margins early in the process. A few innovative business models have emerged in recent years to address this concern, including the Pro-Poor Public-Private-Partnership being piloted in Indonesia, or one-stop-shop firms which sell both microcredit loans for off-grid equipment and the technology itself. But these have so far been limited to a few niche markets.

Ultimately, if access to electricity, modern cooking devices, warm homes, cooked food, the internet, and other modern amenities is to be truly available to all and equitably distributed, then public-policy targets become an elemental, formative part of meeting that moral imperative.

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Energy policies for off-grid villages in Tanzania

Andrew Mnzava

It is hard to talk about development in off-grid villages without talking about energy. Health, education, food security, productive enterprise and environmental well-being, as well as participatory democracy, can all be achieved if good policies are in place, but they depend not only on access to energy but on the provision of information.

Sustainable and clean energy is a big challenge for off-grid villages in developing countries like Tanzania, aggravated by a lack of appropriate policies. Policy formulation needs to look at how best to boost energy access while addressing the barriers that hinder it, most of which relate to knowledge of local developers, financing for off-grid energy projects, the regulatory framework, and knowledge and awareness of the respective communities.

National policies

One of the key successes in supporting rural electrification, and specifically off-grid projects, has been the formulation of a Rural Energy Agency (REA). Tanzania is a good example of this process, with major support beginning in 2005 with the passing of the Rural Energy Act. Today, a Rural Energy Board (REB) comprising government, the private sector, consumer representatives and development partners, governs and oversees Tanzania's REA and the Rural Energy Fund (REF). The REF is capitalised through funds from specific taxes on petroleum products and electricity, and by development partners including the World Bank/International Development Agency (IDA), the Swedish International Cooperation Agency (Sida), the Norwegian Agency for International Cooperation (Norad), and the US government, among others.

Many countries do not have renewable energy policies that foster the development of clean energy and directly support off-grid energy development

Despite the presence of such agencies, many countries do not have specific renewable energy policies that foster the development of clean energy and directly support off-grid energy development. As a result, many REA bodies have found themselves mostly engaged in grid extension[1], with very few supporting off-grid projects. This may be due to a number of challenges ranging from financing to regulatory issues. Key policies should be put in place to overcome such barriers.

The government of Tanzania has an ambitious programme to support off-grid projects in development centres that will not be reached by the interconnected grid before 2020, if at all. A development centre, according to the national electrification prospectus, “is typically a settlement with a population of at least 1,500 inhabitants in 2012, with some existing social or administrative infrastructure (school, dispensary, police station, etc.), good access by roads and some business activities”. In total, 154 projects have been drafted, 18 with power supplied by mini-hydro plants, 63 by rice-husk-fuelled gasifiers and 73 by hybrid diesel-photovoltaic systems[1].

When we look at the sustainability of off-grid projects in general a number of challenges commonly arise, calling for specific responses.

Local developers

Local or national developers are off-grid energy developers who generate and supply power to their surrounding communities. Several individuals or groups may have the potential capital to become local developers but lack information about how to go about setting up off-grid power generation. Even those who have begun a project face challenges arising from a lack of skills in technical planning and implementation and overall project and business management.

This calls for capacity building, awareness raising and specific training of local and national off-grid developers on how to design, build and run a successful off-grid power business[2].

Financing

Developing national energy policies for off-grid villages involves both institutions and communities, as was demonstrated by the analysis of the *Mini-Grid Policy Toolkit*[3] developed by the Africa-EU Renewable Energy Cooperation Programme (RECP). Project financing is one of the biggest

Several individuals or groups have the potential capital to become local developers but lack information about how to set up off-grid power generation

challenges. Loans from financial institutions have not been successful because of their high interest rates and the very long pay-back time of the developers' projects. Governments have tried to introduce subsidies and matching grants, as well as performance grants with support from the World Bank and development partners, but the rate of uptake is still poor and success stories are very few and far between. This relates to deficiencies in developers' skills and knowledge, institutional and regulatory complications, and low community awareness and acceptance.

Corporate finance can be raised to develop and demonstrate business models, and different sources of equity and debt capital can be made available, but access remains challenging[3]. Both the financial sector and the developers' side may lack enough information on how off-grid projects should be designed, implemented and managed, and how developers qualify for funding.

This mini-hydro has been developed on one of the Rift Valley farms in southwest Tanzania to support local agriculture with the provision of clean and sustainable energy.

A. Mnzava

There is a need for bridging between developers and financiers about the availability and offer of loans or grants.

National policies need to address the issue of community and consumer knowledge and ensure the consumer has the capability to take off-grid power

Institutions and the regulatory framework

When it comes to environmental issues, the National Environmental Management Council (NEMC) of Tanzania provides environmental impact assessment certificates before any project can be implemented. If a project involves rivers, such as a hydro project, then the developer needs a permit from the relevant water basin authorities under the Ministry of Water. These are some of the key institutions with regulations that need to be met for a project to be a success – without mentioning the general ones which are also necessary such as business registration, business licensing, tax certificates and so on.

In Tanzania there is one national utility company, TANESCO, which is the main off-taker of generated power. Most developers prefer to sell their power to TANESCO for a guaranteed one-time return on investment, though recently it has proved to be impossible because of long delays in TANESCO's payment to the developers.

Bureaucracy therefore remains a challenge for national off-grid energy developers, particularly considering their lack of experience and skills in the industry. This is exacerbated when there are no links or connections providing ease of access to information between one institution and another, which means that it can take developers up to a year to negotiate all the steps involved in gaining the necessary permits.

A national policy is needed to provide a one-stop centre of information for all applications to facilitate investment in off-grid projects for sustainable development.

Communities-consumers

There have been extensive studies of project financing but very few in terms of consumer financing. Consumer financing is another way of looking at the ability and capacity of consumers and clusters of communities to pay for the power supplied. This has been a challenge in a number of rural communities where off-grid projects have been implemented. Several villagers have failed to connect power to their households as a result of lack of funds to pay for the connection, as well as an inability to pay monthly bills[6].

Table 1 Cost comparison of energy sources[6]

	Electricity		Kerosene	
Upfront costs (TZS)	**Cheapest**	**Expensive**	**Cheapest**	**Expensive**
Fixed costs	310,295	377,045	5,500	13,250
Recurring costs	79,411	79,411	14,840	14,840
TOTAL	389,706	456,456	20,340	28,090
Annualised costs (TZS)	**Cheapest**	**Expensive**	**Cheapest**	**Expensive**
Fixed costs	37,816	43,933	637	1,660
Recurring costs	79,411	79,411	14,840	14,840
TOTAL	117,227	123,404	15,477	16,500

US$ 1 = TZS 2,000

Government efforts to introduce subsidies and grants for each house connected mean that the developer gets paid, but still the rate of uptake has been very slow. Awareness raising, empowering communities and creating community-based models can all help to solve some of the issues, and also lead to improved project safety.

GreenMax Capital advisors have shown the cost comparisons between electricity and kerosene, a common energy fuel in rural areas (Table 1)[6]. Notably, unfavourable upfront and annualised costs are a matter of concern for developers when looking for pay-back on their investment, leading most to sell their power to large national utilities rather than finding ways to provide for off-grid villages[7].

In several countries, the community model has proved to be the best option for remote areas. In these cases the owners and managers in a cooperative or community-based organisation are also the consumers, and therefore have a strong interest in the quality of the service and a real presence in managing it[3,7].

Clean and better energy would provide villages with better health services day and night, better education and easy access to information

National policies need to address the issue of community and consumer knowledge and, *through economic empowerment, ensure that the consumer has the capability to take power generated off-grid.*

Summary

There is a need to formulate national policies for off-grid renewable energy that address all the key angles discussed in this essay. The policies should harmonise the various areas discussed to achieve successful implementation of off-grid energy projects and hence increase the development of off-grid villages. Clearly, clean and better energy would provide villages with better health services day and night, better education and easy access to information through radio, television and mobile phones, as well as ease of starting and establishing small business enterprises for economic development, such as food processing machines to increase food productivity and storage to improve food security.

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Will private-sector finance support off-grid energy?

Tobias S. Schmidt

Providing the world's poor with modern energy services represents an investment challenge. The United Nations Sustainable Energy For All (SE4All) initiative estimates that energy access in developing countries requires investments of US$ 45 billion annually by 2030 to step up to this challenge[1]. This means that the US$ 9 billion per year currently invested in energy access has to be quintupled – not an easy task considering the scarce budgets of the public sector, especially in developing countries.

In my eyes, providing the 1.3 billion people without access to electricity, and the 2.7 billion people dependent on traditional biomass for cooking[2], with modern energy services will not be achieved without the private sector financing a significant share of these investments. Hence, the question of whether the private sector will finance off-grid rural energy is decisive. The good news is that the private sector – in theory – has the economic presence to provide financing at the required scale, with global capital markets amounting to more than US$ 200 trillion[3]. However, private-sector investors and financiers, be it debt providers or equity sponsors, require certain conditions to make them feel confident of investing at a significant scale. Given the high number of people lacking access to modern energy services, such conditions barely exist in the off-grid energy sector.

What are these conditions? Of course there is a range of different types of investors in the private sector, but it is safe to say that most investors primarily consider three main parameters: return, risk and scale.

Return on investment

Unlike most donors or the public sector, private investors demand a return on their investments above a certain threshold, also called the hurdle rate. In other words, the revenues from a private-sector-financed electrification

> ***Private-sector investors and financiers require certain conditions to make them feel confident of investing at a significant scale***

project need not only to cover the depreciation on the equipment, the operational expenditure such as wages, debt service and interest expenses to a bank, for example, but also to provide an annual income for the equity sponsor above a certain hurdle rate. To increase revenues and help surpass the hurdle rate, several sources of value might be combined in a business model – such as national government subsidies or revenues from global carbon markets. Recent research has shown, however, that the most important source of income will be the payments made by the energy consumers themselves – the villagers[4].

In order to guarantee sustained income over the entire lifetime of the investment, business models for smart villages need to ensure a positive income dynamic in the village[5]: the use of modern energy services should lead to an increase in income for the villagers. This helps to ensure that they can afford the consumption of these modern forms of energy in the long run and thereby provide sufficient long-term return for the private investor. But how high is the hurdle rate? How much return is sufficient? This depends strongly on the second relevant factor: risk.

Risk of investment

The minimum return an investor demands depends on the risks present in a project. Each additional risk adds to the hurdle rate. Certain risks can even act as a "show-stopper", making projects entirely unattractive for private-sector investment. Private investors – particularly those willing to invest in long-term infrastructure such as that required for electrification – are typically risk-averse. At the same time, many electrification projects are plagued by high risks stemming from different stakeholders at various governance levels (Table 1).

Some risks can be addressed through the business model of the electrification entrepreneur, but others are beyond the entrepreneur's control and need to be addressed by the public sector. An example of such a risk for an investor is when a village that has been electrified by a private-sector investor becomes incorporated into the main electricity grid: the main grid's cheaper and often heavily subsidised electricity tariffs undermine the private-sector investor's business model[4].

Some risks can be addressed through the business model of the electrification entrepreneur, but others need to be addressed by the public sector

Scale of investment

Private investors typically dislike small project scales. This is due to the considerable effort

Table 1 Common risks in electrification projects, stakeholders driving these risks and their governance level[4,6]

Risk	Stakeholder	Governance level
Regulatory risk *permits, market access, power market regulation*	Public sector	National/(local)
Grid extension risk *arrival of main grid*	Electricity utility/grid operator/grid regulator	National/sub-national
Technology risk *quality of equipment and project planning*	Technology supplier/ engineering contractor	International/ national/(local)
Operations risk *operating and maintaining equipment*	Project developer	Local
Financing risk	Financial sector	National/international
Customer payment risk	Villagers	Local
Public acceptance risk	General public	National/local

and high costs in evaluating potential sources of return and risk for each project. Different project types often also require different legal arrangements, leading to additional costs. These evaluation and structuring costs typically occur long before an investment can generate returns and typically do not increase strongly with project size, which makes larger investment more attractive.

At the same time, almost all projects providing modern energy services to villages require relatively small-scale investment[7]. For household-scale services such as solar lanterns, efficient cook stoves or solar home systems, micro-finance vehicles can be appropriate. However, solutions at the village level, such as electricity mini-grids, require scales of investment which are on the one hand too large for micro-finance investors but on the other too small for typical (energy) infrastructure investors.

Box 1 Policy options

Related to return

- In order to provide adequate *return* for investors, the public sector could provide co-funding through private-public partnerships[8]. But subsidies also play an important role[4]. Policy makers at the national level can remove regulations that cap energy revenues at very low rates.
- Many countries do not allow electrification projects to collect electricity tariffs higher than the often highly subsidised grid rate, despite the fact that villagers have a much greater willingness and capacity to pay[4].
- At the international level, policy makers designing carbon markets with offset mechanisms, or supporting nationally appropriate mitigation actions (NAMAs), can provide differentiated support for projects with a high development impact[9]. As energy access projects typically have a high development impact they would profit from increased carbon revenues.

Related to risk

- Addressing investment *risks* is often called de-risking[10]. To de-risk an investment, risks can be mitigated by addressing their root causes, as in policy reform; risks can be transferred to third parties through guarantees or insurance vehicles; or risks can be compensated by increasing the expected return.

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For village-level solutions, a future option is to bundle several independently operated mini-grids in various villages under one legal investment entity. While this increases the planning, training and operational efforts, it not only allows reaching investment scales which are more interesting for infrastructure investors, but carries a second potential advantage: due to the pooling of several villages, the diversification of risks could lead to a portfolio effect, reducing the minimum rate of return required by the investors.

Policy implications

Policy makers from the global to the local governance level who aim to increase the contribution of the private sector to off-grid rural energy finance can help to create more favourable conditions for private-sector finance. Understanding the three key criteria of private investors is a good starting point.

- Research on grid-connected renewable energy projects[6] has shown that mitigating risks is the most cost-effective approach, followed by risk transfer.
- Compensating risks is typically inefficient. In the case of smart villages, this implies a smart-village strategy that includes policy reform to reduce or completely eradicate policy-induced risks. Where such reform is not enough, or is prevented by political realities, risk transfer instruments should be provided by national governments through their national development banks, or international institutions such as regional development banks or the World Bank.
- To date, risk transfer instruments specific to the smart village do not exist and should be developed.

Related to scale

- A smart-village policy strategy with clear goals is important to reach *scale*. While concepts will have to be tailored to individual villages, from an investor perspective it is important that too many competing concepts are avoided, allowing for relatively standardised business models.
- The governance level of such a strategy depends on the country size: in larger countries, such as India, a strategy on the sub-national level (federal states) could be most effective; in smaller countries, a national or even regional strategy would make sense in order to reach investment scale.

Recommendation

Policy makers in donor countries but also in developing countries should support future research on the topics listed in Box 1 with respect to the development and expansion of smart villages in developing countries.

Key questions concern the quantification of risks, the size of the portfolio effects, the prospect of combinations of grid extension and off-grid electrification, and the feasibility of policy reform – especially given a new international momentum due to the SE4All initiative and the post-Kyoto climate policy.

Acknowledgement

The author would like to thank Steven Comello, Abhishek Malhotra, Anshuman Sahoo, Mayukh Samantha, Gireesh Shrimali and Oliver Waissbein. The discussions with them served as helpful input.

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How electricity changed our lives

Michael J. Ssali

There is a kerosene lamp known in the Luganda language as *tadooba*. It burns like a candle and it gives off thick dark smoke that slowly causes a black coating on the roof of the house, the walls, the furniture and other household items. It is the commonest type of lamp used in poor homesteads in Uganda. Meanwhile, our forests are diminishing because about 95 per cent of the country's households depend on firewood and charcoal for cooking. The use of lamps such as *tadooba* for lighting and firewood for cooking leads to household air pollution dangerous to human health. Nearly 20,000 young children die of indoor air pollution-related pneumonia annually in Uganda, while globally an estimated 3.5 million deaths every year are associated with the problem – mainly women and children in low-income countries[1].

Currently, according to the government's Rural Electrification Strategy and Plan 2013–2022, less than 5 per cent of Uganda's rural population has access to hydroelectricity. This low level of electrification is an impediment to achieving the desired transformation, which includes the provision of cleaner and more efficient technologies for cooking and lighting in all households[2].

During the civil war in our country (1980–1986) my wife, Mary, and I lived in Nairobi, Kenya, where we used electricity for lighting and other household purposes. As we prepared to return to Uganda when the war came to a close, we sold off the television, the cooker, the refrigerator and all our other electrical appliances, since we would not be able to use them in southern Uganda where we meant to set up a small farm and where we had no electricity.

Uganda's forests are diminishing because about 95 per cent of the country's households depend on firewood and charcoal for cooking

Both Mary and I had grown up in homes without electricity and we knew what to expect, but not our children. When they saw their mother lighting the *tadooba*, one of them said, “Mama is lighting a small stove”. They had to see for the first time a charcoal flat iron used for pressing our clothes. They were alarmed to watch her laying the firewood and lighting the fire in the small grass-thatched shade that passed as our kitchen, fearing that it could catch fire and that she could even get burnt herself. It took all of us quite some time to get used to life without electricity.

In 2004, thanks to DANIDA, a Danish donor agency, and the government of Uganda, hydroelectricity was to be extended to neighbouring Rakai district, and our Member of Parliament, Gerald Ssendaula, announced that the transmission lines were to pass through our home area and that several villages including ours – Ngereko in Kisekka sub-county – were to benefit. The good news arrived when we were still burdened with our children’s college tuition fees and the construction of our present house.

Building a house

In rural Uganda people may build their houses according to the materials available to them and according to their financial ability. Even simple houses of mud and wattle can be connected to electricity. To build a strong modern house, however, one must have an architect’s plan approved by the government. The building materials, including bricks, timber, sand, cement and other items, all have to be purchased and the builder has to be paid. Some people spend nearly all their lives saving money and buying building materials for their houses. Mary and I were in the process of building such a house and at the same time trying hard to raise university fees for our daughter and son when it was announced that hydroelectricity was to be extended to our home area. So it was not until 2010 that we were able to have our house connected to electricity.

There are costs involved: a qualified electrician must be hired to carry out the house wiring; households must apply to the electricity distribution companies to be connected; and then they must pay for the electricity they use[3]. Currently, one has to part with 98,000 shillings (US$ 40) or 326,000 shillings (US$ 120) for a “no-pole” or a “one-pole” service, respectively. In a country such as Uganda, where close to 70 per cent of the population lives on less than US$ 2 a day and the average annual per-person income is US$ 6,244, these are very high costs, and the great majority of

Demand for electricity in rural areas has increased with the mushrooming of vocational schools that turn out youths eager to start their own businesses

M.J. Ssali

Clean water – one of the myriad benefits of electrification.

households are still unconnected. Recently, the government came up with a plan to make free connections to houses located close to electric power lines (no-pole connections), which may see several thousands of homes connected.

Changed lives

Electricity dramatically changes lives[2]. Soon after getting connected we purchased a digital satellite television set, an electric flat iron and a few other household electrical appliances, and it is possible for us nowadays to use the computer and to access the internet, right in our home. However, power cuts are nearly a daily fact of life and a nuisance to live with. Sometimes as we watch an interesting television programme the power goes off with no warning from the providers[5]. UMEME, the main distribution company in Uganda, explains that this is inevitable due to the ongoing construction of extension lines.

Before new extension lines are constructed, the distribution companies and government representatives hold meetings with community members to agree on the terms of compensation for people who may have their crops trashed or their houses pulled down in the process of setting up the power lines. The people are warned that electricity can be very dangerous if it is not well installed wherever it has to be connected, and they are also warned not to engage in power theft.

Since it is a long-term government strategy to extend household electricity access to all corners of the country, many youths have acquired training in electrical installation so as to be hired to install power in homes that have to be connected. Some of them, however, are often engaged by dishonest people to make illegal connections or to wire their houses in such a way that some of the power used is not metered. In some cases, people with no training at all in electrical installation have made connections that time and time again have caused house fires and deaths. Distribution companies make routine checks and culprits are often disconnected and made to pay heavy fines.

New businesses

The demand for electricity in rural areas has increased in the past two or so decades with the mushrooming of vocational schools that turn out youths eager to start their own businesses as welders, tailors, carpenters and motor vehicle mechanics among other crafts, all of which require electricity. In our own home area, youths have begun to trade as steel welders, making doors, windows and other things that they easily sell within our community. “With unnatural precision and surprising grace, a mechanical claw dances around a half-meter piece of metal, neatly pouring lubricant down one side and welding it shut in a final flurry of sparks. An auto part falls into a waiting bin”[6]. Others have set up hair and beauty salons while bar owners and shop keepers have acquired refrigerators and sell cold drinks. Rural health centres can now use such equipment as X-rays, scanner machines and other electrical diagnostic appliances. The extension of hydroelectric power to rural trading centres and villages has facilitated the provision of clean piped water and increased the use of water closet (WC) lavatories.

Given the high cost of extending power lines to far-off rural areas, the government is encouraging new energy options such as solar panels for lighting, charging phones and powering household amenities like televisions. Local banks and microfinance institutions are required to prioritise granting loans to people

Local banks and microfinance institutions are required by the government to prioritise granting loans to people intending to install solar power in their homes

intending to install solar power in their homes. Generators are another option, but they burn expensive fuel – often involving long treks to obtain it – and they pollute the environment with smoke and noise. But they are often the machines used to power the music systems needed at rural discotheques and "trans-night" parties, as well as being depended upon to pump water or provide electricity to hospitals, schools and some towns. Given the recurrent power cuts in communities connected to the grid, a standby generator comes in handy whenever the power goes off.

To a large extent, rural electrification has contributed to a reduction in the migration of youth from rural to urban areas, since some of the amenities of large African towns – such as watching football on TV, discotheques, and opportunities for self-employment – are brought closer to home by the availability of electricity. Some youths have opened up internet cafés, phone repair workshops, tailoring shops complete with electric sewing machines, and other such small-scale enterprises in their own villages.

Nearly every home these days owns a mobile phone which must be charged. Yet only a very small percentage of homes have electricity. Some people connected to the grid or to solar power have set up phone-charging centres as a form of income generation. The mobile phone is used for money transfers, and it is a strong driver of agriculture in rural areas. With the use of the mobile phone the rich men in the towns can pay their farm employees without having to travel, and they can also give day-to-day instructions to their workers.

Jobs for a growing population

Electricity is a useful form of energy in agriculture since it can be converted into light and used to power pumps that push water to farms[7]. It is also used for refrigeration and for providing heat[8] – in the past, if a farmer failed to sell some of the day's milk he had to use firewood or charcoal to boil it to preserve it, whereas nowadays many farmers safeguard the milk by keeping it in refrigerators. Here and there, farmers' groups have set up coffee hullers and maize mills that add value to their produce. A farmer in our village uses electricity to pump underground water for his poultry farm and he also uses it to hatch eggs and keep the chicks warm. His poultry farm employs some six youths, which gives credence to an observation made by Engineer

Some risks can be addressed through the business model of the electrification entrepreneur, but others need to be addressed by the public sector

Peter Kiwanuka Ssebalamu, Head of the Mechanical Engineering Department at Mutesa One Royal University, that "provision of electricity to the remote rural areas will keep the youths there instead of going to Kampala and other towns seeking employment".

Countries with unchecked population growth and widely differing GDP per person will continue to present challenges to completing rural electrification

The International Energy Agency reports that globally, 1.3 billion people lack access to electricity and 2.7 billion lack clean cooking facilities[9]. Even with investments of $1 billion per year between 2010 and 2030 for on-grid electricity connections, a billion people would still be without electricity. And with current population growth, billions of people will continue to live without cooking facilities. There is a huge gap in power supply in most developing countries, especially in East Africa, illustrating the need to review their energy policies in order to bridge this gap. Countries in Sub-Saharan Africa with unchecked population growth as well as widely differing GDP per person[4] will continue to present challenges to completing rural electrification.

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Energy and ICT for educational inclusion in Latin America

Javier González Díaz

Although Latin America has experienced a successful decade of reduction in poverty and inequality, it continues to be the most unequal region in the world[1]. The persistence of high levels of social injustice is not accidental: its profound structural causes are rooted in unfair political, economic and social institutional frameworks, which have been shaped throughout history by asymmetric power relations[2].

Among social institutions, educational systems play a critical role in reproducing social inequalities in the modern world. Latin America is no exception. Privatisation, deregulation and the expansion of for-profit fee-charging schools have increasingly eroded and weakened the region's public systems, stratifying access and jeopardising the right to education for all. As a result, and despite improvements, educational systems are still failing society, constituting a persistent source of social exclusion.

If these inequalities are not tackled, the impact of existing educational inequalities over social asymmetries will intensify as human civilisation worldwide moves towards knowledge-based societies. As knowledge increasingly defines power in the modern world, inequality in access to knowledge and information will increasingly consolidate and magnify power asymmetries within and between countries.

Latin America faces several urgent challenges[3,4]. Firstly, access restrictions are still relevant, especially at pre-school, secondary and tertiary levels, and in geographically remote areas. Secondly, the region experiences severe inequality problems. Not only do countries exhibit low levels of learning outcomes, they are unequally distributed among the population. Public funding is insufficient, and teacher quality is low and inadequate, not only in relation to the capacity to deliver the official national

Children and youth living in remote rural locations are literally disconnected from the world, excluded from the opportunities provided by global learning

curriculum, but also in terms of the ability to teach and transfer basic technological skills, which are fundamental to modern labour markets. Additionally, educational infrastructure is still precarious across the region; this is especially acute in rural areas, where a large proportion of students lack access to electricity, internet and computers at their schools and homes. These rural communities are usually among the most vulnerable segments of society and are those most likely to be forgotten and left behind.

Children and youth in remote rural locations are literally disconnected from the world, excluded from the opportunities provided by global learning communities. The numbers are unambiguous: around 34 million people in Latin America have no access to modern electricity services[5]. Nevertheless, the severity of the problem varies across the region[6]. In 2010, countries including Uruguay and Costa Rica had electricity coverage rates beyond 99 per cent, while others such as Bolivia, Nicaragua and Haiti exhibited rates of 77, 65 and 28 per

Access to modern information and communication technologies can transform the learning experience for pupils and teachers alike.

Sjors737/Dreamstime.com

cent, respectively. Moreover, electricity access varies within countries. In Bolivia, for example, 90 per cent of the urban population has access to electricity services, while only 53 per cent has access in rural areas.

Permanent access to electric power in homes and schools opens a range of economic and social development alternatives for isolated communities

This phenomenon strongly affects educational systems. In fact, Duarte, Gargiulo and Moreno[3], using a representative sample of schools from 16 Latin American countries, estimate that around 11 per cent of primary schools in the region have no access to electricity. This percentage rises to 34, 46 and 57 per cent in the case of Panama, Peru and Nicaragua. Moreover, when these figures are analysed taking into consideration the geographical location of schools, the panorama is even more alarming. For example, in these three countries, 46, 75 and 68 per cent of public rural schools, respectively, do not have access to electricity to develop their normal educational activities. Finally, schools' access to electricity varies enormously depending on the socio-economic background of the students attending each school. While almost all schools serving students from the highest income quintile have access to electricity, approximately only half of those serving the lowest income quintile are connected to the grid. This unequal geographic and socio-economic pattern of electrification strongly affects the educational opportunities of Latin American children and their chance of achieving a better future.

Can access to energy and ICT make a difference?

Permanent access to electric power in homes and schools opens a range of economic and social development alternatives for geographically isolated communities. Amongst other options, it allows access to information and communication technology (ICT), which may be successfully used to enhance educational opportunities. Access by itself, however, does not automatically translate into an adequate use and incorporation of ICT into pedagogical practices, and it does not necessarily guarantee a positive impact on learning[7]. Nevertheless, when ICT is adequately adapted, used and effectively incorporated into the learning process by trained teachers and motivated students, it can strongly and positively enhance education in several ways.

The introduction of new innovative technologies facilitates and improves the manner in which learning occurs within the classroom. According to UNESCO, "technology is not neutral; the penetration of ICT in schools can eventually transform pedagogy and the creation

The availability of electricity and ICT helps to motivate teachers, and provides them with better and continuous training opportunities

of knowledge"[8]. It allows students as well as teachers to discover new ideas and compile educational material to be discussed in class, transforming education into an interactive, bi-directional and horizontal pedagogical process. The possibility of using innovative applications helps to overcome spatial and geographical barriers. Virtual learning platforms allow students to access educational content, as well as tackle homework and other assignments from their homes[4,9]. This is especially important for dispersed and isolated communities facing conditions that often limit their capacity to attend school regularly.

Information and communication technology provides teachers with a vast amount of valuable online material to prepare lessons, improving their quality and reducing the time they have to devote to organising and preparing each module. Similarly, the availability of electricity and ICT helps to motivate teachers, and provides them with better and continuous training opportunities: they can access online training courses and share best pedagogic practices, all of which may have a great impact on their teaching skills[8,10]. Moreover, a higher level of virtual connectivity opens a way for further cooperation within and between educational communities. Through this channel, ICT enables the creation of effective educational networks between geographically isolated schools, allowing them to jointly access, develop and share learning materials pertinent to those specific communities.

More specifically – and most importantly – there is robust evidence of the positive impact of computers on learning when these are specifically adapted and used to teach mathematics, science and literacy[11]. Experimental studies that make it possible to establish causality among variables also confirm these findings[12].

In sum, as worldwide experiences show, electricity enables the use of new technologies for educational purposes, constructing a virtual bridge between isolated rural communities and global educational networks.

Real life stories: aiming for the stars

The penetration of ICT in education and its use in vulnerable and isolated communities is already a reality: lives are being changed in poor, rural and remote areas.

Puentes Educativos, one of several innovative projects, has been implemented along these lines since 2010 in more than 400 schools in Chile. Aiming to improve educational quality by introducing the effective use of the new technologies, it provides students with smart phones and free internet access, and teachers with training and specially designed online material, including hundreds of videos adjusted to the local curriculum that they can download and use in their classes.

Besides increasing motivation among students, Puentes Educativos has had a significant effect on learning outcomes. In fact, a recent impact evaluation of the project shows that students from sixth grade increase their test scores in science and English by 10 per cent or more. But the project is not only about test performance: it also allows students to access and share information, and to experience new and far-away realities that they could never encounter in their own localities. No doubt this was the experience of students from San Clemente in the centre-south region of Chile, when their teacher managed to organise a video conference with a scientist working at ALMA, the largest astronomical project in the world, located at an altitude of 5,000 metres in northern Chile. Thanks to the Puentes Educativos project, those children were able to interact with scientists, relate their curriculum to real-life facts and, most importantly, were able to learn – from thousands of kilometres away – how it feels to aim for the stars.

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Improving life for women and girls in Sierra Leone

Christiana A. Thorpe

Women constitute 51 per cent of Sierra Leone's population of 6 million. They are responsible for nearly all household duties, from food production and processing to child bearing and family upbringing. Often, however, women are viewed not as individuals but as part of a male-headed household with some unique needs of their own related to their perceived roles. This approach generally takes little account of their real needs, let alone their potential.

Around 4 million of Sierra Leone's 6 million people live in rural areas with no access to electricity. People depend on firewood and charcoal for lighting, cooking and heating, which is of poor quality, and batteries for electrical appliances, which are costly. The extension of the electricity grid will take some time to reach these communities, some of which are so dispersed and demand so little power that even mini-grids are not an economic solution. The lack of electricity means that they are extremely isolated and have little opportunity for economic improvement.

Smart villages in Sierra Leone: how did they start?

In Sierra Leone, the concept of smart villages began with the idea of distributing solar home systems in rural areas by removing financial and technical barriers. Twelve women, drawn from 12 villages in the northern region of Sierra Leone where rural electricity was a huge challenge, were trained at Barefoot College, Telonia, India[1]. The women were illiterate or semi-literate, and on completion of their training at Barefoot College the issue arose of how to sustain and transfer the knowledge they had gained.

The model promotes decentralised small business and financing systems that enable the rural poor to learn how to pay for their own solar panels

The Barefoot Solar Training Centre was built in 2009 with funds from the government of

Box 1 Has this intervention changed lives?

The solar network is helping to change the lives of women and girls in the following ways:

- **Attitudes:** confidence building and ownership of the project.
- **Health:** home kerosene use, which created respiratory and eye problems, especially for women and girls involved in household chores, has been reduced. Health clinics have also received solar lighting, improving health care; women with babies are particular beneficiaries as they are regular visitors to these clinics.
- **Education:** girls can now study at night in a safe environment and some schools have received solar electrification facilities.
- **Environment:** over the lifetime of each 50-watt panel that replaces kerosene lighting, between 3 and 6 tonnes of carbon dioxide emissions will be avoided.
- **Savings on energy costs:** the solar panels were less expensive than current rural energy options, thus households could make savings. As women are the breadwinners in rural settings, the money saved can be used for other economic purposes.
- **Opportunities for income generation:** Nancy Koroma, head of a family of five in Koya Port Loko district, says that the 35-watt panels allow her to carry out her home activities at night[4]. This frees up her days for selling juice to generate income which helps pay off the loan for the solar system. A random sampling of Nancy's cohort in other regions of Sierra Leone has confirmed how solar power can help alleviate poverty in rural areas, which are heavily populated by women and girls.
- **Employment:** capacity building among the solar grandmothers has provided an avenue for self-employment for the women, as they earn income from the installation or repair of the solar grids around the country. The solar energy enterprise can provide employment for numerous women.

Sierra Leone, and implemented by the National Commission for Social Action (NaCSA). The Barefoot Women Solar Engineers Association of Sierra Leone[2] (BWSEASL) was formed with the sole aim of getting solar technology to all the country's remote and inaccessible villages. The approach was based on the belief that those who benefit from solar electricity are its most important promoters. The model therefore encourages decentralised small business and financing systems that enable the rural poor, especially women, to learn how to pay for their own solar panels. This gives them responsibility for their electricity use and at the same time allows many more people to have access to the technology.

Training illiterate women gives them a new life

The goal of BWSEASL is to give girls and women dignity, respect and independence through the creation of an electricity supply for their village homes. No working contract is signed with the women beneficiaries as the idea is for them to take ownership of the overall concept. The working relationship aims to build tolerance, trust, compassion and generosity with the women.

Capacity building is one of the easiest ways of achieving these goals and a further seven women were selected by the local traditional leaders on their willingness to be sent to India for basic training in solar photovoltaics. They were called the solar grandmothers because they became the trainers of other women in basic solar electrification in Sierra Leone.

By August 2014, 59 women drawn from the different regions of the country had completed their training. They are now expected to electrify a targeted 21,810 houses around Sierra Leone. Plans are underway to train a further 150 female solar engineers[3] selected from each of the country's 14 electoral districts. These women will introduce simple, basic and clean electricity through the use of solar photovoltaics in remote inaccessible villages.

Box 2 Key impacts of the approach

- Electrification of houses by solar panels in villages and essential buildings in rural communities such as schools, health centres, police stations and market centres.
- Construction of two production workshops funded by the United Nations Industrial Development Organization (UNIDO) for micro-enterprises.
- Selection of 149 chiefdom headquarters in Sierra Leone for possible solar electrification, including schools, clinics and social centres.
- Training of caretakers for UNIDO Growth Centres.
- Distribution of solar lanterns to police checkpoints, posts and other public places.
- Construction in 2009 of a training centre for women, supported by the government of Sierra Leone.

Is the approach sustainable?

The BWSEASL began their work by demonstrating rural residents' willingness to pay for the technology. Grants from the government paid the upfront costs for the construction of the Barefoot training centre and for a small number of homes to obtain solar panels. The beneficiaries, along with the rest of the villagers, then created a revolving fund to help others get panels. After a deposit of approximately US$ 115, residents could pay off the loan at about US$ 6 per month, which is less than they used to pay for batteries and kerosene lighting. We have found from interviews that the revolving fund has financed more than 600 solar home systems in marginal rural communities in 12 districts of the country's four provinces.

Women trained by the BWSEASL became entrepreneurs, running small businesses selling the solar panels, and now form a solar network made up of 16 micro-enterprises such as the Solar System Home Management Committee (SSHMC).

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A way of life: energy provision in Africa

Murefu Barasa

Charcoal is one of the most important yet least understood energy sources of the African continent. It is a leading source of livelihoods for village communities in rural areas and the preferred energy source for cooking and heating in urban areas. The production of charcoal provides employment in rural communities because more than 65 per cent of all households in the urban areas of East Africa use it as part of their energy mix. In rural areas hardly any charcoal is used, as communities opt for firewood instead[1]. Any practical alternatives will have to provide a viable income-generating option for rural areas and a competitive energy option for urban households.

After the global oil crisis of 1973, unsustainable use of traditional biomass energy, especially charcoal and firewood, became one of the trending topics in the energy sector at the global scale. Eckholm's publication in 1975[2] raised the profile of traditional biomass energy use in developing countries, and it was followed by a series of publications that linked all traditional biomass energy use with forest degradation and deforestation. By the 1990s, charcoal production and its use in developing countries was marked as a leading environmental threat, with negative impacts linked with deforestation, desertification and widespread soil erosion. This led to blanket moratoria on production and distribution across several countries. Due to the critical role played by charcoal, these measures were, needless to say, ineffective.

Enter Professor Emmanuel Chidumayo[3], whose empirical work published in the 1990s showed that charcoal production does not result in negative impacts in all cases. His work highlighted how the degree of forest or range-land clearing for charcoal varies considerably between countries and between sites within each country. In some cases, the extraction of trees for charcoal, although significant, was below the ecosystem's natural regeneration capacity – its mean annual increment

The lack of accurate data on charcoal trends remains a key challenge in managing the threat of unsustainable charcoal production

measured in tonnes per hectare. He observed that, contrary to the charcoal-crisis narrative, charcoal had little to no impact on the particular savannah ecosystem he studied.

The goal of these and other studies was in no way to downplay the widespread negative impacts of unsustainable charcoal production but to highlight possibilities, albeit marginal, for sustainable charcoal production. The findings helped to explain why the prediction of a total depletion and collapse of Kenya's forestry system by 1986 due to charcoal production was inaccurate. A study by the Beijer Institute in the 1980s had asserted that "if estimates of the consumption and growing stock are anything near correct, the trees will be depleted by about 1986; even if the volume estimates were doubled or tripled, the stock would still be exhausted by 1991 or 2005 respectively. Thus an acute shortage of woodfuel is imminent". The lack of accurate data on charcoal trends, however, remains a key challenge in managing the threat of unsustainable charcoal production – which is both widespread and harmful.

A complex value chain

No one aspires to be a charcoal producer, as it is a low-paying, physically intense and health-threatening undertaking, often done as a last-resort coping mechanism. Charcoal producers in villages are the factories that respond to market demands in many urban areas in East Africa as this is the preferred energy source for cooking and heating, solar-sourced cooking so far being a non-starter. Charcoal is not just an option for urban off-grid households but all households. Those that are connected to the electricity grid do not use electricity to cook (including myself); urban middle-classes typically use liquefied petroleum gas (LPG) in tanks and the rest use a mix that includes charcoal.

Besides the producers – who receive the least number of shillings per kilogram sold to the end user – charcoal has a complex value chain that includes brokers, transporters, wholesalers, retailers and recipients of unofficial payments along the chain. In 2014, the United Nations Environment Programme (UNEP) and Interpol estimated that unofficial payments and bribes to organised criminals, corrupt government officials and militia along the charcoal value chain were between US$ 14 million and US$ 50 million annually in Africa alone. More than 20 million tonnes of charcoal are consumed in Africa every year and this is expected to increase to 46 million

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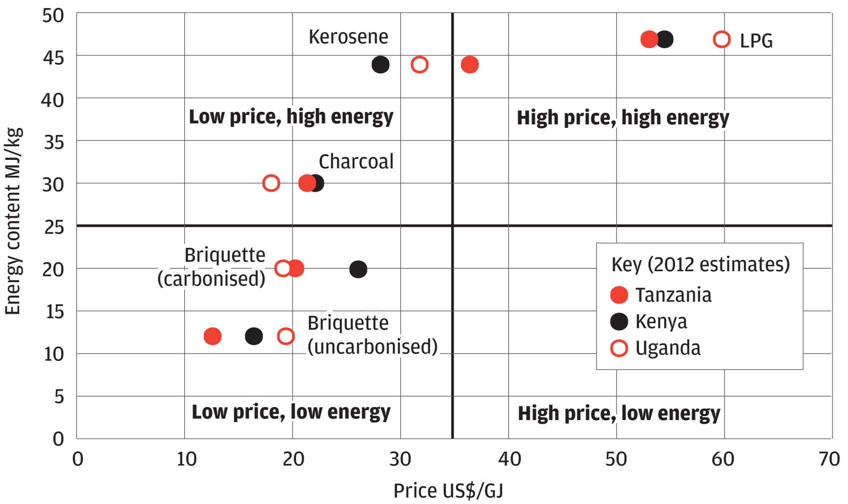
Figure 1 Comparing price and energy content[5]



***Note:** Briquette types vary greatly in design, mass, volume, shape, price and energy content. Uncarbonised briquettes typically have lower energy content averaging 12MJ/kg, compared to carbonised briquettes which average 20MJ/kg.*

tonnes by 2030, driven by sustained population growth, rapid urbanisation, and lack of practical and affordable alternatives[4].

Why the charcoal market?

When compared against other alternatives including briquettes, kerosene, LPG and electricity, charcoal out-competes most on several fronts (Figure 1).

The price of an energy option can be assessed using several metrics. Comparing the price of common energy sources for cooking and heating in Kenya, Uganda and Tanzania, based on an analysis of price per unit of mass (US$ per kilogram) and price per unit of energy output (US$ per joule), explains why some forms of energy are preferred and continue to out-compete other forms. For the first metric, an analysis of the levelling options (incorporating all the costs of an energy-generating system over its lifetime: initial investment, operations and maintenance, cost of investment) based on mass (kg), compares uncarbonised briquettes, carbonised briquettes, charcoal, kerosene and LPG. The second metric levelling options, based on cost per unit of energy output, compares all the options above plus grid-based electricity. Energy density is also a significant metric, comparing the energy output per unit of mass (joules per kg), and is important in determining the portability of an energy form. This is paramount, especially in urban areas where cooking spaces are constrained compared to rural areas, and explains why charcoal is preferred to firewood, and kerosene to charcoal.

Although briquettes have a lower cost price per unit of energy output, they have much lower energy densities. They are comparable to charcoal in terms of price (less than US$ 30 per gigajoule) but cannot compete with charcoal on energy content per unit of mass, with charcoal having values higher than 25 megajoules per kilogram. Both briquettes and charcoal use similar energy conversion technologies (various forms of cook stoves), although briquettes are more difficult to ignite, have much higher ash content and are not so readily available. Additionally, briquettes vary greatly and the market lacks standards or guidelines that can inform purchase. Such advantages make charcoal the undisputed household energy of choice for a majority of urban households, and this has remained the same for several decades.

Some misconceptions

The failure of past renewable energy interventions has been based in part on the limited understanding of the processing of energy selection as well as a lack of viable alternatives to charcoal. Kerosene has a much higher energy content than charcoal and prices are comparable. Although not clean or renewable, this is the energy form that is most likely to compete effectively with charcoal in the urban centres of Africa. Others include mass-produced ethanol or subsidised LPG. The price of charcoal in Kenya is about US$ 22 per gigajoule compared to kerosene at US$ 28 per gigajoule, even though kerosene has up to 50 per cent more energy density.

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The rationale for energy choices at the household level is more complex and certainly goes beyond considerations of price and energy density, although the two factors contribute the most towards informing energy choices. At the household level, energy consumption options and patterns for cooking and heating applications are influenced by price, energy content, ash content, smoke and fumes, the available cooking appliance, the availability of the fuel, the type of food (meal) to be prepared and the time of preparation. Additional criteria include the rate of energy extraction, availability, safety, fluidity and storage requirements.

A techno-utopian alternative to charcoal has to be matched by a social transformation that generates employment and viable income alternatives

Summary

The urban charcoal market is essential for East Africa because it remains a central part of household energy, and the data show what a techno-utopian competitor might expect to come up against – a societal structure that involves not only traditional forms of household energy provision for cooking and heating, but also embedded patterns of rural employment for charcoal production, and a livelihood influenced by shadowy interests along the value chain of charcoal for the urban market. The cautionary scenario is that a top-down techno-utopian solution could advance modern and alternative sources to charcoal as a primary energy source for cooking and living in the urban setting, thereby reducing air pollution and health problems, but that it has to be matched by a bottom-up social transformation that generates employment and viable income alternatives for the producers in smart villages.

Acknowledgement

Part of this research undertaking was supported by the Energy and Environment Partnership for Eastern and Southern Africa Program (EEP) and the African Wildlife Fund (AWF). The views expressed here are solely those of the author and do not in any way represent the views of EEP or AWF.

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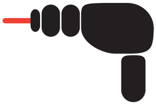
A better future for the bottom billion

Deepak Nayyar



The 20th century has witnessed enormous economic progress, yet widespread poverty persists. Estimates suggest that, in 2014, one in every seven people on Earth lived in absolute deprivation and wretched poverty. This essay poses some big questions about the stark reality and endeavours to provide short answers. Who are the poorest people in the world? Where do they live? Why are they poor? What are the attempted solutions? Why does the problem persist? Is a better future possible? If so, how?

The poorest are those who cannot meet their basic human needs in terms of food and clothing, let alone appropriate shelter or adequate health care and education. The widely used poverty line is US$ 1.25 per day in terms of purchasing-power parity[1]. In 2012, just over a billion people in the world lived below this line, probably unable to reach the critical minimum in terms of nutrition[2]. Infant mortality, life expectancy and literacy rates among the bottom billion remained abysmal, with economic exclusion reinforcing social and political exclusion everywhere.

Demographics

The perennial poor are concentrated in three regions of the developing world. In 2012, 415 million lived in Sub-Saharan Africa, 399 million in South Asia and 157 million in East Asia and the Pacific: altogether 971 million, of whom 292 million lived in India and 84 million in China. In addition, Latin America and the Caribbean were home to 27 million perennial poor, and 11 million lived in the Middle East, North Africa and Central Asia. In 1981, nearly 2 billion people lived in this wretched poverty. This number has halved in three decades. Even so, it remains unacceptably large.

Absolute deprivation

Such poverty persists among people because they do not have the income, or sufficient income, to buy goods and services for meeting their basic needs, including energy to help

Economic exclusion denies people the social opportunities and political participation that might otherwise help them to improve their lives

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Access to energy can enable people to set up their own businesses.

improve their lives. Energy poverty, as much as income poverty, keeps them in a state of absolute deprivation. The underlying reasons are simple: most of them have no assets, such as land or livestock, which could be used to yield an income, so that they have nothing to sell but their labour. Yet some cannot find work, while others – the majority – work very hard but cannot earn enough even to feed themselves, let alone buy fuel. This economic exclusion also denies them the social opportunities and political participation that might otherwise help improve their lives.

Attempted solutions

National governments and international institutions have sought to address this problem through anti-poverty programmes that seek to provide income support for the poor through public works or cash transfers. Sometimes, in some places, this goes together with enabling support through rural electrification or other forms of rural infrastructure. This approach may well be necessary as a means of mitigating poverty – and it does. Experience suggests, however, that it is not sufficient: it is often too little, the delivery is poor, and the leakages are significant. What is more, income support constitutes transfer payments in perpetuity, which cannot eradicate poverty or provide a sustainable solution. Indeed, widespread poverty persists despite such programmes.

Orthodox thinking among economists, increasingly accepted by policy practitioners and political leaders in governments, stresses the importance of economic growth as the only solution to the problem of poverty. Economic growth is obviously necessary. Indeed, between 1981 and 2008, it was a critical factor underlying the reduction in the number of people and the percentage of the population below the poverty line, particularly in Asia. But the belief that it can ever be sufficient represents a triumph of hope over experience.

Persistent problem

It is striking that more than half the bottom billion still live in Asia despite the region's rapid economic growth, rising share of world income, and industrialisation during the period 1980–2010. China and India have witnessed the fastest growth in human history over the past three decades. Yet in 2012, of the poorest billion people in the world, 29 per cent lived in India while 8 per cent lived in China. Sub-Saharan Africa remained home to 42 per cent of the bottom billion despite an impressive growth performance during the 2000s.

This poverty persisted essentially because rapid economic growth was associated with a rise in economic inequality, and little if any of the increments in income accrued to the poorest. Energy poverty reinforced the problem. Such outcomes often lead governments to discover the idea of inclusive growth, but it remains in the realm of rhetoric simply because growth can be inclusive, or pro-poor, if – and only if – it creates employment, livelihoods and energy access in off-grid villages. But that has not happened. Clearly, more of the same will not change reality for a long time.

Better future

The living conditions of the poorest in the world are ethically unacceptable, politically unsustainable and socially dangerous. However, a better world is possible. In this quest, economic growth is essential, yet not enough. The essays in this collection explore how energy access for the poor can perform

> ***Growth can be inclusive, or pro-poor, if – and only if – it creates employment, livelihoods and energy access in off-grid villages***

Employment and self-employment, which could blossom into entrepreneurship, are both instrumental in, and constitutive of, well-being for the poorest

a catalytic role. It should be combined with employment creation, social protection and human development. There could, then, be a better future for the bottom billion.

The well-being of the poor depends on their private income and their public entitlements. Assuming that there is no income from assets, private income – which supports private consumption – in turn depends upon employment levels for those in the world of work and social protection for those who are unemployed. Public entitlements, which support social consumption, depend upon the resources made available by governments for the public provision of services such as health care and education, their delivery and quality, and access for the poor. Thus, a mix of private income and public entitlements that is sufficient to meet basic human needs – food, clothing, shelter, health care and education – together with energy access that can act as a catalyst for development, should help eradicate absolute deprivation and lift the poorest above the poverty line.

Of course, meaningful development is about much more. It must enable ordinary people, men and women, to exercise their own choices for a decent life. In the pursuit of this objective, it is also necessary to provide the poor with access to social opportunities that are the essence of development as an end, and impart the poor with capabilities that are essential as a means of their participation in development through democratic engagement, which improves their well-being. The significance of this proposition is highlighted by the medieval distinction between agents and patients. The bottom billion must be seen as agents, or participants, in a process, who can shape their destinies, rather than as patients, or passive recipients, of the benefits from development programmes designed by benevolent governments or institutions.

Employment and livelihoods

Employment is an imperative both as a means and as an end. Economic growth provides income opportunities for people only through employment creation. Thus, employment and livelihoods are critical as the institutional mechanism that mediates between growth in aggregate income for the economy and growth in private income for individuals or households. Employment, in the form of decent work, is also what imparts dignity to the deprived or excluded. Apart from conventional wage-employment, sustainable livelihoods can be created through self-employment. In villages, home to the poorest, work with assets such as land or livestock can yield an income stream to support private consumption. In sum, employment and self-employment, which could blossom into entrepreneurship, are both instrumental in, and constitutive of, well-being for the poorest.

Incomes from wage- and self-employment are an essential part of a better future for the bottom billion. To begin with, this must be supplemented by public entitlements that support their social consumption, and social protection that provides them with a safety net in difficult times. The most essential public entitlements, which have to be provided by governments, are health care and education. These improve the quality of life for people and create capabilities among them. For the poorest, the components are obvious: safe drinking water, sanitation, vaccination, preventive medicine and community health; and primary education, adult literacy and skill development. The most essential social protection is insurance for health, accidents and life. Since insurance is about pooling risk, this can be done at modest premiums supported largely by governments with contributions from people that increase over time. The outcome in terms of human development could help transform the lives of the bottom billion: it would improve their well-being; it would provide them with access to social opportunities; and it would impart them with capabilities that would, taken together, empower such people to help themselves.

Initial conditions

Urban poverty can be wretched. But most of the poorest people live in villages and depend upon agriculture, directly or indirectly, for their livelihoods. Their ability to help themselves could undergo a dramatic transformation if governments were to help create a physical infrastructure in rural hinterlands that are almost bereft of it. This is feasible. It requires electricity from the grid or off the grid, combined with non-conventional sources of energy, which could be a catalyst not only for the physical infrastructure but also for the social infrastructure in health care and education. It requires investment in rural roads, transport and communications, around which economic activities can develop to create non-agricultural rural employment. It needs irrigation and storage facilities to boost agricultural incomes. Creating these initial conditions could open the door to a much better future for the bottom billion.

People's ability to help themselves could undergo a dramatic transformation if governments were to help create a physical infrastructure in rural hinterlands

Conclusions

The conclusion is simple. Employment is the solution. For people who do not have the income to meet their basic needs, often in villages that have no energy access, employment opportunities are the only sustainable means of reducing and eradicating poverty. The preceding essays argue that energy provision fosters employment opportunities. Moreover, employment creation and entrepreneurial activity mobilise the most abundant yet under-utilised resource in poor countries – the people for development. And the very people who constitute resources on the supply side also provide markets on the demand side. This interactive causation between supply and demand is a potential source of economic growth that highlights the importance of domestic markets in the process of development.

This should lead to some rethinking about the meaning of efficiency beyond the usual conceptions of economic or technical efficiency. Indeed, employment expansion is at least as important as growth in productivity. In a sense, both represent the utilisation of labour as a resource. Why, then, does thinking about efficiency focus on one and neglect the other? It is important to reflect on this question. The answer, which calls for change in both economics and politics, could make a real difference. In the sphere of economics, the meaning of efficiency must extend beyond output per worker or growth in productivity to encompass employment expansion and labour use. In the realm of politics, employment and livelihoods, supported by off-grid energy provision, must become an integral part of the discourse and the process, as a primary objective rather than a residual outcome.

Notes

1. Two poverty lines are used in World Bank estimates. PPP $1.25 is the mean of poverty lines in terms of consumption per person in the poorest 15 countries of the world. There is a second poverty line of PPP $2 per day which is the median poverty line for developing countries as a group.

2. This total number, as well as the number of the poor in each region cited in the subsequent paragraph, is based on World Bank estimates of poverty. See World Development Indicators, online database http://data.worldbank.org/products/wdi. These estimates are not without their problems in terms of methodology and statistical foundations, but are the only possible source for international comparisons over time, which sketch a global picture with broad orders of magnitude.

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Professor Wole Soboyejo received a BSc in mechanical engineering from King's College, University of London, in 1985, and a PhD in materials science from Cambridge University, UK, in 1988. He worked as a Research Scientist at the McDonnell Douglas Research Labs (1988–1992) before joining the Department of Materials Science and Engineering at the Ohio State University, USA, from 1992 until 1999. Between 1997 and 1998, he was a Visiting Martin Luther King Associate Professor at MIT, moving to Princeton University, USA, as a Professor of Mechanical and Aerospace Engineering in 1999. He recently served as the President of the African University of Science and Technology in Abuja, Nigeria (2012–2014). Professor Soboyejo is now back at Princeton, where he is a Professor in the Department of Mechanical and Aerospace Engineering.

Professor Benjamin K. Sovacool is Director of the Danish Center for Energy Technologies and a Professor of Business and Social Sciences at Aarhus University, Denmark. He is also Associate Professor of Law at Vermont Law School, USA, and Director of the Energy Security and Justice Program at their Institute for Energy and the Environment, as well as Editor-in-Chief of the peer-reviewed international journal *Energy Research & Social Science.* Professor Sovacool works as a researcher, consultant and teacher on issues pertaining to renewable energy and energy efficiency, the politics of large-scale energy infrastructure, the design of public policy to improve energy security and access to electricity, and the building of adaptive capacity to the consequences of climate change. Professor Sovacool is also the author of more than 300 refereed articles, book chapters and reports on energy and climate topics. He received his PhD in science and technology studies from the Virginia Polytechnic Institute & State University in Blacksburg, Virginia, USA.

Michael J. Ssali graduated from Makerere University Kampala, Uganda, in 1976 as a secondary school teacher (of English). He taught at St Henry's College Kitovu and later at Kakoma Secondary School in Uganda before migrating to Nairobi, Kenya, from 1980 to 1986, where he studied journalism and contributed articles to the *Daily Nation* and *Kenya Times*. He returned to Uganda to start farming with his wife while at the same time practising journalism. He was Masaka District Chairman of the National Organization for Civic Education and Election Monitoring (NOCEM), from 1993 to 1999. He has toured the USA under the International Visitors Program (1997). He won the Best Business Journalist of the Year Award in 2008 and earned a trip to a few places in South Africa including attending the Highway Africa Conference at Rhodes University in Grahamstown. He writes a weekly column in the *Daily Monitor* titled Farmers Diary, and he is a fellow of b4fa – Biosciences for Farming in Africa (www.b4fa.org).

Professor M.S. Swaminathan, Emeritus Chairman and Chief Mentor of the M.S. Swaminathan Research Foundation, has been acclaimed by *TIME* magazine as one of the 20 most influential Asians of the 20th century. He has been described by the United Nations Environment Programme as "the Father of Economic Ecology" because of his leadership of the evergreen revolution movement in agriculture and by Jávier Pérez de Cuéllar, fifth Secretary-General of the United Nations, as "a living legend who will go into the annals of history as a world scientist of rare distinction". He was Chairman of the UN Science Advisory Committee set up in 1980 to take follow-up action on the Vienna Plan of Action. He has also served as Independent Chairman of the FAO Council (1981–1985), President of the International Union for the Conservation of Nature and Natural Resources (1984–1990), President of the World Wide Fund for Nature (India) from 1989–1996, and served as President of the Pugwash Conferences on Science and World Affairs (2002–2007), President of the National Academy of Agricultural Sciences (1991–1996 and 2005–2007), and Chairman of the National Commission on Farmers (2004–2006).

Dr Christiana A. Thorpe recently retired as Chief Electoral Commissioner of the Sierra Leone National Electoral Commission. She was born in Freetown, Sierra Leone, holds degrees in modern languages from University College Dublin, Ireland and St. Clements University, British West Indies. As Minister of Education, she piloted a new policy on education for Sierra Leone, introducing radical structural and other reforms in the education system. She is a civil society activist on empowerment of women, and established the Forum for African Women Educationalists (FAWE, Sierra Leone Chapter) and Reach in for the Stars Foundation (RIFTS), both addressing issues of female education and overall women's empowerment. Her work has brought accolades and awards for education, elections and the empowerment of women.

Tan Sri Ir Ahmad Zaidee Laidin FASc graduated in electrical engineering at Brighton College of Technology (now University of Brighton, UK), and gained an MSc in technological economics from the University of Stirling, UK. He is a registered professional engineer with the Board of Engineers Malaysia, and was a UK chartered engineer. Elected Academician, Ahmad Zaidee previously served as an engineer in several technical and management positions with the national electricity utility company, and was appointed head of MARA Institute of Technology in Malaysia, which became Universiti Teknologi MARA during his tenure of office. He is an Honorary Fellow of the Institution of Engineers, Malaysia, and the Academy of Sciences, Malaysia, as well as holding honorary doctorates from the universities of Stirling, Oxford Brookes and Manchester Metropolitan, UK, and Universiti Teknologi MARA, Malaysia. He is Honorary Professor of Napier University, UK, a Past President of the Federation of Engineering Institutions of Southeast Asia and the Pacific (FEISEAP), and Honorary Fellow of the ASEAN Federation of Engineering Organizations (AFEO). He represented Malaysia at the World Federation of Engineering Organizations (WFEO) while serving as President of the Institution of Engineers, Malaysia. He is Secretary General of the Academy of Sciences Malaysia and chairs its Energy Task Force, is Chairman of the Board of Directors of Unversiti Teknikal Malaysia Melaka, and is a Board Member of the Sustainable Energy Development Authority of Malaysia.

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