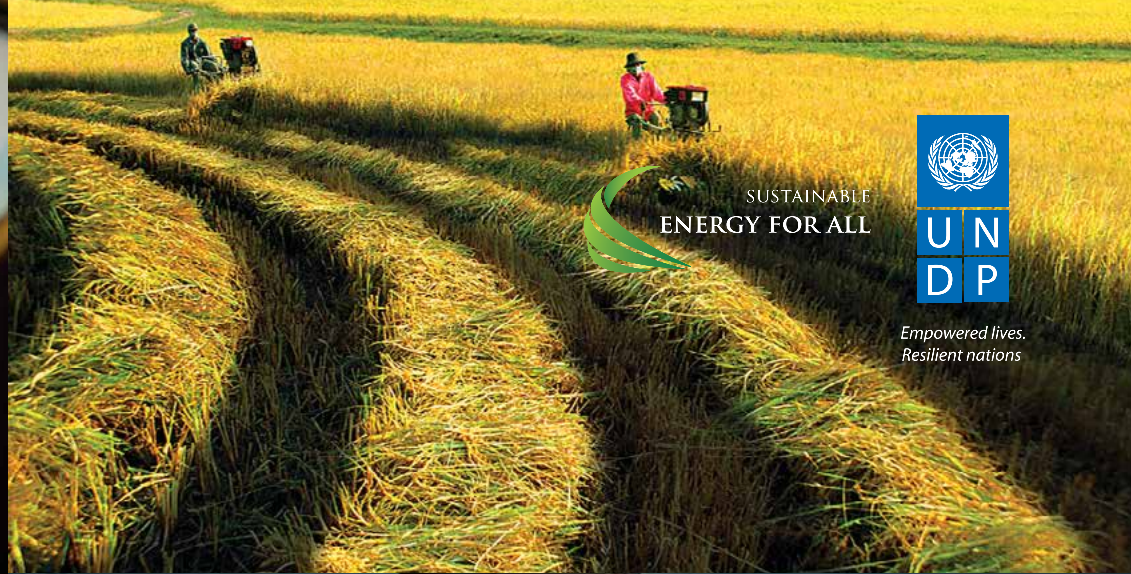

Achieving Sustainable Energy for All in the Asia-Pacific

United Nations Development Programme Asia-Pacific Regional Centre

SUSTAINABLE ENERGY FOR ALL

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Achieving Sustainable Energy for All in the Asia-Pacific

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ACRONYMS AND ABBREVIATIONS

ADB	Asian Development Bank
CEF	Community Energy Fund
CFL	Compact fluorescent lamp
CHP	Combined heat and power
CSP	Concentrated solar power
DPR Korea	Democratic People's Republic of Korea
EGAT	Electricity Generating Authority of Thailand
ESCO	Energy service company
GDP	Gross domestic product
GIZ	Gesellschaft für Internationale Zusammenarbeit
GW	Gigawatt
GWh	Gigawatt hours
HIO	High impact opportunties
IAP	Indoor air pollution
IEA	International Energy Agency
kW	Kilowatt
kWh	Kilowatt hour
Lao PDR	Lao People's Democratic Republic
LED	Light-emitting diode
LKR	Sri Lankan Rupee
LPG	Liquid petroleum gas
MW	Megawatt
OECD	Organisation for Economic Co-operation and Development
PICs	Pacific Island Countries
PPL	PNG Power Limited
PLN	Perusahaan Listrik Negara, Indonesia's State Electricity Company
PNG	Papua New Guinea
PV	Photovoltaic
RA/GA	Rapid assessment and gap analysis
RE	Renewable energy
RECs	Rural Electric Cooperatives
REEs	Rural Electricity Enterprises
REEEP	Renewable Energy and Energy Efficiency Partnership
REDP	Rural Energy Development Programme
RESCO	Renewable Energy Services Company
SE4ALL	Sustainable Energy for All
SHS	Solar home system
SIDS	Small Island Developing States
SIEA	Solomon Islands Electricity Authority
SNV	Netherlands Development Organisation, Stichting Nederlandse Vrijwilligers
SHS	Solar Home System
SIDS	Small Island Developing States
T&D	Transmission & Distribution
TEG	Thermoelectric generators
TWh	Terawatt hours
UNDP	United Nations Development Programme
UNDP APRC	UNDP Asia-Pacific Regional Centre
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
US	United States
V	Volt
W	Watt
WHO	World Health Organization
Wp	Watt-peak
WWF	World Wildlife Fund

NOTE: Unless otherwise indicated all value figures are expressed in US dollars.

1 FOREWORD

The statistics tell a striking story. Globally, 2.7 billion people do not have access to modern cooking facilities and rely on wood, charcoal and other traditional fuels for cooking and heating. The Global Burden of Disease Study (2010) estimated that as many as 3.5 million people die each year from indoor air pollution (IAP). Many more end up suffering from respiratory diseases such as tuberculosis, lung cancer and asthma. In India, a woman living in a rural area typically spends 40 hours per month collecting cooking fuel – an average work week for many of us. More than 1.3 billion people across the world still do not have access to electricity at all.

Rural areas, often highly inaccessible, have the greatest needs; globally, 85 percent of people lacking access to electricity live outside of urban centers.

As individuals, communities, planners, and investors, we can do something about it. Improved cookstoves, biogas digesters and other renewable energy solutions can reduce indoor air pollution and liberate women from the drudgery of collecting fuelwood. In Cambodia, for example, the potential installation of more than 200,000 biogas digesters could produce enough biogas to replace 6 kilograms of firewood per digester per day. Such digesters offer a solution for reduced indoor air pollution that can bring more freedom for women, while at the same time preserving forests and reducing greenhouse gas emissions.

Meanwhile, new ways are being found to make off-grid renewable energy technologies more affordable for the poor and to bring electricity to households, communities and enterprises. In addition to household use, energy access would enable productive activities such as mechanized agriculture, educational tools, health services and small-scale industries. These in turn will lead to poverty reduction and improved prospects for human development. UNDP's Energy Plus approach aims to ensure that productive uses of energy are at the center of energy access efforts. Such an approach will be crucial if we are to meet our universal energy access targets in the years ahead.

In 2011, the Secretary-General of the United Nations launched the "Sustainable Energy for All" (SE4ALL) initiative. This initiative aims to achieve three main goals by 2030: to achieve universal access to energy, to double the rate of improvement in energy efficiency, and to double the share of renewables in the global energy mix. Indeed, many Asian countries are already on their way towards achieving sustainable energy for all. Indonesia increased their electrification rate from around 2 percent in the late 1970s to 65 percent by the mid-1990s. Many countries are giving priority to renewable energy options in their energy policies. Thailand, for example, has set a target of 25 percent renewable energy use within the next 10 years. Lao PDR has also seen a tremendous improvement, jumping from an electricity access rate of 15 percent in 1995 to 75 percent in 2011.

And so SE4ALL is a true possibility. In collaboration with other development partners, the private sector, civil society and national governments, UNDP will use the UN Decade of SE4ALL (2014-2024) to help increase energy access for the people at the bottom of the development pyramid, with a focus on using renewable energy and energy efficiency solutions. Energy access for poor households is essential to eradicate poverty, and it must be part of the post-2015 development agenda. As part of the international community, we all must therefore intensify our efforts and our collaboration to achieve these lofty goals. Our hope is that this publication can be both a theoretical and practical basis for this work.

So let us all work together to achieve universal access to energy by 2030.

Gordon Johnson
Regional Practice Leader
Environment and Energy, UNDP Asia-Pacific Regional Center

2 EXECUTIVE SUMMARY

In 2011, the Secretary General of the United Nations launched the Sustainable Energy for All Initiative (SE4ALL) to create a coordinated global response to the challenge of energy poverty. The initiative aims to ensure sustainable energy for all by 2030 through the achievement of three goals:

- Universal access to modern energy services;
- Double the global rate of improvement of energy efficiency; and
- Double the share of renewable energy in the global energy mix.

By the end of 2012, 11 countries in the Asia-Pacific had adhered to SE4ALL, with eight countries having completed the initial requisite rapid assessments and gap analyses necessary to determine their energy situation and needs. This report is based on a thorough analysis of the data and results from eight nationally produced rapid assessments and gap analyses and ten regionally produced country energy reviews, an evaluation based on a rigorous methodology described in Appendix I.

2.1 The benefits of energy access

The analysis reveals numerous cases throughout Asia-Pacific where access to electricity and modern forms of energy have facilitated the provision of adequate food, shelter, clothing, water, sanitation, medical care, education, and access to information. Electricity supports lighting, communication, transport, commerce, manufacturing, and industry. It can enable provision of refrigerated vaccines, emergency and intensive health care, and pumping of clean groundwater for drinking and irrigation purposes for increasing agricultural productivity. The lack of electricity is particularly damaging to women, who are usually responsible for food preparation and cooking, and young children, who are usually with them. Investing in energy access therefore improves public health, community and household productivity, and reduces greenhouse gas emissions. Providing universal access to gaseous fuels for cooking and electricity provides benefits like improved living standards, livelihood opportunities and climate change mitigation that often far outweigh the costs of the programmes themselves. Furthermore, high-speed transportation, telecommunications, information technology, and a variety of things that enhance the quality of life depend on electricity; none of them can function on traditional fuels. In short, universal access to clean energy is an essential enabler of inclusive development, poverty reduction, and business development, reducing the gap between the rich and the poor as well as dealing with the impacts of climate change. Countless examples have shown that once modern energy is available, communities, the businesses and entrepreneurs benefit enormously from services such as light, power, heat, irrigation, new livelihood opportunities and the cleaner air and water that it provides.

2.2 Household cooking needs

Without access to modern energy services, the use of traditional fuels for cooking, heating and lighting hinders economic development and has severe health impacts. There are, however, opportunities to overcome these barriers: improved cookstoves produce less smoke than traditional stoves; have relatively low cost and are simple to install. Biogas digesters produce gas for cooking and other household needs, and have the potential to meet the cooking needs of millions of households.

2.3 Rural electrification

Many countries in the region have demonstrated substantial progress in expanding grid-based electrification as well as distributed energy systems in the past two decades. Where improvements have been made, electricity has brought multiple development benefits, and case studies show that household incomes can rise substantially once they are given energy access. Universal energy access will be achieved through a combination of grid extension and off-grid systems, depending on the country context. Five countries, including Bangladesh, Malaysia, Philippines, Viet Nam, and Thailand, have been most successful in improving energy access through grid extensions, with some reaching near universal access. This analysis indicates that Bangladesh, Cambodia, India, Indonesia and Mongolia and Nepal can benefit most from improvements in grid-based electrification. Apart from large-scale grid extension efforts, off-grid microhydro is particularly apt to meet the needs of remote communities in mountainous regions and can provide year-round electricity. Solar lanterns meet lighting needs in households and small enterprises, and are low cost. Solar home systems (SHSs) are more expensive option then solar lanterns, but have dropped in cost in recent years and can usually provide more power than lanterns. Micro- and mini-grids can play an instrumental role in global electrification efforts over the next decade, especially in Asia.

2.4 Energy efficiency

Energy efficiency opportunities generally involve practices that are already commercially available and bring quick savings. Because of the fast rate of industrialization in the Asia-Pacific, many such programmes have already demonstrated success. Some of the opportunities include standards and labeling for electric appliances, reducing electric transmission and distribution losses, industrial and commercial energy audits, efficient lighting, demand-side management for reduced energy demand, building codes and regulations to control the energy profile of new buildings, energy efficiency funds and combined heat and power (CHP) solutions.

2.5 Renewable energy

Asian countries have a diverse and significant amount of renewable energy potential that can be converted into usable modern energy services. The 18 countries evaluated in this report could more than meet all of their electricity needs *exclusively* with available renewable energy resources, and the resources with the most technical potential are:

- Solar energy featuring prominently in Bangladesh, Malaysia, and Thailand;
- Wind energy in Mongolia, the Philippines, Sri Lanka, and Viet Nam;
- Geothermal energy in Fiji, Papua New Guinea (PNG), the Philippines, and the Solomon Islands;
- Small hydro in India (given its low cost), Samoa, and the Solomon Islands;
- Large hydro in Bhutan, Cambodia, Fiji, India, Indonesia, Lao PDR, Nepal, and PNG; and
- Biomass in Bangladesh, Cambodia, India, Indonesia, Malaysia, and Sri Lanka.

2.6 Barriers and impediments

Despite the wide range of benefits that expanding energy access, promoting renewable energy, and encouraging energy efficiency bring, realizing them is not without substantial challenges. This report identifies technical barriers such as lack of equipment, expertise or maintenance, and economic and financial barriers such as distorted energy prices, poverty, and lack of financing. Political and institutional barriers include constrained capacity to plan and implement projects as well as corruption and instability. Social and cultural barriers encompass things such as community opposition and lack of awareness.

2.7 Overcoming barriers and impediments

Though these challenges are real, they can be, and have been, overcome. However, ordinary energy markets and the private sector will not by themselves quickly address energy poverty and expand energy access. As a result, the very poor "fall through the cracks" and are too politically distant and economically costly to provide with energy services. This means that energy poverty will not be eliminated without targeted intervention that goes beyond the current interest of private sector entities to invest. Current projections suggest that the investment required to eliminate energy poverty by 2030 is $49 billion per year, only 3 percent of total global energy infrastructure investments yet well above the $14 billion that is presently being invested each year.

Thus, to ensure equal development and access for all, there is a need for specific programming to reach the poorest at the bottom of the ladder that are not served by commercial energy providers or large-scale energy projects. It is the poor households unlikely to be served by the private sector, government, or financial institutions—the energy poor that even the International Energy Agency (IEA) projects will not gain access to modern energy by 2030—that development partners will need to consider serving. Thankfully, a series of successful business and financial models already exist backed by the empirical success of numerous case studies. Failure to utilize, replicate, and scale-up these successful models, and to learn from these case studies, prevents already disadvantaged families from participating in the Asian economic miracle; it also maintains the unequal distribution of wealth in societies.

2.8 The road ahead

The report concludes with three recommendations. First, it argues that energy access should be treated as the most urgent SE4ALL goal and that development partners should emphasize energy access for productive purposes to the bottom of the pyramid. Second, it notes that any post-2015 development agenda for SE4ALL should promote "bottom-up energy solutions", and it must recognize the specificity of country needs, there is no "one-size-fits-all" solution. Bottom-up solutions, including renewable energy and energy efficiency technologies, are a crucial part of the overall SE4ALL strategy addressing the energy service needs of rural and urban communities and entrepreneurs who are not served by the central grid in case of electricity or centralized distribution systems in case of cooking and heating fuels. Such energy solutions fit into country plans that aim at reducing poverty, enhancing gender equality and achieving the Millennium Development Goals. Third, the report recommends that an energy knowledge hub be established in the Asia-Pacific for improved coordination and better support for implementing "bottom-up" solutions and meeting these specific country needs.

3 INTRODUCTION

Thomas Edison started generating electricity more than 130 years ago and electric utilities have been generating, transmitting, and distributing power commercially for more than a century. Yet as of 2009, 1.3 billion people, roughly one in every five, lack access to electricity, 85 percent of them in rural areas.[1] Furthermore, almost 3.5 billion people, or one in two, remain partially or wholly reliant on fuels such as wood, charcoal, dung, coal, and kerosene for cooking, and 2.7 billion depend on those fuels entirely.[2] An additional 1 billion people have access only to unreliable or intermittent electricity networks.[3] Put another way, the poorest three-quarters of the global population still only use ten percent of global energy.[4]

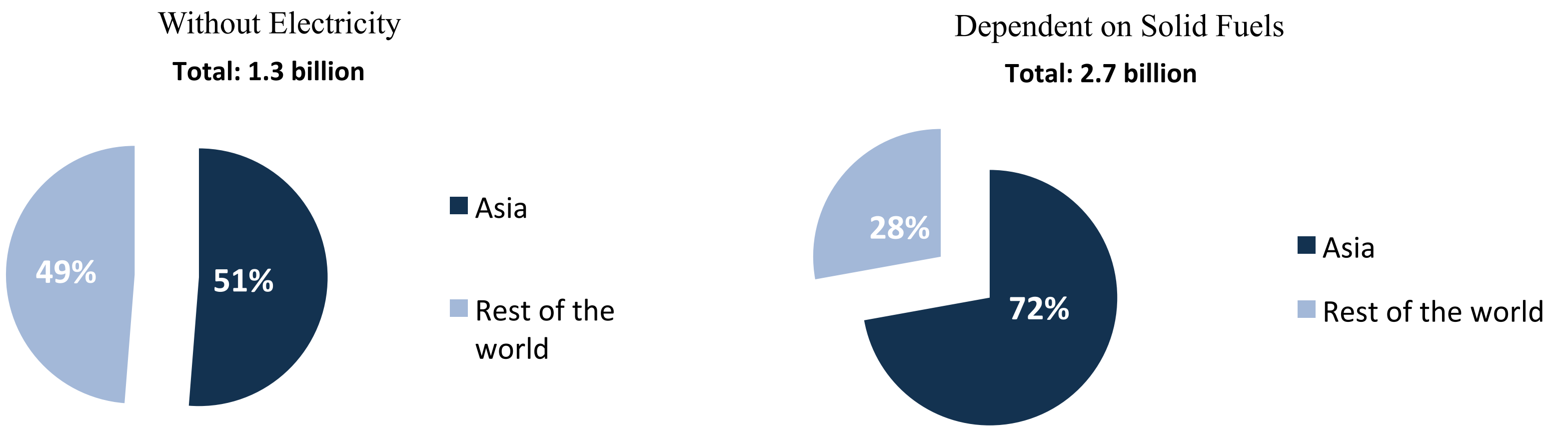
As table 1 and figure 1 show, this is predominately a problem for countries in the Asia-Pacific. Though Africa consumes less energy per capita than most Asian countries (with a few exceptions, such as India), 51 percent of those without access to electricity globally as well as 72 percent of those dependent on traditional fuels globally reside in Asia.

Table 1 Key energy poverty indicators for selected Asia-Pacific countries

	Electrification rate (percent, 2009)	Population without electricity (millions, 2009)	Population dependent on traditional fuels, wholly or partially (percent, 2012)	Population dependent on traditional fuels, wholly or partially (millions, 2012)
Afghanistan	15.5	25.84	95.0	31.73
Bangladesh	41	86.75	89.0	135.64
Bhutan	72	0.20	67.0	0.50
Cambodia	24	10.62	95.0	13.75
China	99.4	8.01	80.0	1,082.88
DPR Korea	26	17.94	97.7	23.99
Fiji	88.9	0.09	40.0	0.35
India	75	301.94	82.0	1,031.85
Indonesia	64.5	84.28	72.0	176.23
Iran	98.4	1.17	--	--
Lao PDR	55	2.75	95.0	6.06
Malaysia	99.4	0.17	1.0	0.29
Maldives	99.8	0.001	43.0	0.14
Marshall Islands	74.5	0.01	30.0	0.02
Micronesia	64.6	0.04	46	0.05
Mongolia	67	0.89	51.0	1.45
Myanmar	13	41.41	95.0	46.29
Nepal	43.6	16.60	81.0	25.12
Pakistan	62.4	64.11	81.0	145.76
Papua New Guinea	17.6	5.52	90.0	6.45
Philippines	89.7	9.45	45.0	43.41
Samoa	96.0	0.01	70.0	0.13
Solomon Islands	16.0	0.44	95.0	0.54
Sri Lanka	76.6	4.84	67.0	14.22
Thailand	99.3	0.48	72.0	50.32
Timor-Leste	22.0	0.86	98.7	1.17
Tonga	93.9	0.01	56.0	0.06
Tuvalu	96.7	0.0003	32.0	0.003
Vanuatu	27.0	0.17	79.0	0.20
Viet Nam	97.6	2.09	70.0	62.81
Mean / Total	**63.88**	**687**	**69.5**	**2,901**

Source: UNDP International Human Development Indicators Database, Global Alliance for Clean Cookstoves country specific database, 2012 National Rapid Assessment and Gap Analyses, UNDP APRC Country Energy Reviews, UNDP Energy Access Case Studies supplemented with Worldbank data, Marshall Islands Demographic and Health Survey 2007 Final Report, FSM Census of Population and Housing 2010, Tonga Household Income and Expenditure Survey 2009, Tuvalu Household Income and Expenditure Survey 2010.

Figure 1 Proportion of people in "Energy Poverty" in the Asia-Pacific



Source: *Energy for All: Financing Access for the Poor*. Paris: OECD/IEA (2011).

Poverty and energy deprivation go hand-in-hand, with energy expenses accounting for a significant proportion of household incomes in many developing countries. Generally, 20 to 30 percent of annual income in poor households is directly expended on energy fuels, and an additional 20 to 40 percent is expended on indirect costs associated with collecting and using that energy, such as health care expenses, injury, or loss of time, compared to a global average of only 4 to 8 percent.[5] In other words, the poor pay on average eight times more for the same unit of energy than other income groups. In extreme cases, some of the poorest households directly spend 80 percent of their income obtaining cooking fuels.[6]

Complicating matters, about 1 billion people live below $1.25 per day in the Asia-Pacific, leading one recent study to proclaim that "the state of human deprivation compels us to consider a paradigm shift to universal energy access and a minimal standard for quality of life. Energy security policies must be pro-poor."[7] A UNDP study concurred, noting that the urban poor typically have some access to electricity but its quality is substandard, service unreliable and intermittent, and connections informal. The rural poor often go without modern energy services entirely and when they do have access, it tends to be from inefficient standalone diesel systems, poorly run micro-grids that are expensive and susceptible to failure, or unreliable connections to the national grid.[8]

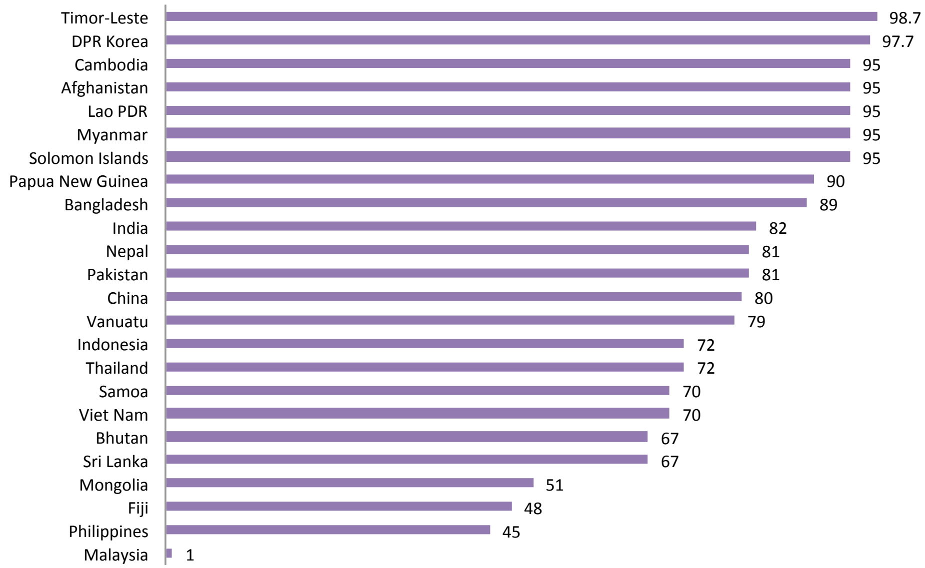
Motivated in part by the scale and severity of energy poverty, the United Nations announced 2012 as the "International Year for Sustainable Energy for All" (SE4ALL) and 2014 through 2024 as the "Decade of Sustainable Energy for All". These announcements lead a global agenda to rally national governments, development partners, the private sector, and civil society to realize three goals by 2030: (1) ensuring universal access to modern energy services, (2) doubling the share of renewable energy in the global energy mix, and (3) doubling the global rate of improvement in energy efficiency.[9]

This report provides a series of recommendations for how countries serious about reaching the SE4ALL goals can be put on a path towards doing so. Its primary sources of data are eight national Rapid Assessment and Gap Analyses—conducted as part of the SE4ALL initiative—coupled with ten Country Energy Reviews compiled by the United Nations Development Programme Asia-Pacific Regional Centre (UNDP APRC).[10] All factual claims stated below come from these data sources unless otherwise noted with a footnote. When necessary, data from these reports were supplemented with secondary sources. For more details about the research methods, readers are invited to read Appendix I.

This report proceeds to discuss four key constituents of the SE4ALL goals: household cooking needs (sometimes called "thermal" needs), rural electrification (including small-scale renewable energy as well as micro- and mini-grids), energy efficiency, and larger commercial-scale grid-connected renewable energy.

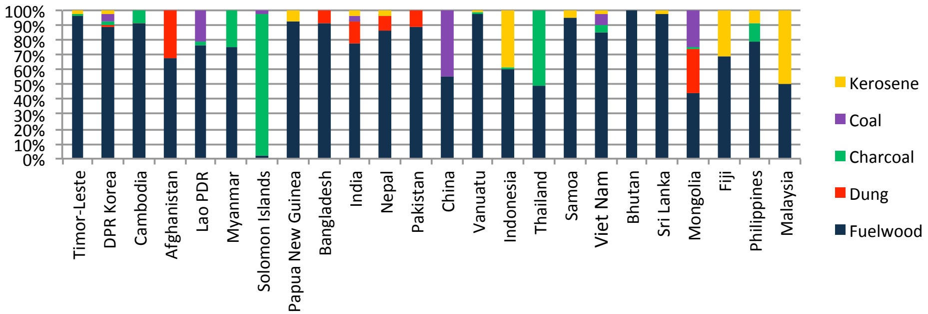
In pursuing this fourfold structure, the section on household cooking needs includes improved cookstoves and biogas digesters. The idea is to identify opportunities for those countries with more than 90 percent of their population dependent on solid fuels for household needs shown in figure 2, such as Timor-Leste, DPR Korea, Cambodia, Afghanistan, Lao PDR, Myanmar, the Solomon Islands, and PNG, to commercialize cleaner cookstoves and other devices. As figure 3 shows, household energy use is complex, with many homes "fuel stacking" and reliant on multiple sources of fuel at once.

Figure 2: Dependence on traditional fuels: Selected Asia-Pacific countries (percent 2012).



Source: UNDP International Human Development Indicators Database, Global Alliance for Clean Cookstoves country specific database.

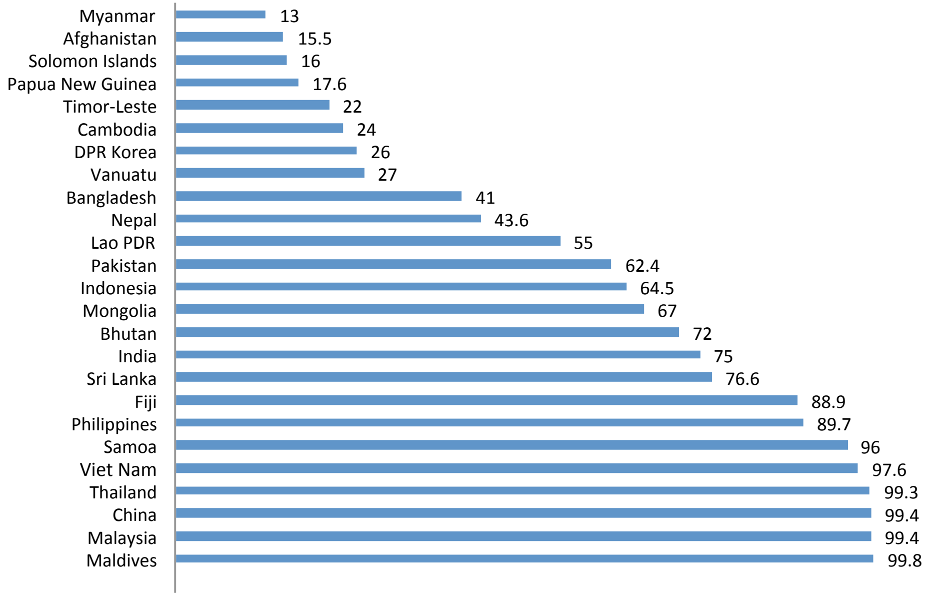
Figure 3 Traditional fuel use: Selected Asia-Pacific countries (2010)



Source: Global Alliance for Clean Cookstoves 2012 country briefs.

For rural electrification, the report focuses intently on both "grid" solutions, such as large-scale efforts to extend centralized electricity networks, and "off-grid" or "mini-" and "micro-grid" options such as SHS and microhydro dams. Its aim is to inform those countries depicted in figure 4 that are striving to increase their electrification rates in the Asia-Pacific, such as Bangladesh, Cambodia, the Solomon Islands, and PNG, on how they can scale up their electrification efforts.

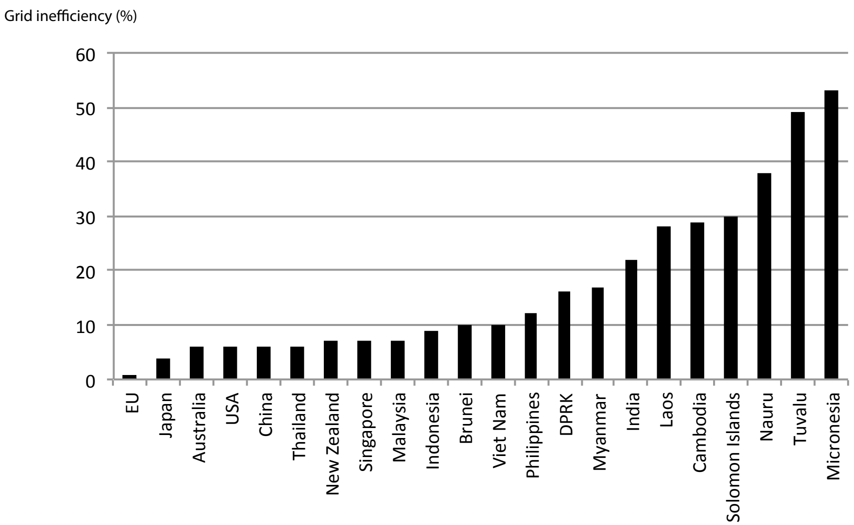
Figure 4 Electrification rate: Selected Asia-Pacific countries (percent of population, 2009)



Source: UNDP International Human Development Indicators Database, 2012 National Rapid Assessment and Gap Analyses, UNDP APRC Country Energy Reviews, UNDP Energy Access Case Studies supplemented with Worldbank data.

By "energy efficiency" the report refers to the reduction of energy use as the result of improved performance, increased deployment of more efficient equipment, or the alteration of consumer habits. Energy efficiency efforts can include substituting resource inputs or fuels, changing preferences, or altering the mix of goods and services to demand less energy. It is a resource historically proven, through decades of experience and thousands of programmes, to be the most cost effective way of responding to increases in demand. The IEA World Energy Outlook estimated that each additional $1 spent on energy efficiency in electrical equipment, appliances, and buildings avoids more than $2, on average, in energy supply investments.[11] As figure 5 shows, some countries, such as DPR Korea, India and Myanmar, lose 15 to 29 percent of their electricity to inefficiencies affiliated with transmission and distribution. In some Pacific Island Countries (PICs), such as Tuvalu and Micronesia, the percentage is close to *half*.[12]

Figure 5 Transmission and distribution inefficiency: Selected countries (percent, 2010)



Source: Data for the four PICs comes from Pacific Power Association. (2011). *Performance Benchmarking for Pacific Power Utilities*, p. 33. All other data taken from Sovacool, B.K., I. Mukherjee, I.M. Drupady, and A.L. D'Agostino. (2011). Evaluating Energy Security Performance from 1990 to 2010 for Eighteen Countries. *Energy* 36(10), pp. 5846–5853.

The final SE4ALL area covered by the report is renewable energy, a term that describes a variety of sources, approaches, systems and technologies ranging from wind turbines and solar panels to hydroelectric dams and geothermal power stations. The attractiveness of these options is that they are from renewable energy resources that are often indigenous and free; for the most part, any amount generated from sunlight or wind does not compete with the sunlight or wind available elsewhere. Moreover, the fuel cost for some renewables such as wind and solar can be known for decades into the future, something that cannot be said about conventional technologies whose fuel prices vary widely. Furthermore, although renewable energy technologies have their own associated set of environmental and social impacts, they do not meltdown, rely on hazardous fuels, or depend on a fuel cycle of mining or milling that must extract fuels out of the earth (with the exception of some landfill gas capture facilities). When roughly quantified and put into monetary terms, the negative externalities for coal power plants are 74 times greater than those for wind farms, and the ones from nuclear power plants are 12 times greater than solar photovoltaic (PV) systems.[13] Put succinctly, oil, gas, coal, and uranium are susceptible to rapid escalations in price and price volatility, whereas renewable fuels are often free for the taking, widely available, and inexhaustible.

In choosing to assess SE4ALL in the Asia-Pacific, the report narrows its focus mostly to 18 countries. These countries are:

- Bangladesh
- Bhutan
- Cambodia
- Fiji
- India
- Indonesia
- Lao PDR
- Malaysia
- Mongolia
- Nepal
- Papua New Guinea
- Philippines
- Samoa
- Solomon Islands
- Sri Lanka
- Thailand
- Vanuatu
- Viet Nam

These countries were selected for two key reasons. First, they are diverse, and include a broad sample of different types of energy markets, geographic sizes, population densities, energy resources, and policy challenges. Second, at the time research for this report began, 11 of them had opted-in to the SE4ALL Initiative and the remaining six—India, Papua New Guinea, Samoa, the Solomon Islands, Thailand and Vanuatu—were added to give greater representation of the sub-regions of Asia-Pacific. Other major energy poor countries would have been included, but the research was constrained by resources.

After documenting the benefits of energy access and previewing the SE4ALL energy dynamics of these 18 countries, the report analyses a common set of technical, economic, political, and socio-cultural barriers that affect all of them before presenting solutions on how to overcome these barriers and the report's three conclusions.


lenovo

4 THE BENEFITS OF ENERGY ACCESS

As this section shows, the expansion of energy access contributes to four major and interrelated sets of positive consequences: declining rates of poverty, enhanced human health, gender equality and improved education, and reduced levels of environmental degradation. The second part of this section then presents case studies of where countries in the Asia-Pacific have successfully expanded household energy access, invested in rural electrification and energy efficiency, and promoted renewable energy.

4.1 Poverty and economic security

Electricity and modern forms of energy are crucial to meeting the primary development challenge of providing adequate food, shelter, clothing, water, sanitation, medical care, education, and access to information. Electricity supports lighting, communication, transport, commerce, manufacturing, and industry. It can enable provision of refrigerated vaccines and emergency and intensive health care, the pumping of clean groundwater for drinking and irrigation for increasing agricultural productivity. The lack of electricity is particularly damaging to women, who are responsible for food preparation and young children who are often under the care of mothers while they are cooking at home. Without electricity, women are typically forced to spend significant amounts of time searching for firewood for cooking and heating needs. Electricity makes so many things possible that some have even viewed its provision as a fundamental human right.[14]

Moreover, when enabled by the necessary financing, technical capacity, and market and regulatory support, renewable energy and energy access can make possible a variety of income generating activities, including mechanical power for milling grain, illumination for factories and shops, heat for processing crops, and refrigeration for preserving products.[15]

The broader use of renewable energy helps insulate economies from fossil fuel price spikes and diversifies the energy mix, producing significant macroeconomic savings. For instance, countries with underperforming electricity networks tend to lose 1 to 2 percent of gross domestic product (GDP) growth potential due to blackouts, over-investment in backup electricity generators, energy subsidies, and inefficient use of resources.[16]

Dependency on fossil fuels, particularly oil, results in severe macroeconomic shocks. One study looked at the world average price of crude oil for 161 countries from 1996 to 2006, when prices increased by a factor of seven, and concluded that lower-middle income countries were the most vulnerable followed by low-income countries, even though these countries consumed less oil per capita than industrialized or high income countries.[17] The reason is that the ratio of value of net oil imports to GDP tends to be higher in lower income countries, meaning they spend a greater share of their GDP on energy imports. Indeed, poor Asian households have suffered dramatic increases in the price of fossil-fueled energy, paying on average 74 percent more from 2002 to 2005 for their energy needs. This included paying:

- 171 percent more for cooking fuels;
- 120 percent more for transportation;
- 67 percent more for electricity;
- 55 percent more for lighting fuels; and
- 33 percent more for petroleum-based fertilizers and other agricultural inputs.[18]

Another study noted that the rise in oil prices during 2010 and 2011 placed an additional 42 million people in the Asia-Pacific region into poverty.[19] A third study assessed the close connection between rising oil prices and food prices, and documented an almost perfect relationship between the two. Higher oil prices resulted in rising input costs for agriculture such as oil based fertilizers and fuel for motorized and mechanized equipment, as well as a greater demand for biofuels which then divert agricultural feedstocks to produce fuel rather than food. Both factors created higher food prices, and the number of malnourished increased from 848 million in 2004 to 923 million in 2007.[20] Renewable energy, by displacing the use of oil, kerosene, and diesel, can ameliorate these negative trends.

4.2 Household health

Affecting numerous interrelated domestic health and development issues, investments in energy access can enhance maternal health, reduce infant mortality, and help curtail disease epidemics. Based on the number of lives lost and disabilities incurred annually, the largest immediate benefit of sustainable energy access is the displacement and reduction of IAP. Indeed, one just-released study examined the relationship between household cooking fuels and low birth weights, and found conclusively that "primary use of coal, kerosene, and biomass fuels is associated with significant decreases in mean birth weight" and that "increased risk of neonatal death is strongly associated with household use of coal".[21] More on these harms from IAP are presented in Chapter Five on "Household Thermal Needs".

However, countries without access to modern energy systems also tend to have more dilapidated health systems; consider that compared to industrialized countries, infant mortality rates are more than five times higher in developing countries, as is the proportion of children below the age of five who are malnourished (eight times higher), the maternal mortality rate (14 times higher), and proportion of births not attended by trained health personnel (37 times higher).[22] Indirect health effects also occur when traditional fuel becomes scarce or prices rise. Meals rich in protein, such as beans or meat, are avoided or undercooked to conserve energy, forcing families to depend on low protein soft foods such as grains and greens, which can be prepared quickly. In other cases, families stop boiling drinking water when faced with an energy shortage.[23]

The provision of modern energy services can improve general health by enabling access to potable water, cleaner cooking facilities, lighting, and refrigeration.[24] Renewable based electricity can also enable modern preventative, diagnostic, and medical treatment, including the electrification of health-care facilities and energy for medical equipment, sterilization, security, and information and communication technology. Educational awareness raising programmes about epidemics and hygiene tend to be enhanced through the modern tools of mass media, such as radios and televisions, which require electricity. The lack of clean water and proper sanitation, a significant cause of disease, furthermore, is linked with lack of access to energy, which can be used to draw subsoil water and sterilize water before use.[25]

4.3 Gender and education

With greater access to energy, women across the Asia-Pacific can educate themselves or engage in productive activities rather than spending hours a day searching for fuelwood. Investments in energy access can promote gender equality and increase school attendance for children. For instance, women comprise the majority of those vulnerable to energy scarcity; time spent in fuel collection can range from one to five hours per day, frequently with an infant strapped to their back. As the Asian Development Bank (ADB) has reported:

> *The energy-poverty nexus has a distinct gender bias: of the world's poor, 70 percent are women. Access to and the forms of energy used by a poor community have significantly different impacts on the men and women in it. Existing social and work patterns, particularly in rural communities, place a disproportionate burden of fuel and water collection and their use in the household for cooking on women and girl children, who consequently have to devote long, exhausting hours to this purpose rather than more productive activities, family welfare, or education. However, women's role in decision-making within the household and community is usually very restricted, reducing their say in issues of spending levels and choices, including with respect to energy. This includes the types of fuels used, amounts of energy purchased, the devices and technology chosen, as well as domestic infrastructure characteristics (e.g., stove design, ventilation, etc.). Such decisions are made by the male head of the household, although their burden is borne by the women.*[26]

The labor and time intensity of fuelwood collection, one of these burdens, depends on not only the availability of fuel, but also traveling distance, household size, and season. In the summer months, when wood must be stockpiled for the winter in countries with harsh climates, some women gather firewood twice a day, each trip taking two hours.[27] In some developing countries, girls spend more than seven times as many hours collecting wood and water than adult males, and 3.5 times as many hours compared to boys the same age.[28] In India, for instance, the typical woman spends 40 hours collecting fuel per month during 15 separate trips, many walking more than six kilometers round trip.[29] This amounts to 30 billion hours spent annually

(82 million hours per day) collecting fuelwood, with an economic burden (including time invested and illnesses) of $6.7 billion (300 billion rupees) per year.[30]

In addition, current energy production entails occupational hazards that almost uniquely befall women and children. People carrying cooking fuels suffer frequent falls, back aches, bone fractures, eye problems, headaches, rheumatism, anemia, and miscarriages from carrying weights often 40 to 50 kilograms, nearly as much as their body weight. The energy needs of rural women can be further marginalized if men control community forests, plantations, or woodlots, and if there are other "high value" wood demands by the community that displaces their foraging grounds for fuel.[31]

The educational impacts of energy poverty include absenteeism from school as well as increased incidence of illness. Numerous medical studies have documented a strong connection between the effects of IAP mentioned above and acute respiratory infections in children, which is the principal cause of school absences in many countries.

Conversely, energy access can help improve both education and gender equality. Table 2 depicts a variety of ways they can enhance the status of women by saving time and improving health. One study of the Philippines noted that the odds of being illiterate are far greater for individuals that lack electrical lighting.[32] Energy services can also enable schools to recruit and retain better qualified teachers.[33] Lighting from solar and microhydro technologies can extend the time children have to study at night, and can also lead to better equipped schools with computers and the Internet.

Table 2 Benefits of modern energy services for women

Energy Source	Benefits		
	Practical	**Productive**	**Strategic**
Electricity	Pumping water, reducing the need to haul and carry mills for grinding, improved conditions at home through lighting	Increased possibility of activities during evening hours, refrigeration for food production and sale, power for specialized enterprises and small businesses	Safer streets, participation in evening classes, access to radio, television, and the Internet
Biomass (improved cookstoves)	Improved health, less time and effort gathering fuelwood, more time for childcare	More time for productive activities, lower cost of space and process heating	Improved management of natural forests
Mechanical	Milling and grinding, transport and portering of water and crops	Increased variety of enterprises	Access to commercial, social, and political opportunities

Source: ADB. (2007). *Energy for All: Addressing the Energy, Environment, and Poverty Nexus in Asia*. Manila.

4.4 Deforestation and climate change

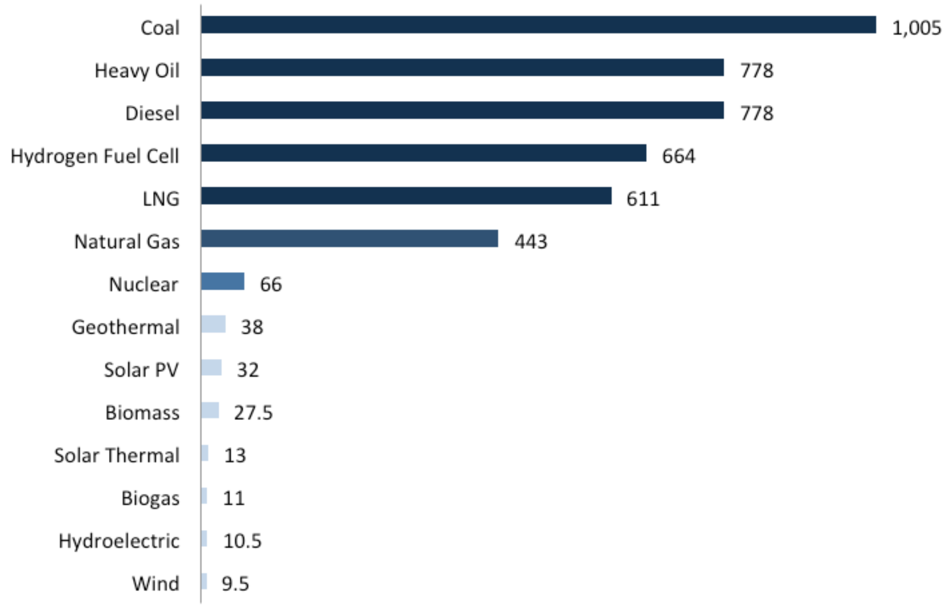
Prudent investments in sustainable energy access can help reduce deforestation and mitigate emissions of greenhouses gases that contribute to climate change.

Since billions of individuals rely on biomass for cooking and heating, about 2 million tons of it is combusted every day.[34] Where wood is scarce, or populations are dense, the growth of new trees is not enough to match demand for fuel, resulting in deforestation, desertification, and land degradation. Even when entire trees are not felled, the collection of dung, branches, shrubs, roots, twigs, leaves, and bark can deplete forest ecosystems and soils of much needed nutrients.[35] It can also damage agricultural production: when wood supplies are scarce, people often switch to burning crops—which threatens food security. Moreover, the deforestation and erosion caused by harvesting reduce the fertility of surrounding fields. One recent assessment attributed 6 percent of global deforestation to fuelwood collection.[36]

For example, in Bangladesh trees and bamboo meet about 48 percent of all domestic energy requirements followed by agricultural residues that offer 36 percent and dung that offers 13 percent.[37] Widespread destruction of forests has occurred to satisfy energy needs, with homestead forest cover reduced to eight percent of its original area[38] and half of Bangladesh's natural forests being destroyed in a single generation by people collecting fuelwood.[39] Similarly, about four percent of China's standing forests serve as a source of fuel and roughly 13 percent of cultivated land in China is used to grow fuelwood.[40]

Apart from its environmental damage, fuelwood-driven deforestation results in two significant social and economic impacts: an increased burden on fuelwood collectors and farmers, and increased fuel prices. First, as stockpiles are depleted, women and children need to travel longer distances to collect fuel, requiring more time and energy. Moreover, such collection typically interferes with the viability of farms and other rural livelihoods that rely on trees for their own income.[41] Second, deforestation results in

Figure 6 Lifecycle greenhouse gas emissions (grams of CO_2e/kWh)



Source: Sovacool, B.K. (2008). Valuing the Greenhouse Gas Emissions from Nuclear Power: A Critical Survey. *Energy Policy* 36(8), pp. 2940–2953.

severe price increases of fuelwood. As deforestation in Bangladesh has accelerated, demand for wood has outpaced supply, causing the price of wood to increase from $0.35 in 1980 to $1.27 in 1991 and $1.69 in 2007 per bunch. When put into the context of the typical household budget, about 50 percent of the annual income of rural households in Bangladesh is now spent on fuel.[42]

A second environmental impact of energy poverty involves climate change and black carbon. Burning solid fuels in open fires and traditional stoves has significant global warming effects, due to the release of methane and carbon dioxide.[43] Reliance on biomass fuels and coal for cooking and heating is responsible for about 10 to 15 percent of global energy use, making it a substantial source of greenhouse gas emissions.[44] One study, for example, projected that by 2050 the smoke from wood fires will release about 7 billion tons of greenhouse gases into the atmosphere.[45]

By contrast, when direct and indirect carbon emissions are included, renewable sources of power are the least greenhouse-gas intensive sources of energy, a benefit shown by figure 6. Furthermore, renewable energy technologies and strategic investments in household energy access not only mitigate emissions, they can also promote adaptation to climate change and a suit of social and economic benefits displayed in table 3.[46]

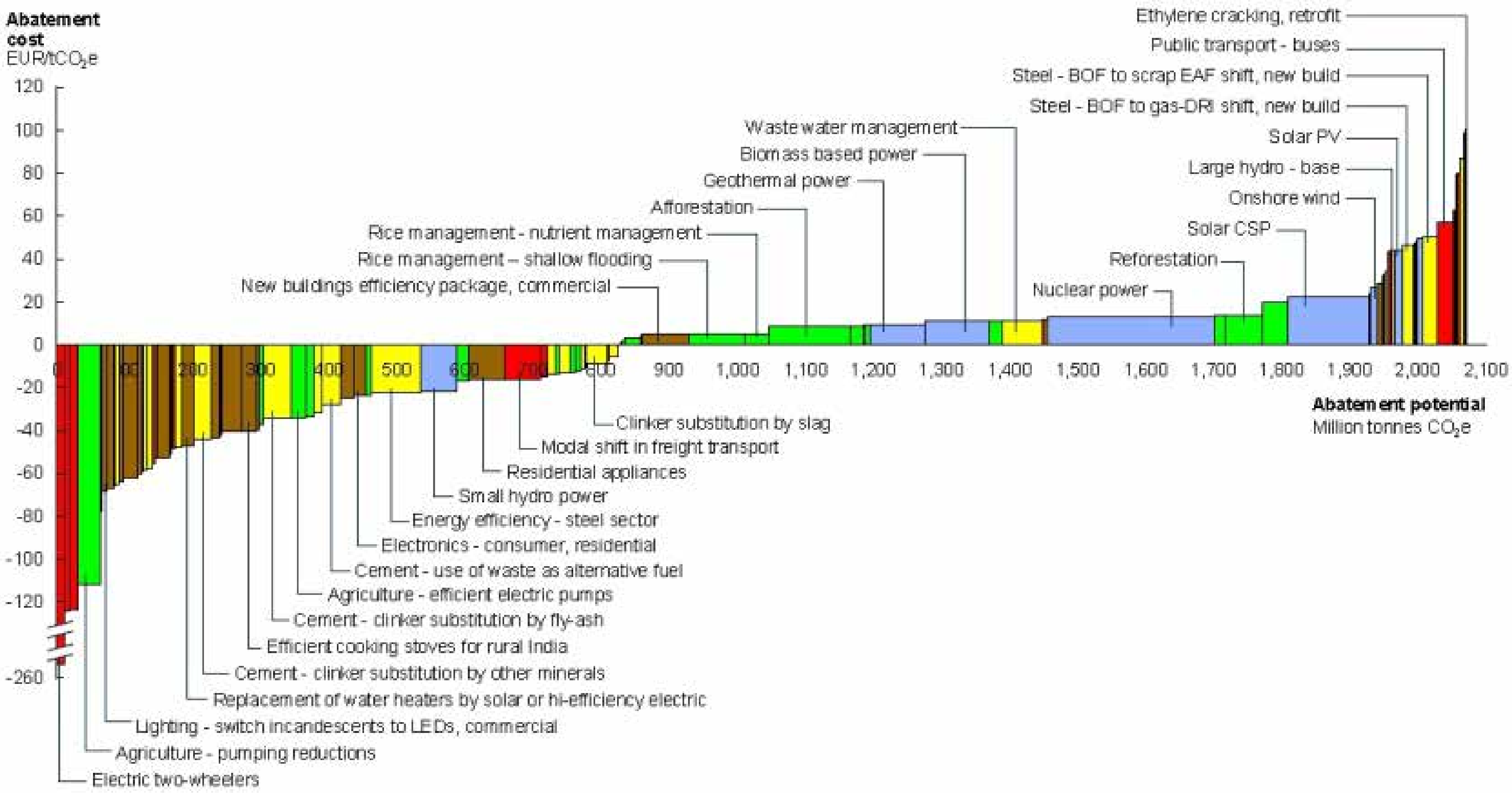
Table 3 Climate change and development benefits of renewable energy

Type	Application	Mitigation Benefits	Adaptation Benefits	Social and economic development benefits
Biomass	Electricity generation and heat	Reduced use of charcoal and fuelwood, less pressure on natural resources	Reduces the likelihood of deforestation and desertification	Creation of jobs and livelihood opportunities, reduced drudgery, reduction of incidents related to IAP and respiratory infections
Wind	Crop processing, irrigation, and water pumping	Decreased dependence on wood/biomass, avoidance of CO2 emissions	Reduced vulnerability to water scarcity, more adaptation choices through irrigated agriculture	Income generation, improved quality of life, reduced risks of vector borne-diseases, improved water supply/food security, school attendance (especially for girls), reduced migration
Biogas plants	Production of sludge for fertilizer	Reduced use of pesticides and fertilizers	Adapting to soil erosion, aridity, and environmental degradation	Better prospectus for agricultural productivity and income generation
Solar home systems	Cooking, lighting, and water heating	Less consumption of fuelwood, kerosene and batteries, improved local air quality	Illuminated studying and access to information and communication technology	Improved quality of life as well as better health and sanitation through streetlights and boiled water
Microhydro	Lighting, agricultural processing	Reduced greenhouse gases, protection of land	Improved social resilience	Improved health, greater school attendance

Source: Christensen, John, Fatima Denton, Amit Garg, Sami Kamel, Romeo Pacudan, and Eric Usher. (2006). *Changing Climates: The Role of Renewable Energy in a Carbon-Constrained World*. Vienna: REN21/UNEP, p. 28.

Investments in energy access can also cut carbon emissions. McKinsey & Company investigated what India could do to lower its greenhouse gas emissions by 30 to 50 percent per year by 2030.[47] The most "feasible" options (figure 7) with best cost abatement curves, included light-emitting diode (LED) lighting, cookstoves, and small hydropower. If pursued properly, a combined effort to follow McKinsey's recommendations would cut energy consumption by 22 percent, reduce 100 million tons of metallurgical coal imports, reduce 60 million tons of oil imports, reduce electricity capacity by 20 percent, and reduce coal use by 45 percent.

Figure 7 India's cost abatement curve (cost below 100 Euros per ton)



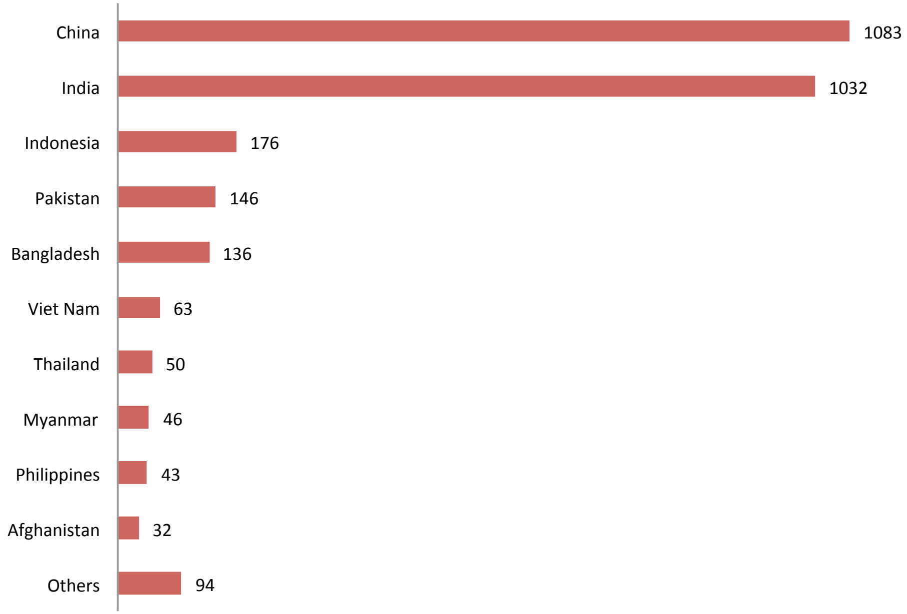
Source: McKinsey & Company. (2009). *Environmental and Energy Sustainability: An Approach for India*. Boston: McKinsey & Company. Note that blue represents investments in the electricity sector, yellow represents industry, red represents transport, brown represents buildings and habitats, and green represents agriculture and forestry. Abatement costs are given in Euros per ton of carbon dioxide equivalent, abatement potential is listed in million tons of carbon dioxide equivalent. LEDs refer to light emitting diodes. CSP refers to concentrated solar power. BOF refers to basic oxygen steelmaking. EAF refers to electric arc furnace steelmaking. DRI refers to direct reduced iron steelmaking. Solar PV refers to solar photovoltaic panels.

5 HOUSEHOLD THERMAL NEEDS

This section of the report looks at household thermal needs—essentially the various ways that households cook and prepare food, and the ways that they generate heat to keep warm.

Most homes without access to modern forms of energy cook and combust fuels directly inside their home. Ten countries in the Asia-Pacific—China, India, Indonesia, Pakistan, Bangladesh, Viet Nam, Thailand, Myanmar, the Philippines, and Afghanistan—account for 96.7 percent of people in Asia-Pacific dependent on traditional fuels to meet their cooking/heating energy needs, as figure 8 shows.

Figure 8 Population with no or only partial access to modern fuels in Asia-Pacific (millions, 2012)



Source: UNDP International Human Development Indicators Database, Global Alliance for Clean Cookstoves country specific database.

For instance, almost 90 percent of people in Bangladesh cook with traditional fuels such as firewood, jute sticks, and agricultural waste. In Bhutan, more than 80 percent of rural households, where 70 percent of the population resides, are largely dependent on traditional fuels such as firewood and kerosene.[48] Cambodia is extremely dependent on wood and solid fuels for household energy needs. In 2011, firewood and charcoal represented 95 percent of all energy used for cooking in the country.[49]

In India, a typical rural woman spends 40 hours collecting fuel every month during 15 separate trips, many walking more than 6 kilometers round trip.[50] This amounts to 30 billion hours spent annually (82 million hours per day) collecting fuelwood, with an economic burden (including time invested and illnesses) of $6.7 billion (300 billion rupees) per year.[51] In Lao PDR, almost 90 percent of rural households and over half of urban households use firewood for cooking, and the use of charcoal as the main cooking fuel has almost quadrupled from 1995 to 2005. In Nepal, 81 percent of the Nepali population use solid fuels for cooking (mostly wood), destroying about 12.5 million tons of biomass and forestland each year.[52]

A 2007 World Bank survey reported that 98.7 percent of households in Timor-Leste, a country of roughly 1 million people, used fuelwood as their primary source of energy for cooking. Sixty percent of the rural populations in Timor-Leste spend 1-3 hours a day searching for fuelwood.[53] The World Bank estimates the annual economic cost of IAP resulting from traditional cookstoves in Timor-Leste to be $12.5 million or 1.4 percent of Gross National Income.

However, burning firewood, dung, charcoal, and other fuels has severe health consequences. As the World Health Organization (WHO) explains:

> *The inefficient burning of solid fuels on an open fire or traditional stove indoors creates a dangerous cocktail of not only hundreds of pollutants, primarily carbon monoxide and small particles, but also nitrogen oxides, benzene, butadiene, formaldehyde, polyaromatic hydrocarbons and many other health-damaging chemicals.*[54]

There is both a damaging spatial and temporal dimension to such pollution. Spatially, it is concentrated in small rooms and kitchens rather than outdoors, meaning that many homes have exposure levels to harmful pollutants sixty times the rate acceptable outdoors in city centers in North America and Europe.[55] Temporally, this pollution from stoves is released at precisely the same times when people are present cooking, eating, or sleeping, with women typically spending three to seven hours a day in the kitchen.[56]

Even when these homes have a chimney and a cleaner burning stove (and most do not), such combustion can result in acute respiratory infections, tuberculosis, chronic respiratory diseases, lung cancer, cardiovascular disease, asthma, low birth weights, diseases of the eye, and adverse pregnancy outcomes; as well as outdoor pollution in dense urban slums that can make air un-breathable and water undrinkable.[57] Table 4 shows the most common, and well-established, health impacts of IAP.

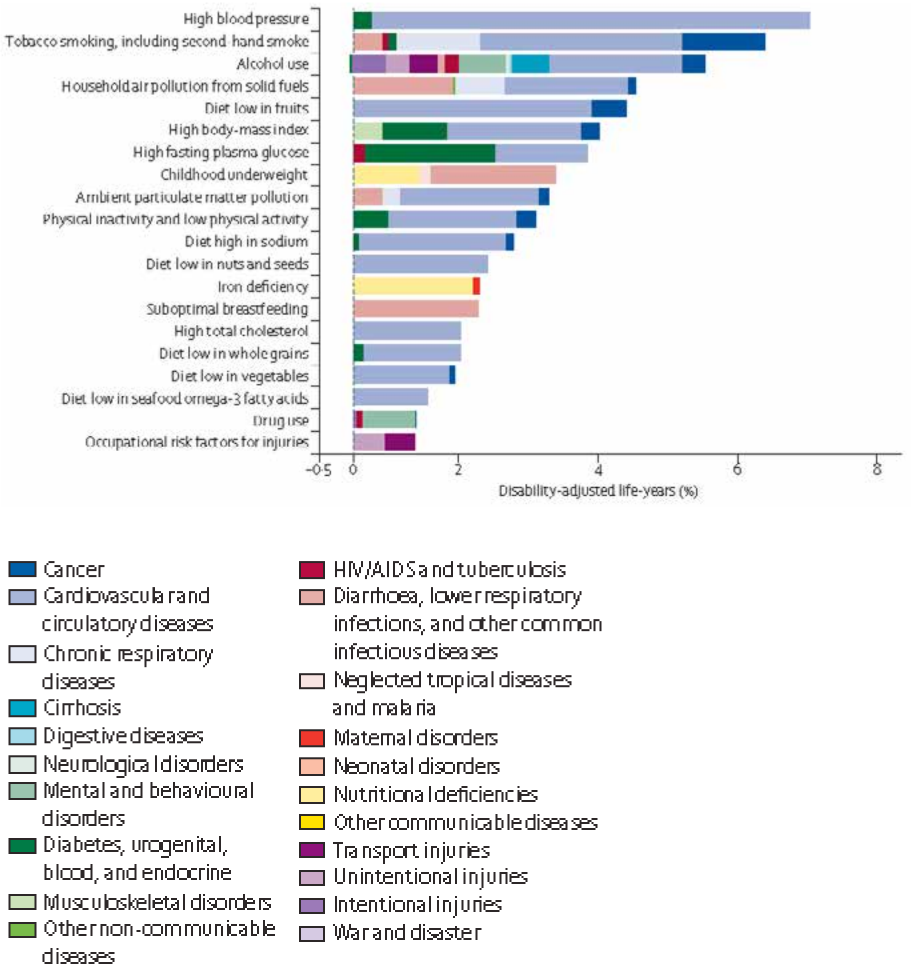
Strikingly, IAP ranks *fourth* on the global burden of disease risk factors at almost five percent, coming after only high blood pressure (almost 8 percent), tobacco smoking and second hand smoke (about 7 percent), and alcohol use (about 6 percent).[59] This places it well ahead of physical inactivity and obesity, drug use, and unsafe sex, as figure 9 depicts. In India and all of South Asia, cookstove smoke is the *highest* health risk factor, ranking above smoking and high blood pressure. It is second for Sub-Saharan Africa, third for Southeast Asia, and fifth in East Asia. Air pollution from conventional cookstoves is therefore responsible for 3.5 million direct premature annual deaths. The cost of this burden to national health care systems, not reflected in the price of fuelwood or energy, is $212 billion to $1.1 trillion.[61]

Table 4 Health impacts of cookstove pollution[58]

Health Outcome	Evidence	Population	Relative Risk
Acute infections of the lower respiratory tract	Strong	Children aged 0-4 years	2.3
Chronic obstructive pulmonary disease	Strong	Women aged more than 30 years	3.2
	Moderate	Men aged more than 30 years	1.8
Lung cancer	Strong	Women aged more than 30 years	1.9
	Moderate	Men aged more than 30 years	1.5
Asthma	Specified	Children aged 5-14 years	1.6
	Specified	Adults aged more than 15 years	1.2
Cataracts	Specified	Adults aged more than 15 years	1.3
Tuberculosis	Specified	Adults aged more than 15 years	1.5

Source: WHO. (2006). *Fuel For Life*. Geneva: WHO.

Figure 9 Burden of disease



Attributable to 20 leading risk factors in 2010 for both sexes (percent of disability-adjusted life years globally).

Source: Lim et al. 2012.

Two key alternatives—improved cookstoves, and biogas digesters—can minimize many of these health-related risks. Indeed, WHO estimates that if half of the global households that still use traditional fuels and stoves switched to cleaner cooking sources, over a ten-year period, families would save $34 billion per year and generate an economic return of $105 billion per year.[62]

5.1 Improved cookstoves

The three basic components of any cookstove are a combustion chamber where wood or charcoal are burnt with air; a heat transfer area, where hot gases actually heat pots and cook; and a chimney which removes hazardous gases outside the cooking area. Improved cookstoves sometimes require a switch away from charcoal or coal to "healthier" fuels such as grass, crop residues, and firewood; they have a grate and an improved combustion chamber; and they almost always have a chimney. They utilize higher temperature ceramics, fire resistant material, longer lasting metals, and possess more insulation and a better frame that guides hot gases closer to cooking pots. They can cook more food at once and many have coils around the combustion chamber to heat water while cooking is in process. Some improved stoves are connected to radiators or space heaters so that heat could be recycled and/or vented to other rooms and some stoves send heat through pipes directly into a brick platform that occupants sleep on at night. Other improved stoves are "fuel flexible" and can combust coal and biomass, although doing so requires homeowners to insert a different combustion chamber for each fuel. Improved stoves are also often aesthetically pleasing with beautifully designed tile and artwork, making them something to be proud of and handed down to children, regarded as a family asset.[63]

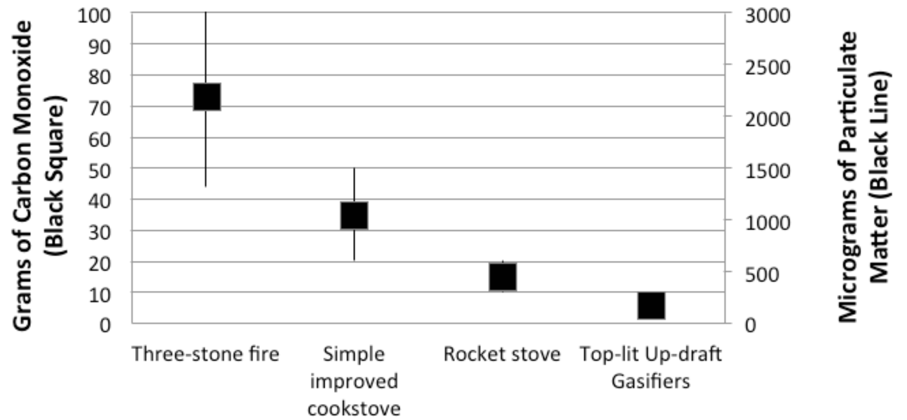
The most popular models are one-, two-, and three-mouthed clay cookstoves which cut fuel use by half and have chimneys that create a smoke-free cooking environment, improving air quality within the home. These efficient cookstoves not only result in less fuel consumption (typically reducing fuel needs by 40 to 50 percent), they also facilitate shorter cooking times, generate more heat, and reduce IAP by 20 percent. The technical benefits of these improved stoves, moreover, are manifold. They can be installed quickly, often taking only one to two days. Under China's National Improved Stoves Programme, improved stoves lasted longer, with lifetimes of ten years compared to five for traditional stoves. They were constructed in China with prefabricated models taking only seven to 15 days to mold, and they cost only $12 for a complete three-mouthed model with a chimney.[64] Throughout Asia, national cookstove programmes have also been shown to provide local employment and entrepreneurship opportunities for local artisans.[65]

Newer designs of cookstoves, especially those made in the past decade, only multiply such benefits. Thermoelectric generators (TEGs) are becoming cost-competitive and enable stoves to generate both heat and a small amount of electricity that they use to power a fan, which increases the efficiency of combustion, or to charge small devices such as mobile phones.[66] These TEG stoves have been shown to reduce harmful pollutants ten to twenty *times* the rate of ordinary improved stoves. Natural draft, rocket stoves reduce emissions of key health pollutants by two to three times compared to an ordinary cookstove, and natural draft gasifier stoves can reduce those pollutants by five or six times.[67] Microgasifiers, those small enough to fit under a cooking pot at a "convenient height", can cleanly burn biogas with almost smoke free combustion, provide a steady flame with no waiting, and can be operated over extended periods of time (no tending of a fire). Moreover, microgasifier stoves reduce soot, black carbon, and particulate matter. They need less total biomass fuel, due to their efficiency.[68] Figure 10 shows some of the environmental and health advantages from improved cookstoves, rocket stoves, and gasifier stoves.

Almost all countries among the sample of 18 would benefit from or are benefitting from improved cookstove programmes, some potential exceptions being:

- Indonesia, where a largely successful liquid petroleum gas (LPG) substitution programme and large subsidies for kerosene have reduced dependence on fuelwood;
- Malaysia, where a large proportion of homes use LPG, or electricity for cooking;
- Philippines, where roughly half the population already has access to an improved stove;
- Sri Lanka, where household needs are met mostly with electricity, kerosene, and gas for cooking, and many homes also have improved stoves;
- Thailand, where almost two-thirds of people have access to an improved stove.

Figure 10 Emissions from four types of cookstoves (Five Litre Water Boiling Test)



Source: Roth, Christa. (2011). Micro-gasification: Cooking with Gas from Biomass. Berlin: GIZ.

Every other country, however, has significant improved cookstove potential. In Bangladesh, the German International Cooperation, GIZ, has disseminated over 450,000 improved cookstoves and Grameen Shakti has distributed another 300,000. In Cambodia, the Group for the Environment, Renewable Energy and Solidarity reports that they have sold more than 2 *million* "New Lao" stoves as of March 2011.[69] India has almost 1 *billion* people in need of an improved stove, and large potential also exists for in many other Asian and Pacific countries.

5.2 Biogas digesters

Biogas is a clean fuel produced through anaerobic digestion of animal, agricultural, and domestic wastes. These three forms of organic waste and water typically enter a chamber where they are left to ferment and decompose, producing both biogas as well as digested slurry that can be turned into an organic fertilizer.[70] Smaller-scale, two- to three- cubic metre biogas plants tend to be used in homes and communities, suitable for providing gas and heat for cooking three meals a day for an average-sized family. Commercial scale systems exist as well, with these larger units offering enough gas to meet the energy needs of neighborhoods, restaurants, tea stalls, and bakeries. These larger systems, installed near large farms, poultry suppliers, and livestock ranches, can supply enough gas for up to a thousand families.

Though theoretically every country in the Asia-Pacific could utilize some form of biogas to meet the cooking needs of households, the rapid assessment and gap analyses identified Bangladesh, Bhutan, Cambodia, Fiji, India, Nepal, Samoa, and Viet Nam as having the best potential.

Biogas digesters, or biodigesters, operate well in Cambodia due to the country's warm climate, dependence on agriculture (producing many forms of waste that can be digested), and availability of local materials and expertise for manufacturing, installing, and maintaining systems. One study undertaken by the National Biodigester Programme in the six provinces of Kampong Cham, Svay Rieng, Prey Veng, Kampong Speu, Takeo and Kandal found technical potential for at least 224,000 units. One digester can convert 4 cubic meters of waste into 1.44 cubic meters of biogas per day, enough to burn a single stove for 3.5 to 4 hours—meaning biogas can displace 6 kilograms of firewood, 2 kilograms of charcoal, 0.7 liters of kerosene, or 1.8 kWh of electricity per day. This means, as table 5 summarizes, that digesters can pay for themselves within 2 years.[71]

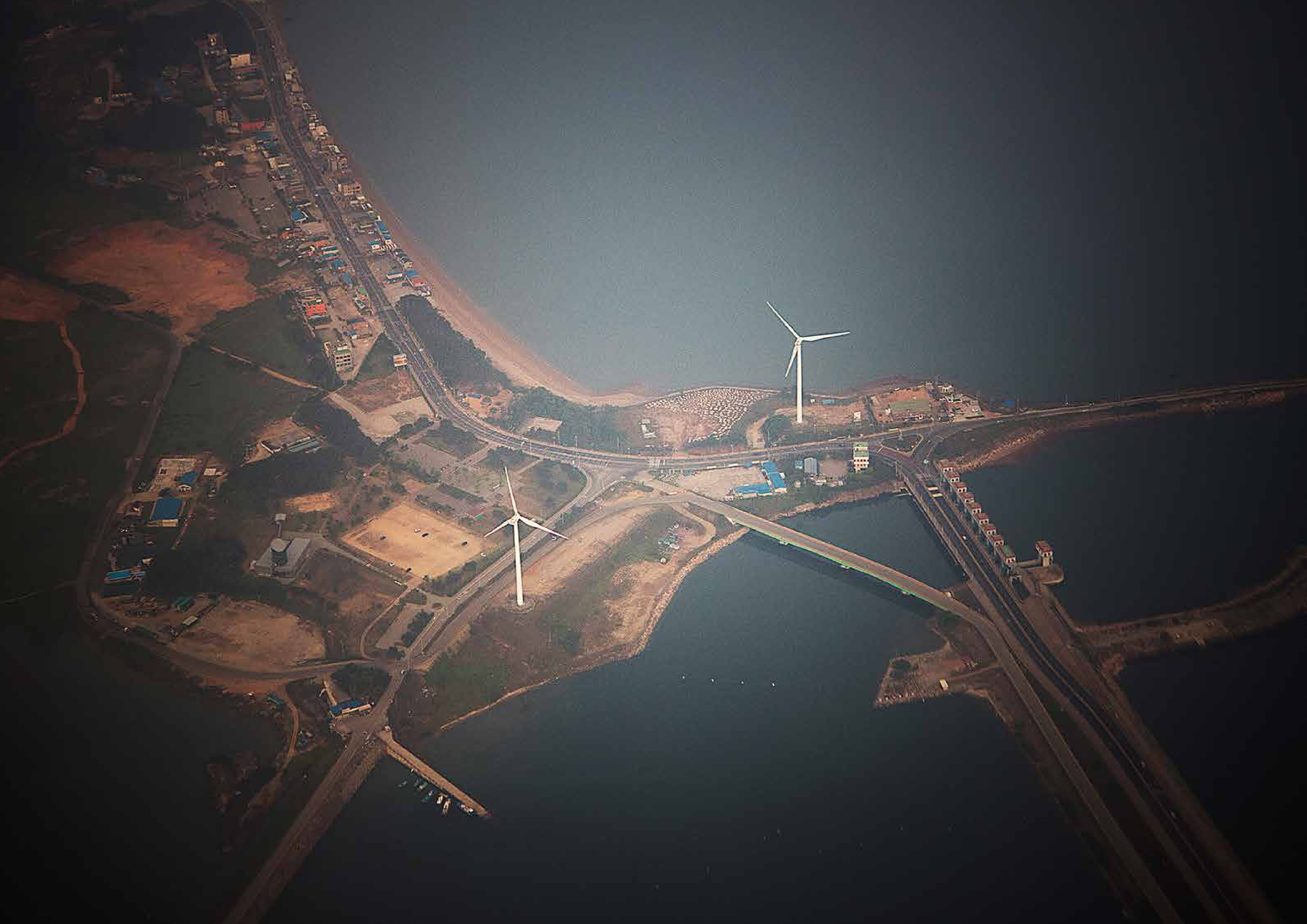
India is the fifth largest consumer of biogas in the world, with most biogas derived from animal waste (poultry and livestock associated waste) and cow dung. One assessment has estimated the potential for an additional 25 to 30 million households.[72]

The Nepali farming system is heavily dependent on livestock, with at least 1.2 million households owning cattle and buffalo, there is technical biogas potential for at least 1 million household-size plants, 57 percent located in the Terai plains, 37 percent in the hills and 6 percent in remote hills.[73] According to the Alternative Energy Promotion Center, as of July 2011, 241,920 biogas plants were installed in more than 2,800 Village Development Committees and in all 75 Districts under their Biogas Support Programme. In addition, 2,907 biogas plants were installed under the Gold Standard Biogas Project.[74] Still, other estimates of Nepali biogas utilization have calculated that potential for family-sized biogas plants, operating on agricultural residues, could fuel at least another 200,000 units.[75] Many other Asian countries are also estimated to have substantial potential for biogas digesters.

Table 5 Payback period for biodigesters in Cambodia

Type of Fuel Sources	Quantity saved	Cost per unit	Total cost saved per day	Total cost saved per year	Payback period without subsidy	Payback period with subsidy (US$150)
Firewood	6 kgs	US$ 0.07	US$ 0.42	US$ 153	2.7 years	1.7 years
Charcoal	2 kgs	US$ 0.20	US$ 0.42	US$ 153	2.7 years	1.7 years
Kerosene	0.7 litre	US$ 0.65	US$ 0.46	US$ 166	2.5 years	1.5 years
LPG	0.5 kg	US$ 1.00	US$ 0.50	US$ 183	2.3 years	1.3 years

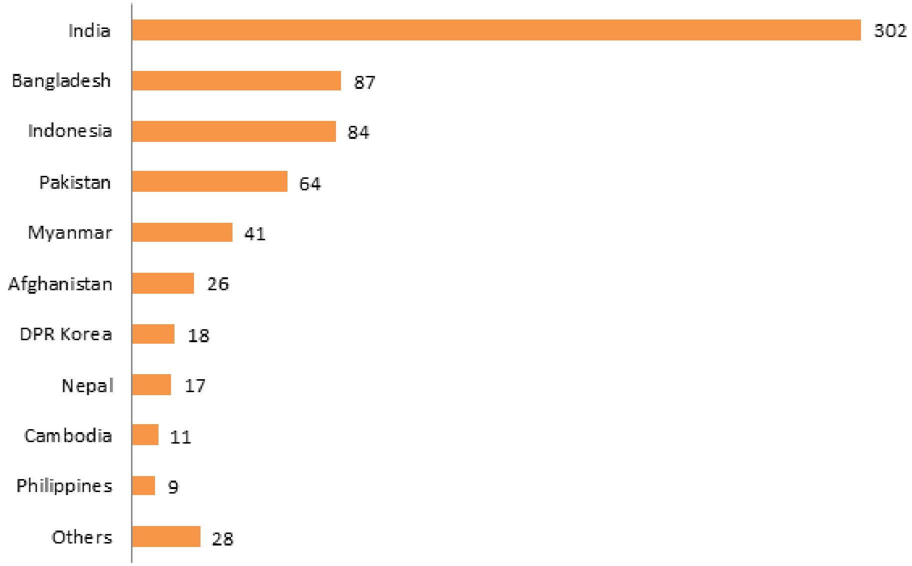
Source: National Biodigester Programme Cambodia Information Folder October 2011.



6 RURAL ELECTRIFICATION

The Asia-Pacific is also home to ten countries that have populations of nearly 10 million or more without access to electricity. As figure 11 reveals, India, Bangladesh, Indonesia, Pakistan, Myanmar, Afghanistan, DPR Korea, Nepal, Cambodia, and the Philippines account for 96.1 percent of people without access to electricity across the Asia-Pacific in 2009.

Figure 11 Population without electricity in the Asia-Pacific (millions, 2009)



Source: UNDP International Human Development Indicators Database, 2012 National Rapid Assessment and Gap Analyses, UNDP APRC Country Energy Reviews, UNDP Energy Access Case Studies supplemented with Worldbank data.

In these countries, the provision of electricity through grid extension, mini-grids, or off-grid systems can help to expand income-generating activities that contribute to human development, as well as to diversify the economies of developing countries against fossil fuel shocks and price spikes.

6.1 Grid extension

Lack of electricity from the national grid limits the productive hours of the day for business owners and heads of households, and also inhibits the types of business opportunities available. Grid electrification, combined with appropriate government, financial and technical training, can make a variety of income generating activities possible, including mechanical power for milling grain, illumination for factories and shops, heat for processing crops, and refrigeration for preserving products.[76] In the Philippines, for instance, investments in the electrification fund are largely justified on the grounds that Philippine households typically see income gains of $81 to $150 per month when they become connected to the grid, as table 6 reveals.

Table 6 Summary of rural household benefits from electricity in the Philippines

Benefit category	Benefit value (US$)	Unit (per month)
Less expensive and expanded use of lighting	36.75	Household
Less expensive and expanded use of radio and television	19.60	Household
Improved returns on education and wage income	37.07	Household wage earner
Time savings for household chores	24.50	Household
Improved productivity of home business	34.00 (current business), 75.00 (new business)	Business

Source: World Bank. (2002). Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits. Washington, DC: World Bank ESMAP Program.

In PNG, household surveys concerning electrification conducted by the World Bank have found that:

- In all cases, lighting is considered the most important and immediate benefit;
- Knowledge of the outside world and entertainment opportunities offered by TV and VCR (today it would be DVDs or MP3s) are viewed as key benefits, especially by men;
- Women report time savings of three to four hours per day;
- Lighting and TV are said to have contributed positively to children's education through extended study hours and informal learning;
- Electrified homes have incomes higher than non-electrified homes of 27 to 100 percent
- Increases in assets are attributed mainly to the acquisition of electricity producing equipment and appliances.[77]

Similarly, in Vanuatu, household surveys indicate homes without electricity desperately want it for service such as lighting, water pumping, cold storage of fish and meat, TVs and DVD players, and mobile-phone charging.[78] Improved electricity provision can also provide power to schools and small hospitals, and serve local industries such as sawmills, crop processing, workshops, and other emerging forms of small, medium and micro enterprises.

As we elaborate in the section of the report presenting case studies, Bangladesh, Malaysia, Philippines, Viet Nam, and Thailand represent arguable "trend setters" that have made considerable progress in their electrification efforts. Other countries, such as Fiji, PNG, the Solomon Islands, and Vanuatu, have grid networks that are unlikely to expand further in the near-term, often due to geographic limitations (they consist of thousands of islands and archipelagos or have inaccessible mountainous terrain), and still others, such as Bhutan, Lao PDR, and Sri Lanka, have ambitious and mostly successful electrification programmes in place that are both adding large numbers of customers and obviating incentives to invest in off-grid alternatives. With Bangladesh, Cambodia, India, Indonesia, Mongolia, and Nepal all recognized as having large grid electrification potential, a summary of their needs and challenge is worth review.

6.1.1 Bangladesh

About four-fifths of Bangladesh's rapidly growing population of 144 million lives in rural areas, and almost four decades after the country's independence, shortages in natural gas, which provides 70 percent of commercial energy (electricity and liquid fuels), are now common. The most recent numbers offered by the Rural Electrification Board show an estimated 71 percent of households without access to the electricity grid, and due to natural disasters some years such as 2008 to 2009 actually saw a *negative* electrification rate. Previous estimates calculate that kerosene, natural gas, and electricity combined meet less than 1 percent of rural household energy needs.[79] For comparison, energy consumption in Bangladesh is less than one-tenth the global average, and 96 million people lack access to the grid.[80] National planners expect the need for $10 billion worth of investment by 2020 only to maintain the grid and stop load shedding.

6.1.2 Cambodia

In 2012, 35 percent of Cambodian households had access to electricity, and in provincial towns and rural areas 25 percent of households had access. Only 6 percent access the grid and 3 percent have some type of off-grid or mini-grid source. Of the remaining 75 percent without access, most are estimated to use automotive batteries for occasional supply and approximately one-third forgo access entirely.[81] The geographic gaps in coverage have begun to be filled by 600 Rural Electricity Enterprises (REEs), privately owned vendors that have entered the retail electricity sector to provide electricity to households. In 2011, these REEs supplied about 5 percent of the country's electricity to about 115,000 isolated customers in rural towns. The REEs offer a variety of services including battery recharging, connecting households to micro-grids, and supply electricity through diesel generators, though they have also been accused as charging exorbitant rates.[82]

6.1.3 India

Though most rural villages, about 93, have electricity access, the formal electrification rate (excluding informal connections and theft) among actual households is much lower, about 75 percent, with some 140,000 villages out of 586,000 lacking any connection to the grid whatsoever in 2009. India thus suffers from a "severe shortage" of electricity capacity, with blackouts a "common occurrence" throughout main cities and total demand for electricity rising at more than 7 percent per year.[83] As one assessment put it, "additional capacity has failed to materialize in India in light of market regulations, insufficient investment in the sector, and difficulty in obtaining environmental approval and funding for hydropower projects" and "coal shortages are further straining power generation capabilities".[84] Even where electricity access is available, the quality of supply remains poor because power is often unavailable during the evening hours when people use it the most.[85] Only 7 out of 28 states have achieved 100 percent village electrification, and many large states such as Assam, Bihar, Jharkhand, Orissa, Rajasthan, and Uttar Pradesh have lagged behind electrification efforts. Though Andhra Pradesh and Tamil Nadu have "officially" achieved complete village electrification, a recent field study by The Energy and Resources Institute (TERI) indicates that many hamlets and forest fringe villages do not have access to any form of electricity.[86]

6.1.4 Indonesia

Indonesia has made progress in increasing access to electricity for its population. The national electricity access rate went from a low of 2 percent in the late 1970s to 65 percent in 2009. Much of this electricity access progress occurred in the decade starting in late 1980s and was significantly slowed down in the aftermath of the Asian Financial Crisis that started in 1997, and a huge number of Indonesians still lack access to electricity. The World Bank estimates that about 81 million people were without electricity in 2009, making Indonesia, one of the top ten countries with largest number of people lacking access to electricity. Compared to other East Asian and Pacific countries with relatively similar economic strength, Indonesia's electricity access rate is among the lowest.

6.1.5 Mongolia

Mongolia confronts high rates of poverty, low population density, and low per capita electricity use. With a per capita income of $1,870 per year, Mongolia has grown in recent years to become classified as a lower middle income country. Despite this, UNDP reports that "a substantial portion of the population in Mongolia still lacks access to electricity despite an expansion in the country's energy infrastructure."[87] The country's large geographic size, low population density and nomadic herding lifestyle practiced by approximately one fourth of the country's population make transmitting and distributing electricity difficult, a feat compounded by old and inefficient Russian generators that frequently break down and are completely dependent on fossil fuels.

6.1.6 Nepal

Nepal's national electrification rate in 2009 was about 44 percent, meaning around 17 million people did not have access to electricity. Moreover, the Nepal Electricity Authority, the state-owned monopoly supplier of power for the country, serves only 15 percent of the total population of Nepal.[88] For this small number of customers, average electricity supply is less than eight hours per day, with load shedding accounting for up to 16 hours during winter. In December 2008 the Nepal Government declared a "national energy crisis" and approved an Energy Crisis Management Action Plan.[89] In January 2009, things got even worse as drought in one part of the country reduced water available for hydroelectricity generation, and floods in another part breached the embankments of the Kosi River, toppling a crucial transmission line importing power from India. Such events provoked the World Bank to declare that "Nepal is experiencing an energy crisis of unprecedented severity, caused by years of under-investment and sharp growth in electricity demand."[90] Other recent studies have concluded that "Nepal has strikingly low levels of access and electricity consumption compared to many other developing countries."[91]

6.2 Micro-grids and mini-grids

A mini-grid refers to a localized or isolated grouping of electricity generation, distribution, storage, and consumption within a confined geographic space.[92] While in some instances mini-grids can be interconnected to national electricity networks, in most cases they operate autonomously and at lower loads and voltages. Though definitions vary, mini-grids are often locally managed, they involve less than 10 MW of installed capacity, they serve small household loads, and they possess a radius of 50 kilometers or less. Micro-grids are even smaller and typically operate with less than 100 kW of capacity and at even lower voltage levels and possess a three to eight kilometer radius.[93] Mini- and micro-grids can be powered by fossil fuels, such as diesel generators or fuel cells, or by renewable energy sources such as microhydro dams, solar

PV plants, biomass combustion and wind turbines. When configured properly, such mini- and micro-grids can operate more cost effectively than centralized generation from a power grid.[94]

At least five countries in the Asia-Pacific—Nepal, Sri Lanka, Lao PDR, Mongolia, and Viet Nam—have been experimenting with mini- and micro-grids for rural electrification over the past decade. Nepal's Rural Energy Development Programme (REDP), Sri Lanka's Energy Services Delivery Project, and the Rural Electrification Project in Lao PDR all entailed components tailoring grid, micro-grid, and off-grid solutions to local circumstances. The Sri Lankan project went so far as to specifically target different beneficiaries: SHS for rural households, off-grid microhydro units with micro-grids for village cooperatives, and grid-connected microhydro units for tea plantations and independent power producers. The Rural Energy Access Project in Mongolia, similarly, pursued a two-pronged strategy of isolated diesel and solar hybrids for some herders but micro-grids for others living near *soum* centers (in Mongolia, a *soum* is equivalent to a district or county).[95] Viet Nam's Renewable Energy for Remote Island and Mountain Communes Project financed the construction of ten mini-hydropower facilities, with a capacity of less than 7.5 MW each, in several northern provinces of Viet Nam. It built more than 100 kilometers of low-voltage micro-grid networks and electrified 50 villages and 5,000 households.[96] Due to the isolated nature of their remote communities and the particular distribution of renewable resources such as microhydro or biomass, Bhutan, Cambodia, Fiji, PNG, Samoa, the Solomon Islands, and Vanuatu also have potential to further expand energy access through mini- and micro-grids.

Indeed, the IEA expects micro- and mini-grids to play an instrumental role in global electrification efforts over the next decade, especially in the Asia-Pacific. The IEA's most recent numbers suggest that national grid extension is the most suitable option for all urban areas and for around 30 percent of rural areas, but not a cost effective option in more remote rural areas.[97] Therefore, in the Asia-Pacific 70 percent of rural areas are assumed to be connected either with mini-grids (65 percent of this share) or with small, stand-alone off-grid solutions (the remaining 35 percent)—as table 7 shows. Out of a total generation requirement of 838 TWh, 56 percent (or 470 TWh) will be provisioned via mini-grid and isolated off-grid technology.

Table 7 Generation requirements for universal electricity access (2030, TWh)

	On-Grid	Mini-Grid	Isolated Off-Grid*	Total
Africa	196	187	80	463
Developing Asia	173	206	88	468
China	1	1	0	2
India	85	112	48	245
Other Asia	87	94	40	221
Latin America	6	3	1	10
Developing Countries	379	3,993	171	949
World	380	400	172	952

Source: IEA. (2012). World Energy Outlook 2012. Paris: IEA. *Isolated off-grid technology refers to small capacity systems, including micro-grids and other technologies listed in this section.

6.3 Off-grid and isolated units

Rural and poor households throughout Asia need not be served only by the grid or micro- and mini-grids. They can also receive electricity through microhydro dams, solar lanterns, and PV SHSs. Other, larger options, such as commercial-scale biogas and biomass, wind, solar, and geothermal units, are discussed in Chapter Eight on renewable energy.

6.3.1 Microhydro dams

Unlike their larger counterparts which require reservoirs, microhydro plants utilize low-voltage distribution systems and simpler designs that often have a natural river intake, de-sanding basin, masonry lined canal, forebay, penstock, powerhouse, short tailrace, and electronic load controller. By "micro" we refer to what is commonly discussed as either "micro" (less than 100 kW) or "small" (less than 10 MW).[98] Microhydro units have a distinct set of advantages since they can provide not only electricity, but also mechanical energy for milling, husking, grinding, carpentry, spinning, and pump irrigation. Local people can also be trained to manage them without any technical background in engineering or maintenance. They can also provide electricity in remote mountain areas unsuited for biogas (because fermentation takes more time at higher altitudes) and SHSs in areas prone to fog and cloud cover. The potential of micro and small hydro facilities for countries in Asia-Pacific is discussed in greater detail in the section of the report on "Renewable Energy" below.

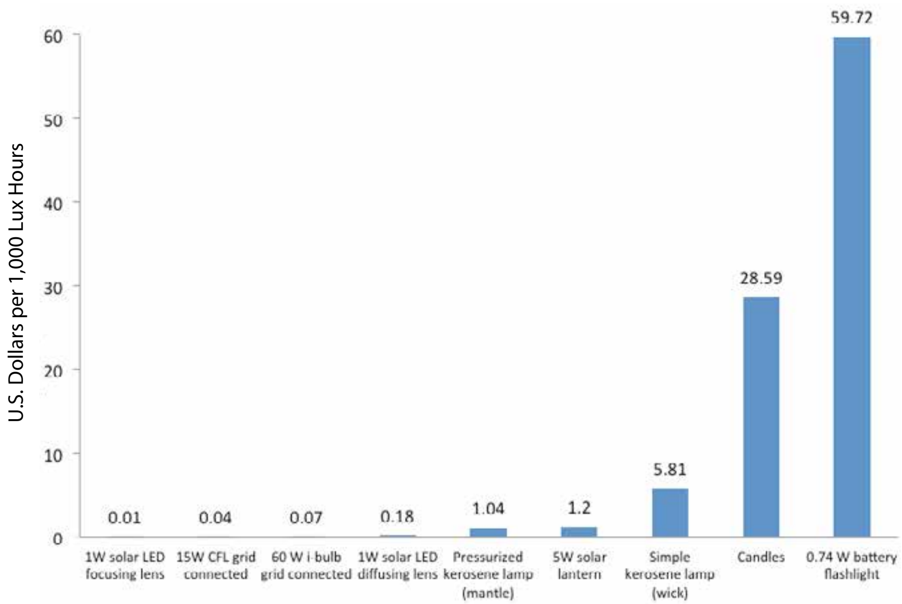
6.3.2 Solar lanterns

Solar lanterns, sometimes referred to as "Pico-PV systems" and "solar LEDs," refer to very small solar units, often independent solar flashlights or lanterns, that can use LEDs or other lighting devices. These small systems, less than 10 Watt-peak (Wp) with a voltage up to 12 V, have advantages over SHSs because they are often less capital intensive, and more versatile.[99] When costs of equipment are amortized over three years and inclusive of fuel, energy, replacement lamps, wicks, mantles, and batteries, it has been estimated that the cheapest option by far to operate a lamp four hours a day for one year is a 1 W solar LED.[100] Put another way, they can pay for themselves in one month to two years compared to kerosene, and have lower costs of lifetime ownership than almost any other system on the market, as figure 12 shows. Because of this extreme cost competitiveness, virtually every country among the 18 has potential for solar lantern dissemination. Even countries with high electrification rates, such as Malaysia and the Philippines, have market potential for solar lanterns, which can be used in remote communities, areas where grid electricity is unreliable or unaffordable, or for those who work or roam far from electricity grids, such as herders and fishermen.

6.3.3 Photovoltaic solar home systems

The SHS commonly consists of a solar PV module, battery, charge controller, and lamp(s). Customers in off-grid and rural areas can often choose from a variety of systems and technologies. Larger systems often have the capacity to connect televisions, radios, and other electric appliances. These systems have seen their competitiveness decline in the past few years due to advances in solar lanterns (see below) and rapid expansion of grid electrification.

Figure 12 Cost of illumination services for various lighting sources



Source: Mills, Evan. (2005). The Specter of Fuel-Based Lighting. *Science* 308, pp. 1263–1264. Lux-hours describe the perceived luminous intensity of light by the human eye, multiplied by the number of functional hours.

Costs include equipment purchase price amortized over 3 years, fuel, electricity, wicks, mantles, replacement lamps, and batteries. Performance characteristics values reflect common equipment configurations and include dirt depreciation factors for fuel lanterns and standard service depreciation factors for electric light. Assumptions are 4 hours/day operation over a 1-year period in each case, \$0.1/kWh electricity price, \$0.5/liter fuel price. We estimate an average of 11 liters of lighting fuel per household per month; observed values vary from 2 to 20 liters.

7 ENERGY EFFICIENCY

Increased energy efficiency is one of the goals of Sustainable Energy for All. Current demographic, economic, social, and technological trends pose major challenges to the global energy system and increase the need for intelligent energy efficiency solutions. If more ambitious energy policies beyond those already planned are not implemented between now and 2030, it is projected that the world's energy consumption will increase by 30 to 50 percent.

In developing countries, energy consumed by the industrial sector is frequently in excess of 50 percent of the national energy supply. Energy efficiency measures contribute to development and reduce costs both for public and private sector. Adopting energy efficient technologies could, by 2030, reduce global projected electricity consumption of buildings and industry by 14 percent. In more industrialized countries, investments in energy productivity can contribute to job creation. Energy efficiency practices are already commercially available and ready to be utilized, and in many countries they are being adopted without dependence on subsidies or further research. Energy efficiency is an opportunity that is not capital intensive, reduces consumption of water and other resources, contributes to reducing greenhouse gases emissions, and is not prone to catastrophic failure. Energy efficiency can specifically reduce the financial burdens for energy consumers, decrease net import dependency for importers or enhance exports for exporters, and improve local economic competitiveness and employment.[101]

Experiences from numerous Asian countries already confirm many of these points. In Bhutan, for example, major industrial electricity customers such as steel manufacturers, aluminum smelters, chemical companies, and cement makers could cut their energy use cost-effectively by 9 to 35 percent without *decreases* in output and profit, as energy efficiency costs more than balance energy savings.[102] Cambodia's energy efficiency potential amounts to as much as 467 GWh per year, or almost one-third of national energy demand, mostly through potential improvements to the residential sector, which uses most of the country's electricity.[103] India has cost effective energy savings potential of 10 to 70 percent for households and 8 to 40 percent for industries available.[104] In Indonesia, about 181.18 GWh of electricity consumption can be saved by 2025 through implementation of energy efficiency and conservation measures, displacing 20 to 26 percent of expected national electricity consumption.[105] In Sri Lanka, energy efficiency efforts are so cost effective that spending Sri Lankan Rupee (LKR) 1.22 billion is projected to reap LKR 135 billion in financial savings.[106]

"Though this energy efficiency potential exists in every country in the sample, it takes many different forms in practice, with existing efforts falling into the eight broad categories previewed by table 8. They are, in order of most popular, labels and standards for electric appliances (present in 12 countries) followed by programmes reducing electric transmission and distribution losses (ten countries) and industrial and commercial programmes (ten countries) proceeded by lighting (eight countries), demand-side management (five countries), building codes (six countries), energy efficiency funds (four countries), and government programmes for combined heat and power and cogeneration (three countries)."

Although countries in the Asia-Pacific are undertaking various energy efficiency activities, there are others that have not yet taken advantage of this option. No country within the sample, for example, utilizes supply- or demand-side management of automobiles; only a few countries like India, Malaysia, and Vanuatu promoted ascending block-rate pricing; and only a few have decoupled electricity revenues from sales so that energy efficiency utilities can operate.

For instance, one way of promoting energy efficiency in the transport sector is practicing demand side management of automobiles—directly shaping consumer behavior, and implementing congestion road pricing. Singapore, for example, has pursued a synergetic approach to urban transport policy that involves both "carrots" and "sticks".[107] Aspects have included controls over vehicle ownership and caps on the numbers of vehicles sold, steady improvement of public mass transit, road pricing schemes, and the provision of real-time information to drivers. Supply-side components have invested in train and bus infrastructure and constructed electronic road pricing schemes, whereas demand-side components attempt to alter behavior in

Table 8 Summary of energy efficiency policies and programmes in the Asia-Pacific

	T&D Loss Reduction	Demand-Side Management	Efficient Lighting	Electric Appliance Standards/ Labels	Industrial/ Commercial Programmes/ Energy Audits	Building Codes	Combined Heat and Power	Energy Efficiency Funds
Bangladesh	✓	✓	✓	✓	✓		✓	
Bhutan				✓				
Cambodia			✓	✓				
Fiji					✓		✓	✓
India	✓	✓	✓	✓	✓	✓	✓	✓
Indonesia	✓	✓	✓	✓	✓	✓		
Lao PDR	✓	✓						
Malaysia				✓	✓	✓		
Mongolia	✓				✓	✓		
Nepal	✓							
Papua New Guinea						✓		
Philippines	✓	✓	✓	✓				
Samoa	✓		✓	✓	✓			
Solomon Islands	✓		✓	✓				
Sri Lanka				✓	✓	✓		✓
Thailand	✓				✓			✓
Vanuatu			✓	✓				
Viet Nam				✓	✓			

Source: Country Rapid Assessment and Gap Analyses, and Country Energy Reviews (2012).

favor of alternative transport options by restricting the number of private vehicles and raising vehicle registration fees.[108] The Singaporean Ministry of Transport estimates that almost 5 million trips (about 60 percent) occur per day using mass rapid transit, light rail transit, and buses—impressive figures given that the country has a population of less than 5 million people.

Another tool utilized only rarely is ascending block rate pricing and decoupling revenues from sales for the electricity sector. The promotion of ascending block rate pricing, where customers are charged higher rates for electricity the more they consume, has encouraged more efficient use in India, Malaysia, Vanuatu, and Viet Nam.

Another important policy innovation is decoupling the profits of electricity and natural gas utilities from their sales volumes. Some states in North America are adopting this policy, which allows electric utilities to keep a small share of the savings they achieve for their customers. In other words, the utilities are "rewarded for cutting your bill, not for selling you more energy".[109] The Natural Resources Defense Council has noted that the relatively simple act of decoupling ensures that utilities cannot make windfalls by encouraging higher (and at times, unnecessary) sales and are not penalized when energy-efficiency programmes and other efforts reduce consumption.[110]

7.1 Electric appliance standards/labels

Nonetheless, numerous Asian countries have labelling programmes or are in the process of implementing them. Bangladesh has a standards and labeling scheme, which lays down minimum energy performance standards for energy intensive equipment and appliances. In Bhutan, a study conducted under USAID's South Asia Regional Initiative programme examined the potential for a standards and labeling programme and estimated that the use of efficient fluorescent lamps, rice cookers and refrigerators, complemented by a public awareness campaign to promote efficient appliances could potentially save 5-8 MW electricity peak demand over a five-year period.[111] In Malaysia, a voluntary labeling programme covers refrigerators, fans, ballasts, lamps, air conditioners, televisions, insulation materials, and electric motors, which can receive a label like the one depicted in figure 13. These labels are being implemented in tandem with the country's Sustainability Achieved via Energy Efficiency programme, which is aiming to save 7,300 GWh of electricity by 2020. These savings are to be accomplished by the phasing out of inefficient models from local markets, with 100,000 rebate vouchers for five-star rated (the most efficient) refrigerators and 65,000 vouchers for five-star air conditioners being allocated so far, and 4,000 retail outlets participating with 12 brands to select products from. As of 2012, 66.3 GWh have been saved and the five-star refrigerators have accomplished a 12.4 percent market share and the five-star air conditioners a 7.1 percent market share.

Figure 13 Sample of a Malaysian Energy Efficiency Label for air conditioners

Source: Malaysia Country RA/GA 2012.

7.2 Transmission and distribution loss reduction

Asia-Pacific countries in the sample have a diversity of programmes aiming to reduce electricity transmission and distribution losses. In Indonesia, the state electricity company Perusahaan Listrik Negara (PLN) has been installing additional transformers and extending its low voltage network, training staff on how to reduce technical losses, setting up dedicated electricity loss reduction teams at headquarters and regional offices, and using devices to monitor electricity use to control consumption from street lighting. So far these actions have led to a reduction of network losses from 11.45 percent in 2006 to 9.70 percent in 2010. Similarly, in Lao PDR, Electricité du Laos has upgraded substations and transformers, optimized feeder line lengths, replaced old meters, and mainstreamed state-of-the-art software and hardware for computerized monitoring. The Nepal Electricity Authority currently pursues a loss reduction strategy of rehabilitating 27 feeders and distribution lines, and reducing system losses in transmission and distribution have also been initiated in Bangladesh, India, Mongolia, Philippines, Samoa, and the Solomon Islands.

7.3 Industrial and commercial programmes/energy audits

Asia-Pacific countries also save energy by improving the efficiency of industrial and commercial enterprises. Bangladesh has a formal Energy Audit Cell created in 1984 to conduct energy audits in several industries. In Fiji, the Department of Energy has conducted "preliminary energy audits" of a few government and commercial buildings such as Food Processors Limited, the Prime Minister's Office, G. L. Chartered Accountants, the Auditor General's Office, and Tapoo City.[112] The non-governmental organization World Wildlife Fund (WWF) estimated in 2011 that the typical hotel and resort operation in Fiji could cut energy consumption by 21 percent and save about $100,000 per year in energy bills.[113] India has a National Mission for Enhanced Energy Efficiency, passed in 2009, which has a Perform, Achieve, and Trade scheme calling for market mechanisms to enhance energy efficiency within large energy intensive industries, and an Energy Efficiency Project Financing scheme which promotes fiscal incentives such as tax exemptions for energy efficiency service companies (ESCOs) and creates a revolving fund to promote carbon finance. India also has Certified Energy Auditors and Certified Energy Managers programmes. In Indonesia, the Directorate General of Electricity and Energy Utilization has a programme that provides free energy audits for industries through PT Koneba, which has also carried out audits in the cement, pulp and paper, iron and steel, and fertilizer sectors. Other programmes also exist in Malaysia, Mongolia, Samoa, Sri Lanka, and Viet Nam.

7.4 Efficient lighting

A remarkably diverse number of lighting efficiency programmes exist among the sample of 18 Asia-Pacific countries. Bangladesh has launched the Efficient Lighting programme which aims to replace incandescent light bulbs with energy efficient and quality compact fluorescent lamps (CFLs) in households. About 10.5 million CFLs have been distributed in Phase I and another 7.5 million will be distributed in the second phase. In Cambodia, the Office of Energy Efficiency within the Ministry of Industry, Mining and Energy has promoted energy efficiency in the garments industry for lighting, and in Indonesia PLN manages an incandescent lamp replacement programme which sells CFLs at half market price. Lighting efficiency programmes are ongoing in India, the Philippines, Samoa, the Solomon Islands, and Vanuatu.

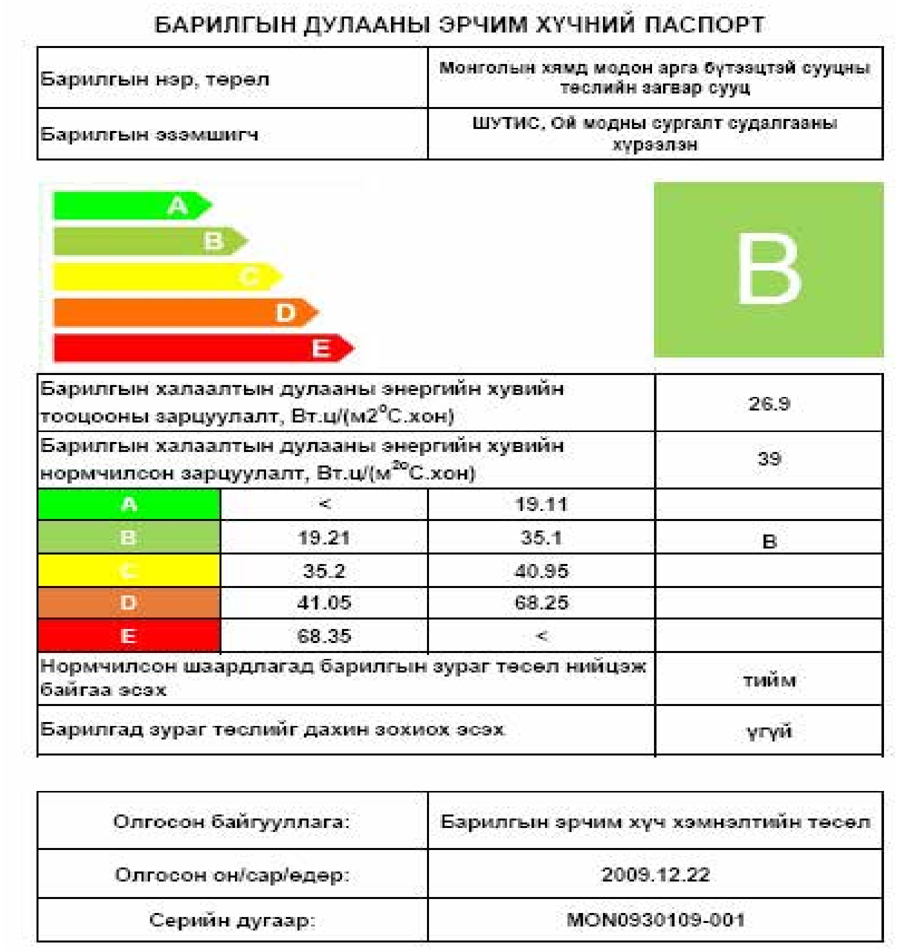
7.5 Demand-side management

Demand-side management includes utility-scale programmes which attempt to reduce demand for energy. Bangladesh's Agricultural Demand Side Management programme is replacing inefficient pump sets, substituting diesel sets with solar driven pumps, other agricultural equipment, and distributing more efficient street lighting. India's 2009 National Mission for Enhanced Energy Efficiency has a "Market Transformation Scheme" accelerating the shift to demand-side management programmes, supplemented with financing from the Clean Development Mechanism of the Kyoto Protocol. An autonomous Bureau of Energy Efficiency also exists within the Ministry of Power, responsible for promoting energy efficiency, and State Designated Agencies are statutory bodies set up by states to implement energy conservation measures at the state level. In Thailand, a demand side management programme has developed a five-year master plan, targeting 13 specific programmes across the residential, commercial, and industrial sectors, and built 330 "green learning rooms" to increase awareness about energy efficiency in schools.[114]

7.6 Building codes

Energy efficient building codes are less established than labels, audits, lighting, and other programmes, but do exist in at least six countries within the sample. Indonesia's Presidential Instruction No. 10/2005 requires Central and Regional Government to implement energy efficiency and conservation measures in government buildings. Through UNDP support, Mongolia's Building Law, Housing Law, and Urban Planning Law provides the necessary legal basis for the updating of the Mongolian building code energy efficiency provisions systems and resulted in labels such as the one shown in figure 14. PNG has adopted an energy efficient code, though it is not clear if it is enforced. Sri Lanka has a Code of Practice on Energy Efficient Buildings to ensure energy efficiency features are included in the design and construction of large-scale buildings, with mandatory compliance expected to be announced by the Urban Development Authority by the end of 2013.

Figure 14 A sample Energy Efficiency Label for a Mongolian building



БАРИЛГЫН ДУЛААНЫ ЭРЧИМ ХҮЧНИЙ ПАСПОРТ

Барилгын нэр, төрөл	Монголын хямд модон арга бүтээцтэй сууцны төслийн загвар сууц
Барилгын эзэмшигч	ШУТИС, Ой модны сургалт судалгааны хүрээлэн

Барилгын халаалтын дулааны энергийн хувийн тооцооны зарцуулалт, Вт.ц/(м2°С.хон)			26.9
Барилгын халаалтын дулааны энергийн хувийн нормчилсон зарцуулалт, Вт.ц/(м^{2o}С.хон)			39
A	<	19.11	
B	19.21	35.1	B
C	35.2	40.95	
D	41.05	68.25	
E	68.35	<	
Нормчилсон шаардлагад барилгын зураг төсөл нийцэж байгаа эсэх			тийм
Барилгад зураг төслийг дахин зохиох эсэх			үгүй

Олгосон байгууллага:	Барилгын эрчим хүч хэмнэлтийн төсөл
Олгосон он/сар/өдөр:	2009.12.22
Серийн дугаар:	MON0930109-001

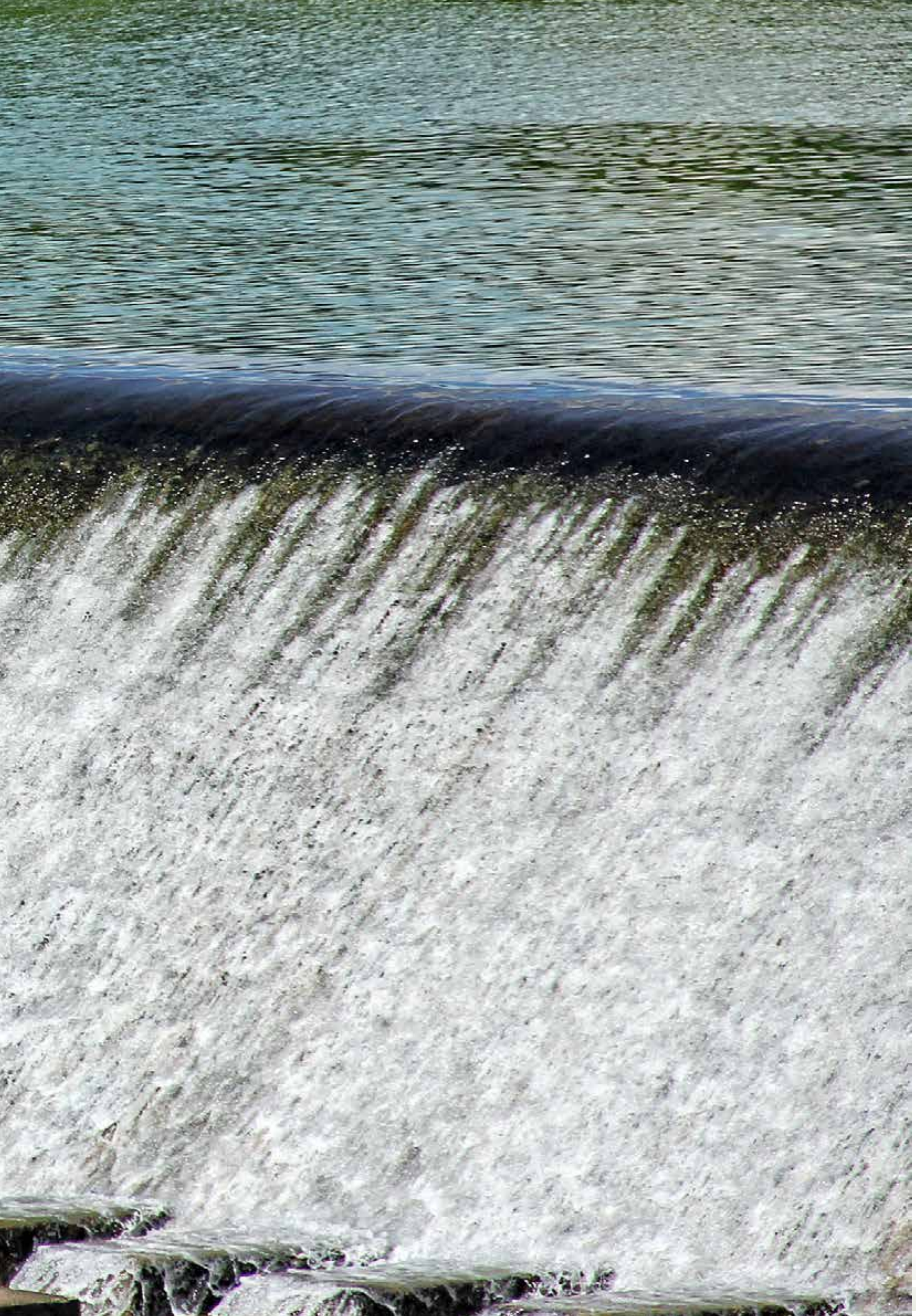
Source: Mongolia Country RA/GA 2012.

7.7 Energy efficiency funds

Energy efficiency funds are also less common than other options, but they are emerging in India, Sri Lanka, and Thailand. India's 2009 National Mission involves a revolving efficiency fund as part of its efforts to accrue investments under the Clean Development Mechanism of the Kyoto Protocol. Sri Lanka has their Sustainable Guarantee Facility available for energy efficiency improvement projects carried out through energy service companies. Thailand has an Energy Conservation Promotion Fund, created in 1992, which funds various energy conservation activities through soft loans and grants, and it has spent roughly $40 million on energy efficiency projects so far.[115]

7.8 Combined heat and power

A final nascent but important energy efficiency measure being introduced in Bangladesh and India is requirements for cogeneration and CHP. CHP systems produce thermal energy and electricity from a single fuel source, thereby recycling heat that is normally wasted in most conventional generation systems. Recycled thermal energy may be used directly for air preheating, industrial processes that require large amounts of heat, even space cooling and refrigeration. Bangladesh has roughly 1,200 MW of CHP potential for its natural gas combined cycle power plants, and in the gas sector 13 billion cubic feet of gas from industrial boilers and another 50 billion cubic feet of gas can be saved every year if waste heat was recycled in CHP/cogeneration plants. India's "Power Sector Technology Strategy" is also promoting retrofits and upgrades at power plants and prototyping Integrated Gasification Combined Cycle clean coal power facilities and CHP units.



8 RENEWABLE ENERGY

From the geothermal reserves of Indonesia and the Philippines and the agricultural waste in Malaysia and Thailand to the water moving through the Mekong Delta and the Himalayas to the winds through the Gobi desert and offshore, Asia-Pacific countries have a diverse and significant amount of renewable energy potential that can be converted into commercially viable electricity and energy. One global assessment recently calculated that renewable energy sources can produce incredibly cheap power without subsidies. At the low end of the range, table 9 shows that hydroelectric, geothermal, wind, and biomass can all generate electricity for 12 ¢/kWh or less.[116]

As table 10 summarizes, if technically potential resources were accessed, sited, and built properly, the 18 countries in the sample could more than meet all of their electricity needs *exclusively* with existing, commercially available renewable electricity technologies. In 2009, for example, these countries combined had 318,161 MW of installed capacity but had 1,969,875 MW of technical renewable electricity potential, more than 6.2 *times* the size of their existing grids, though this would require further trading of electricity between countries than currently takes place (as some could not be entirely self-sufficient). Also, technical potential is not the same as economic or achievable potential. Indeed, for these reasons many Asian countries are aggressively promoting renewable energy sources as part of their future capacity additions.

Because installed capacity gives only a crude indication of potential since electricity generators have varying capacity factors and operational lifetimes, the calculation can be repeated focusing on electricity generation. In this case, presuming typical capacity factors for new systems installed in 2010 (resulting in a conservative estimate since those factors will likely continue to improve), these 18 countries generated 1,577,879 GWh in 2010 but had 3,332,592 GWh of renewable electricity potential—enough to meet *twice* their collective demand. Figure 15 shows how this potential is not uniform, with some countries such as Bangladesh having mostly solar energy whereas Bhutan and Nepal possess abundant hydroelectric potential and Mongolia, Sri, Lanka and Viet Nam boast substantial wind potential.

Table 9 Levelized cost of energy for new renewable power plants (2010)

	Technology	Characteristics	Typical Production Costs (US ¢/kWh)
Commercial/utility-scale grid-connected systems	Large hydro	10 MW to 18,000 MW	3-5
	Small hydro	1 to 10 MW	5-12
	Onshore wind	1.5 to 3.5 MW (rotor diameter 60-100 meters)	5-9
	Offshore wind	1.5 to 5 MW (rotor diameter 70-125 meters)	10-20
	Biomass power	1 to 20 MW	5-12
	Geothermal power	1 to 100 MW (binary, single- and double-flash, natural steam)	4-7
	Rooftop solar PV	2 to 5 kWp	17-34
	Utility-scale solar PV	200 kWp to 100 MWp	15-30
	CSP	50-100 MW (trough) 10-20 MW (tower)	14-18
Hot water, heating, and cooling	Biomass heating	1 to 20 MWth	1-6
	Solar hot water/heating	2 to 200 square meters (evacuated tube and flat plate)	1-20
	Geothermal heating	1 to 10 MWth (heat pumps, cooling, direct use, chillers)	0.5-2
Biofuels	Ethanol (sugar)	Sugarcane and sugar beets	30-50 ¢/liter
	Ethanol (corn)	Corn	60-80 ¢/liter
	Biodiesel	Soy, mustard seed, palm, jatropha, and waste oils	40-80 ¢/liter
Small-scale off-grid systems	Minihydro	100 to 1,000 kW	5-12
	Microhydro	1 to 100 kW	7-30
	Picohydro	0.1 to 1 kW	20-40
	Biogas digester	6 to 8 cubic meters	3-14
	Biomass gasifier	20 to 5,000 kW	8-12
	Small wind turbine	3 to 100 kW	15-25
	Household wind turbine	0.1 to 3 kW	15-35
	Village-scale mini-grid	10 to 1,000 kW	25-100
	Solar home system	20 to 100 Wp	40-60

Source: REN21. (2012). *Global Status Report*. Paris: REN21 Secretariat. The "Levelized Cost of Energy," or LCOE, refers to the cost of operating an energy system over its entire lifetime. It therefore includes capital costs as well as operations and maintenance expenses, fuel costs, interest in loans, and depreciation.

Table 10 Renewable energy technical potential for selected Asia-Pacific countries

	Total Installed Capacity (MW)	Technical Renewable Energy Potential (MW)	Annual Total Electricity Generation (GWh)	Annual Renewable Energy Potential (GWh)	Composition/Notes
Bangladesh	6,454	51,511	33,922	84,298	50,174 MW of solar, 1,330 MW rice husk, 37 MW bagasse. At a capacity factor of 17 percent, those solar facilities would generate 74,719 GWh per year; at a capacity factor of 80 percent, the rice husk and bagasse facilities would generate 9,579 GWh.
Bhutan	1,488	10,020	1,620	52,595	10,000 MW small and large hydro, 20 MW a mix of solar energy, wind energy, and biomass. Annual Total Electricity Generation (GWh) includes exports to India and energy from IPPs. At a capacity factor of 60 percent, those hydro facilities would generate 52,560 GWh. At an average capacity factor of 20 percent, the solar, wind, and biomass facilities would generate 35 GWh.
Cambodia	516	34,480	1,018	152,363	6,700 MW of solar, 15,400 MW of biomass, 1,000 MW of biogas, 10,000 MW of hydro, 1,380 MW of wind. At a capacity factor of 60 percent, those hydro facilities would generate 52,560 GWh. At a capacity factor of 17 percent, those solar facilities would generate 9,978 GWh. At a capacity factor of 60 percent, those biomass and biogas plants would generate 86,198 GWh. At a capacity factor of 30 percent, those wind farms would generate 3,627 GWh.
Fiji	205	159.2	800	825	27 MW of biomass, 3.2 MW of solar PV, 80 MW of hydro, 1 MW of small hydro, 38 MW of geothermal, 2.3 million liters of coconut biodiesel which could generate about 10 MW of electricity. At a capacity factor of 60 percent, those hydro facilities would generate 426 GWh. At a capacity factor of 60 percent, those biomass, geothermal, and biodiesel facilities would generate 394 GWh. At a capacity factor of 17 percent, those solar facilities would generate 4.6 GWh.
India	177,000	274,561	899,000	1,315,474	150,000 MW of hydro, 48,561 MW of wind, 15,000 MW of small hydro, 51,000 MW of biomass, and 10,000 MW of geothermal. At a capacity factor of 60 percent, those hydro facilities would generate 867,240 GWh. At a capacity factor of 60 percent, those geothermal and biomass facilities would generate 320,616 GWh. At a capacity factor of 30 percent, those wind farms would generate 127,618 GWh.
Indonesia	32,898	162,360	169,786	400,000	41,436 MW of hydro, 450 MW of small hydro, 27,150 MW of geothermal, 49,810 MW of biomass, 9,280 MW of wind. 400,000 GWh taken from IEA and presumes potential achievable by 2030.
Lao PDR	700	25,000	3,717	131,400	23,000 MW of hydro, 2,000 MW of small hydro. Presuming those hydro facilities operated at a capacity factor of 60 percent, they would generate 131,400 GWh.
Malaysia	27,179	4,000	125,045	130,000	410 MW of Biogas, 1,340 MW of biomass, 390 MW of solid waste, 1,370 MW of solar PV, and 490 MW of hydro. 130,000 GWh taken from IEA and presumes potential achievable by 2030.
Mongolia	944	1,101,000	4,576	2,896,056	1,000 MW hydro, 1,100,000 MW of technical wind potential, presuming 10 percent is achievable amounts to 110,000. Presuming those hydro facilities operated at 60 percent capacity, they would generate 5,256 GWh. Presuming those wind facilities operated at a capacity factor of 30 percent, they would generate 289,080 GWh.
Nepal	710	44,949	3,851	226,460	2,100 MW of solar PV, 716 MW of wind, 42,133 MW of hydro. At a capacity factor of 17 percent, those solar facilities would generate 3,127 GWh. At a capacity factor of 30 percent, those wind farms would generate 1,882 GWh. At a capacity factor of 60 percent, those dams would generate 221,451 GWh.

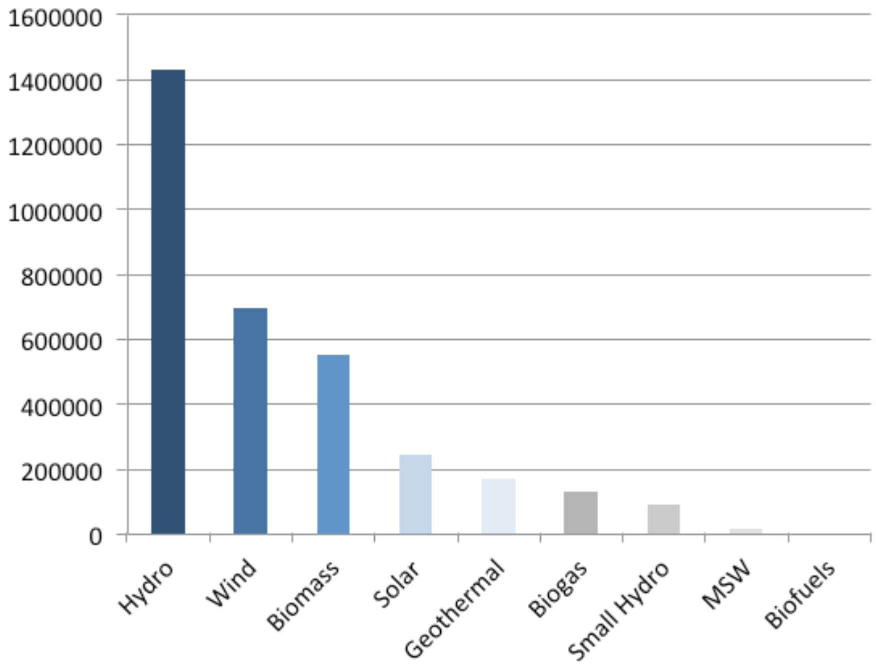
	Total Installed Capacity (MW)	Technical Renewable Energy Potential (MW)	Annual Total Electricity Generation (GWh)	Annual Renewable Energy Potential (GWh)	Composition/Notes
PNG	582	4,995.7	1,870	25,653	150 MW of wind, 4,000 MW of hydro, 5.7 MW of small hydro, 800 MW of geothermal, some biofuels production. Annual Total Electricity Generation figure of 1,870 GWh includes off-grid generation from industrial facilities and mines. Presuming those hydro and geothermal facilities operated at a capacity factor of 60 percent, they would generate 25,259 GWh. Presuming they operated at a capacity factor of 30 percent, those wind farms would generate 394 GWh.
Philippines	16,359	76,720	67,743	125,000	920 MW of biomass, 70,000 MW of wind, 1,300 MW of small hydro, 4,500 MW of geothermal. 125,000 GWh taken from IEA and presumes potential achievable by 2030.
Samoa	42	45	111	210	7 MW of solar PV, 30 MW of hydro, 4 MW of geothermal, 9 million liters of biodiesel which could fuel about 4 MW of electrical capacity, some biomass and biogas. At a capacity factor of 17 percent, those solar facilities would generate 10.4 GWh. At a capacity factor of 60 percent, those hydro, geothermal, and biodiesel facilities would generate 200 GWh.
Solomon Islands	37	336	84	1,766	326 MW of hydro, 10 MW of geothermal. Presuming these facilities operated at a capacity factor of 60 percent, they would generate 1,766 GWh.
Sri Lanka	3,088	28,460	10,718	85,910	160 MW solar, 300 MW small hydro, 4,000 MW biomass, 24,000 MW wind. Presuming those solar facilities operated at a capacity factor of 17 percent, they would generate 238 GWh. Presuming the hydro and biomass facilities operated at a 60 percent capacity factor, they would generate 22,600 GWh. At a capacity factor of 30 percent, those wind farms would generate 63,072 GWh.
Thailand	31,447	12,672	158,963	150,000	2,000 MW of biomass, 160 MW of municipal solid waste, 120 MW of biogas, 5,000 MW of solar PV, 800 MW of wind, 4,542 MW of hydro, 50 MW of small hydro, some biofuels. 150,000 GWh figure taken from the IEA and presumes potential achievable by 2030.
Vanuatu	31	18	55	91	1 MW of solar, 7 MW of small hydro, 10 MW of geothermal, some sawmill waste, biomass gasification, and biofuels. At a capacity factor of 17 percent, those solar facilities would generate 1.5 GWh. At a capacity factor of 60 percent, the hydro and geothermal facilities would generate 89 GWh.
Viet Nam	18,481	139,187	95,000	205,000	3,800 MW of hydro, 2,887 MW of small hydro, 10,000 MW of pumped hydro, 400 MW of geothermal, 1,600 MW of biomass, 120,500 MW of wind. 205,000 GWh taken from IEA and presumes potential achievable by 2030.

Renewable Energy Potential Compared to Total Installed Capacity (MW) and Annual Total Electricity Generation (GWh) in Selected Asia-Pacific Countries, 2009.

Source: Country Rapid Assessment and Gap Analyses and the IEA. Note that, most of the time, if an estimate was not provided in the Country Rapid Assessment and Gap Analysis, it was not included in this table. "Technical" potential refers only to what is theoretically possible, not what is economic or achievable. It also assumes that such countries can "evacuate" such energy through transmission and distribution networks, have markets for it, and can sell it.

When aggregated, figure 15 illustrates that by far the largest renewable energy resource for the 18 countries in this report is hydroelectricity, followed by wind energy and biomass. Taken together, these three resources represent more than *80 percent* of the region's resource base—2,682,840 GWh out of 3,332,592 GWh of technical potential.

Figure 15 Renewable energy potential: Selected Asia-Pacific countries (Gwh)



Source: Country Rapid Assessment and Gap Analyses, and Country Energy Reviews, 2012.

To give readers a more precise sense of where this potential lies, table 11 previews the renewable energy resource potential for each of the 18 countries, with:

- Solar energy featuring prominently in Bangladesh, Malaysia, Mongolia, and Thailand;
- Wind energy in Mongolia, the Philippines, Sri Lanka, and Viet Nam;
- Geothermal energy in Fiji, PNG, the Philippines, and the Solomon Islands;
- Small hydro in India (given its low cost), Samoa, and the Solomon Islands;
- Large hydro in Bhutan, Cambodia, Fiji, India, Indonesia, Lao PDR, Nepal, and PNG; and
- Biomass featuring in Bangladesh, Cambodia, India, Indonesia, Malaysia, and Sri Lanka.

The countries reviewed did not favor commercial-scale, grid-connected energy generation from biomass prominently enough to be discussed further in this section, though some of these technologies are assessed in the section above on Household Thermal Needs.

Table 11 Renewable energy potential: Selected Asia-Pacific countries

	Solar	Wind	Geothermal	Small Hydro	Large Hydro	Biogas	Biomass	Municipal Solid waste	Biofuels for electricity generation
Bangladesh	1	3					2		
Bhutan	3	3		2	1		3		
Cambodia	3	5			1	4	2		
Fiji	5		2	6	1		3		4
India		3	5	4	1		2		
Indonesia		4	3	5	1		2		
Lao PDR				2	1				
Malaysia	1			3		4	2	5	
Mongolia	3	1		2	2				
Nepal	2	3			1				
PNG		3	2	4	1				5
Philippines		1	2	3			4		
Samoa	2		3	1		4	4		3
Solomon Islands			2	1					3
Sri Lanka	4	1		3			2		
Thailand	1	4		7	2	6	3	5	8
Vanuatu									
Viet Nam		1	5	3	2		4		

Source: Country Rapid Assessment and Gap Analyses, and Country Energy Reviews, 2012.
Notes: Large hydro includes pumped hydro. Biomass includes rice husks, bagasse, residues, palm oil mill effluent, empty fruit bunches, and cassava. Biofuels includes coconut biodiesel, jatropha, and sugarcane ethanol. Numbers indicate ranking in terms of priority, with 1 indicating the most favored option.

8.1 Solar

Solar energy was the largest renewable energy resource for Bangladesh, Malaysia, and Thailand. One recent study conducted jointly by the Center for Development Research in Germany and the Islamic University of Technology noted that the technical potential for grid-connected solar PV systems was so large throughout 14 widespread locations that Bangladesh could install 50,174 MW of it, though such a large amount of solar capacity would need to be integrated into the grid and/or coupled with energy storage. Not only do such centralized solar PV facilities have the potential to expand existing electricity capacity by roughly a factor of ten, they can also do a number of things off-grid systems cannot do. The larger-scale grid-connected solar facilities, the study notes, can reduce energy and capacity losses throughout the entire distribution network, and avoid the need for costly transmission and distribution upgrades.[117]

In Malaysia, the IEA calculates that solar is the most abundant renewable energy resource, given the country's close proximity to the equator and support from a newly implemented National Renewable Energy Policy and Action Plan, which includes an attractive feed-in tariff for up to 150 MW of near-term solar PV deployment.

Thailand, too, has abundant average solar radiation ranging from 5.0 to 5.3 kWh/m^2/day, and the northern and northeastern regions receive 2,200 to 2,900 hours of sunshine per year.[118] Thus, 50,000 MWh of solar potential exist in the country, and many commercial enterprises are seeking to invest in harnessing it. About 60 MW have so far been installed, though 90 other solar farms were announced with financing and purchasing agreements in place for an additional capacity of 250 MW[119] and 341 plants with 326 MW of capacity in the construction and planning period.[120] The World Bank has projected that as much as 5,000 MW of capacity could be theoretically developed over the next decade.[121]

8.2 Wind

Mongolia, the Philippines, Sri Lanka, and Viet Nam had the largest resource potential for wind energy. Mongolia's potential is substantial, with wind resources occupying almost 10 percent of the country's total land area with power density of 400-600 W/m^2. These resources could potentially supply over 1,100 GW of installed capacity. All of its provinces, called *aimags*, have at least 6,000 MW of wind potential, three *aimags* have at least 20,000 MW, and nine *aimags* more than 50,000 MW of wind power potential. As table 12 shows, these resources are so large they could potentially power all of *Asia* and generate 2,550 TWh per year. Yet hardly any of this potential has been harnessed, with the country's first 50 MW wind farm installed in Salkhit valley of Tuv aimag in 2011.

Table 12 Wind energy potential in Mongolia

Category	Wind at 30 m height		Total area coverage		Total capacity MW	Energy to be produced GWh/year
	Power W/sq.m	speed m/s	Sq.km	%		
3	300-400	6.4-7.1	130,665.	81.3	905,500	1,975,500
4	400-600	7.1-8.1	27,165	16.9	188,300	511,000
5	600-800	8.1-8.9	2,669	1.7	18,500	60,200
6	800-1000	8.9-9.6	142	0.1	1,000	3,400
Total			160,641	100.0	1,113.300	2,550,100

Source: RA/GA for Mongolia, 2012.

The Philippines, moreover, has the most developed wind energy capacity in Southeast Asia with 33 MW installed as of 2009 (though this number is far below the installed capacity of China or India). Wind mapping surveys reveal that the country could generate as much as 70,000 MW from economically exploitable wind resources located in 47 provinces, with the most significant resources in the north and northeast of the country.[122] Surveys in Sri Lanka have also revealed 24,000 MW of wind energy potential there. And with a coastline of 3,000 km, and average wind speeds of 5.6 m/s in coastal regions, and up to 8 m/s on certain islands, the potential for wind power generation is high in Viet Nam, with an achievable capacity of 120.5 GW.

8.3 Geothermal

Geothermal energy is most viable in Fiji, PNG, the Philippines, and the Solomon Islands (it also has significant potential totaling 27,150 MW in Indonesia, though this comes third after the potential for hydro and biomass). Given the volcanic nature of Fijian islands, their Department of Energy estimates that at least 14 "feasible" sites exist with at least 38 MW of potential: 15 MW from Viti Levu and 23 MW from Vanua Levu, with a preliminary plan to develop 3.5 MW at Savusavu as a pilot project, though as of 2012 nothing has been developed.[123]

PNG, too, has immense geothermal potential at 21.9 TWh or 800 MW, meaning the country could meet all of its energy needs through geothermal plants, although as of 2010 only 56 MW had been installed in the country.[124] With a total installed capacity of 1,966 MW, geothermal provides 12 percent of electricity in the Philippines, making it the second largest producer of geothermal electricity in the world after the United States. This capacity already saves the country more than $600 million per year in avoided fossil fuel imports. To realize the estimated 4,500 MW that could be economically and technically harnessed "immediately", the government is currently committed to developing as much as 100 MW and it has drilled 36 exploratory wells with at least 11 earmarked for private sector financing. In the Solomon Islands, roughly 10 MW of geothermal potential has been calculated in the areas of Nggurara and Paraso Bay, and in March 2012, the Government issued a prospecting license to explore the geothermal resources on the island of Savo, offshore from Honiara. Surveys in October 2012 may lead to construction of a facility that can supply power into the main grid via submarine cables by 2016.[125]

8.4 Small hydro

Small hydroelectricity is the resource with the most potential for India, Samoa, and the Solomon Islands. India has 15,000 MW of small hydro potential with the largest number of sites in Arunachal Pradesh with total capacity of 1,333.04 MW but the richest state (in terms of potential) is Himachal Pradesh with 547 sites of total capacity of 2,268.41MW.[126] The World Bank has calculated that small hydropower in India is "one of the least expensive and most attractive forms of renewable energy" but also one that "lies largely untapped".[127]

Samoa, furthermore, has substantial small hydroelectric potential, with the Vailoa, Lata, Vaita'i and Sili Rivers on Savai'i with the best potential for microhydro and small hydro dams and the rivers of Namo, Lotofaga, Tafitoala and Faleseela having the best potential on the island of Upolu. A 3 MW Savai'i Hydroelectric Plant is currently being constructed and expected to come online at the end of 2012 or in early 2013.[128] The Electric Power Corporation in Samoa also identified six sites for hydroelectric expansion and is currently carrying out feasibility assessments for another 20 MW.[129]

The Solomon Islands has significant potential too, and the government has developed a database with more than 100 optimal sites for small hydro development, 62 of which have a capacity of more than 11 MW. One Japanese study projected that the total hydroelectric potential for the Solomon Islands exceeded 326 MW, more than ten times the capacity of its current grid, with most of this capacity (three quarters) located on Guadalcanal.[130] One 15 MW hydropower project on the Tina River near Honiara is currently underway, with a feasibility study completed in 2010 by Hydro Tasmania and estimated annual electricity production of 60 GWh. Requests for proposals and bidding has been delayed. The existing projection is to build the project by 2016, however, this is highly unlikely due to ongoing issues with land ownership.[131]

8.5 Large hydro

Large hydro is the renewable energy resource with the most potential across the sample of 18 countries, having high technical potential in Bhutan, Cambodia, Fiji, India, Indonesia, Lao PDR, Nepal, and PNG. Bhutan already meets it electricity needs primarily from hydropower plants, and it plans to add an additional 10,000 MW of hydropower capacity by 2020, which will primarily be for exports but will also help Bhutan meet domestic demand.

The technical potential of hydropower resources in Cambodia is estimated at 10,000 MW, with around 50 percent of these resources located in the Mekong River Basin, 40 percent on tributaries of the Mekong River, and the remaining 10 percent in the south-western coastal areas.[132]

Hydroelectricity is a backbone of the Fiji electricity sector, providing 48 percent of power in 2010. In September 2008 the Sinohydro Corporation Limited of China was commissioned to construct the $150 million 41.7 MW Nadarivatu Renewable Hydro Power Project, expected to generate 101 million kWh per year, save $25 million (F$44 million) in annual fuel costs, and reduce carbon emissions by 66,000 tons per year. That facility started operating in September 2012.[133]

India has about 37,000 MW of installed hydroelectric capacity but a total potential of 84,000 MW at a 60 percent load factor (or 150,000 MW at lower load factors).[134] The IEA expects India to add 13,000 MW of new hydroelectric capacity from 2012 to 2017.[135]

Indonesia has abundant hydropower resources and the Ministry of Energy and Mineral Resources estimated its hydropower potential at about 41,436 MW with small (mini and micro) hydro potential accounting for a tiny share, about 450 MW.

In Lao PDR, hydropower is the predominant renewable energy source. Almost all on-grid electricity generated within Lao PDR comes from hydropower: 97 percent of the current 700 MW capacity are hydropower plants (though much of this amount is exported to Thailand). However, the currently exploited hydropower resource represents a tiny fraction of the potential, which is estimated at 26,500 MW with about 23,000 MW technically exploitable.

Various projections suggest that due to its mountainous terrain Nepal has 83,000 MW of exploitable hydropower resources, and almost 43,000 MW of "economic potential" shown in table 13 which could generate 180,000 GWh/yr, emanating from thousands of its fast flowing rivers and streams that total a length of more than 45,000 kilometers. Yet so far the country has tapped less than 750 MW of this potential, and hydroelectricity meets less than 1 percent of total national energy consumption.[136]

Table 13 Nepal hydropower potential (in MW)

River basin	Potential in MW				
	Total theoretical potential	Number of project sites	Technical potential	Number of project sites	Economic potential
Sapta Koshi	22,350	53	11,400	40	10,860
Sapta Gandaki	20,650	18	6,660	12	5,270
Karnali and Mahakali	36,180	34	26,570	9	25,125
Southern River	4110	9	980	5	878
Total	83,290	114	45,610	66	42,133

Source: Surendra, K.C. et al. (2011). Current Status of Renewable Energy in Nepal: Opportunities and Challenges. *Renewable and Sustainable Energy Reviews* 15, pp. 4107-4117.

PNG has considerable hydroelectric potential, since its land area encompasses nine large drainage divisions for river basins. The total theoretical hydropower potential for PNG is therefore about 175 TWh per year[137] and 4,000 MW of "economically exploitable" potential.[138] Existing hydroelectric capacity, much like other countries in Asia, is a mere fraction of this potential, with 162 MW installed. Interestingly, in late 2010 Australia and PNG agreed to build a 1,800 MW hydropower plant in PNG that would export 1,200 MW of electricity to Queensland through an undersea cable. Origin Energy, Australia's second largest producer, is submitting a feasibility study to be completed by the end of 2012.[139]

Large hydroelectric dams are an important renewable energy resource for countries in the Asia Pacific, even though they can seriously degrade the environment and present grave social impacts when communities must be forcibly relocated. As a disadvantage, the act of building large hydroelectric dams with reservoirs degrades water quality in at least two ways: during construction when impoundment must occur, contributing to the diversion of water, flooding, and erosion; and during operation, when the dam acts as a physical barrier within rivers. An additional problem is that tropical environments are prone to the proliferation of algae near the surfaces of nutrient-rich reservoirs, dramatically depleting the oxygen level of the water in concert with the decomposition of vegetation and soils—hurting fish—and emitting significant amounts of greenhouse gases. Socially, every year about 4 million people are displaced by activities relating to hydroelectricity construction or operation, and 80 million have been displaced in the past 50 years from the construction of 300 large dams.[140]

However, large dams also have important advantages. As the 22,500 MW Three Gorges Dam in China can attest to, such facilities can provide incredibly large amounts of energy. Over the course of their lifecycle, they have fewer greenhouse gas emissions than both fossil-fueled facilities and nuclear power plants. Unlike wind and solar, which are intermittent during the day, they can provide baseload electricity twenty-four hours a day. They also represent a key sector of renewable energy investment: 31 GW of hydroelectric capacity was added in 2009, an increase in capacity second only to wind power among all sources of renewable energy. Total installed capacity and investments in hydropower also dwarf that of all other major renewable sources of energy. China roughly doubled its hydroelectric capacity from 2004 to 2009 and significant expansion is expected in Brazil, India, Russia, Turkey, and Viet Nam.[141] And once built, they tend to produce electricity very cheaply over long periods of time, and they have very positive energy returns on investment (meaning society gets much more energy out of them compared to what gets put into them).[142]

The implication is that large dams are an essential part of SE4ALL, but to ensure they are sustainable they must be properly managed. How hydroelectric facilities, how communities are consulted, and the strength (or weakness) of environmental and social impact assessments will determine the degree to which large dams can produce net social and economic benefits or costs.

8.6 Biomass

Biomass is a resource with the most potential for Bangladesh, Cambodia, India, Indonesia, Malaysia, and Sri Lanka. In Bangladesh, 9 million tons of rice husks are produced annually from the country's 100,000 rice mills that could be utilized to generate 300 MW of electricity today and up to 1,330 MW by 2030. Nearly 800,000 tons of sugar bagasse is also produced from 14 sugar mills, enough to generate 37 MW of electricity.

Cambodia possesses a mosaic of biomass energy resources in the form of plantation forests as well as rubber plantations and agricultural residues that come from processing corn, rice, and palm oil. One study conducted by Japan's Institute for Global Environmental Strategies and the Cambodian Research Centre for Development estimated an energy generation potential of 15,400 MW or 19,000 GWh per year, more than 30 times Electricité du Cambodge's installed generation capacity—and that amount excluded biomass from natural forests and some agricultural residues.[143]

Because India has an agrarian economy, biomass generation costs are very low, similar to those from wind energy. India has almost 700 million tons of biomass agricultural residues of which one-fifth can be used for electricity. The Ministry of New and Renewable Energy projects that 17,000 MW of power could be generated from agricultural residues and another 34,000 MW of power can be derived from wood and energy plantations on wastelands.[144]

Furthermore, Indonesia and Malaysia possess very large biomass sources arising from their palm oil industries and agricultural sectors, and Sri Lanka has at least 4,000 MW of “dendro” energy mostly available from farming residues and tea plantations.

9 BARRIERS AND IMPEDIMENTS

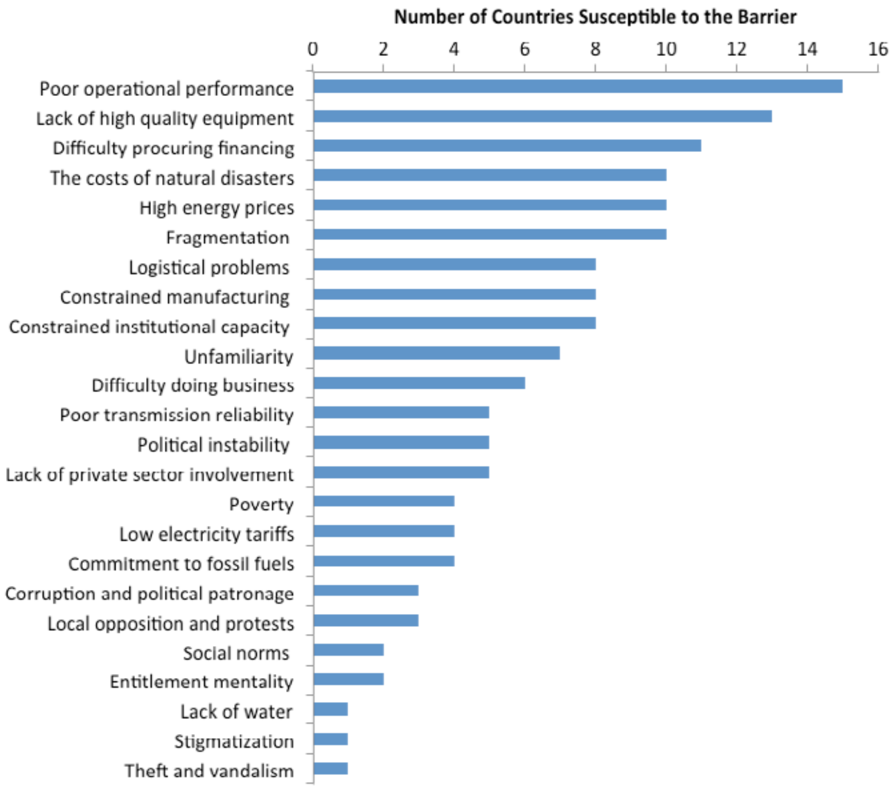
Despite the many and multifaceted social and economic benefits of expanding energy access, at least 24 separate types of barriers impede progress. As table 14 illustrates, and as socio-technical systems theory predicts (see Appendix I for more on that concept), these barriers fall roughly into technical, economic and financial, political and institutional, and social and cultural categories. Technical barriers include things like lack of equipment, expertise or maintenance whereas economic and financial barriers relate to high energy prices, poverty, and lack of financing. Political and institutional barriers include constrained capacity to plan and implement projects as well as corruption and instability. Social and cultural barriers encompass things such as community opposition and lack of awareness. As figures 16 and 17 also imply, every country in the sample confronts a multitude of these barriers.

Table 14 Types of barriers and impediments to SE4ALL

Dimension	Barrier
Technical	Lack of high quality equipment, expertise, and/or standards and certifications
	Poor operational performance, difficulty in providing maintenance, and/or low load factors
	Logistical problems including installation or project delays
	Constrained manufacturing capacity and dependence on imported materials and manufacturing constraints
	Poor transmission reliability/high technical losses/limited transmission capacity
	Lack of water
Economic and financial	The costs of natural disasters
	Distorted energy prices and/or subsidies for fossil fuels
	Difficulty doing business
	Poverty, lack of available capital, and/or inability to reach the extreme poor
	Low electricity tariffs/inability to recover costs/unfavorable power purchase agreements
	Difficulty procuring financing and/or lack of knowledge among financial institutions
Political and institutional	Political instability
	Constrained institutional capacity and/or high staff turnover
	Fragmentation and poor coordination in energy policymaking
	Corruption and political patronage
	Commitment to fossil fuels
	Limited private sector involvement
Social and cultural	Stigmatization
	Local opposition and protests
	Unfamiliarity, lack of knowledge and information and/or unrealistic expectations
	Theft and vandalism
	Social norms and consumer preferences
	Entitlement mentality to energy services

Source: Country Rapid Assessment and Gap Analyses, and Country Energy Reviews (2012), categorized according to the social-science systems approach summarized in Appendix I.

Figure 16 Twenty-four barriers to achieving SE4ALL in selected Asia-Pacific countries



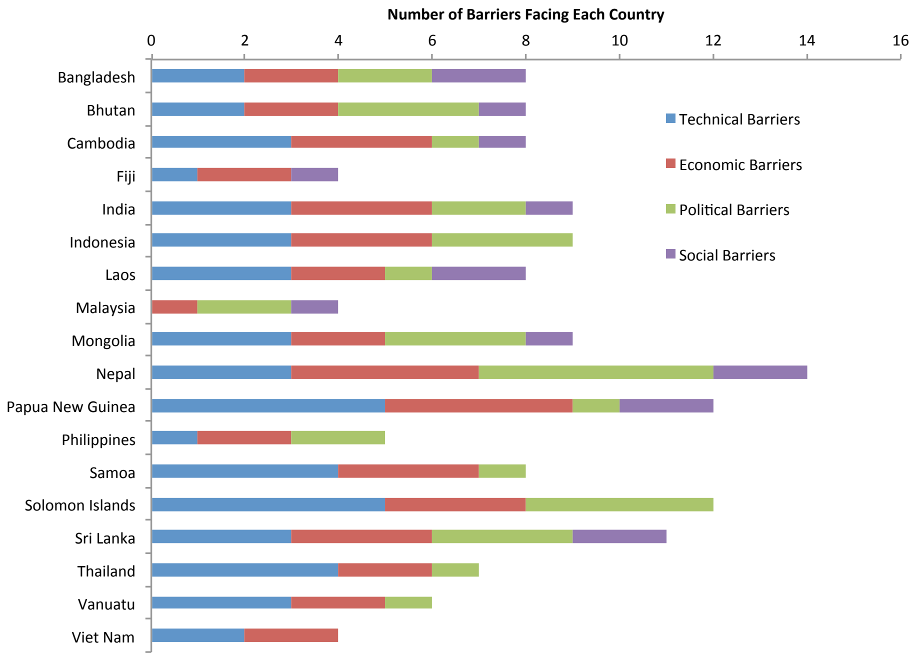
Source: Country Rapid Assessment and Gap Analyses, and Country Energy Reviews (2012), categorized according to the social-science systems approach summarized in Appendix I.

Though the section above separates these barriers into 24 distinct categories, in many cases they (a) can be particular to a technology, place or region and (b) often overlap and intersect. For instance, geothermal power development in Indonesia faces impediments cutting across technical, economic, political, and social dimensions. These barriers include:

- momentous investment needs that are estimated to be as much as $10-12 billion to achieve the government's renewable energy "fast track" programme;
- insufficient policy and regulatory support for implementation of the Geothermal Law;
- inadequate incentives and pricing mechanisms that fail to both reflect the environmental benefits of the technology and enable investors to secure a return commensurate with the higher risks they face especially when developing unexplored (green) geothermal fields;
- limited institutional capability to properly plan geothermal development and sufficiently engage suitable developers; and
- weak domestic capacity in the areas of resource assessment, equipment manufacturing, construction, and operation and maintenance of geothermal energy facilities.

In PNG, there is a similar, multidimensional and complicated matrix of barriers facing SHS. The country's rugged terrain and frequent storms and disasters make transporting and distributing SHSs difficult. End-users are not well trained in simple maintenance, leading many SHSs to break down prematurely. Economic obstacles include poverty and lack of capital among end users, who have enough trouble meeting subsistence needs and little money left aside to purchase a SHS. Limited financing and financial illiteracy make it even harder for rural households to commit to owning their own SHS. Political obstacles include poor institutional capacity within the government, the national electricity provider, and even development partners to effectively distribute SHSs, as well as a system of patronage where "big men" provide electricity or energy services to their constituents or clan members for free. National governments are often committed to increasing income from extractive industries and fossil fuels, which can be at odds with policies supporting SHSs. SHS technologies have also been prone to

Figure 17 Summary of barriers to achieving SE4ALL targets in selected Asia-Pacific countries



Source: Country Rapid Assessment and Gap Analyses, and Country Energy Reviews (2012), categorized according to the social-science systems approach summarized in Appendix I.

unusually high rates of vandalism and theft. Under a *wantok* system rooted in tribal traditions, clans there share resources. Solar panels, which benefit a particular house or individual instead of the community, assault this system of *wantok*. Tribal communities have therefore smashed hundreds of solar panels or, worse, threatened their owners.[145]

This section discusses these types of barriers in greater detail, though it does not provide examples from every country, in order to keep its length manageable. Instead, it offers a few illustrative examples for each barrier category, and it attempts to keep the barriers classified into distinct, though interrelated categories.

9.1 Technical

9.1.1 Lack of equipment or expertise

Perhaps the simplest technical barrier, one afflicting many countries across the sample, is lack of equipment, expertise, or resources. In Lao PDR, business owners and operators report a lack of appropriate electrical equipment for productive use activities as an obstacle to expanding access to energy. Given that well-qualified electricians tend to concentrate in larger towns and cities, rural business owners and operators report a lack of qualified electricians in their local areas as an obstacle to using electricity for productive uses.

One major technical barrier to fully harnessing Nepal's hydroelectric potential is the country's hydrology. The rugged and mountain alpine terrain endows Nepal with plentiful moving water, but the South-West monsoon delivering it is inconsistent. About 80 percent of the country's rain occurs from June to September, the remaining 20 percent falls as snow during the dry season. This mismatch between when water is available and when it is needed year-round to generate hydroelectricity creates a complicated engineering challenge, leading severe load shedding particularly in winter, of up to 18 hours at times.

A recent independent evaluation of Thailand's renewable energy sector noted that "the absence of skilled manpower and spare parts" is a "prime" barrier, with capacity lacking particularly in wind energy and municipal solid waste combustion.[146] Shortages of raw materials such as steel and concrete have become another prominent barrier for renewable energy expansion, and biomass powered facilities have reported difficulties procuring feedstocks, with most biomass resources produced during harvesting periods from December to April, leaving a gap for the rest of the year.[147] Similarly, Thailand has significant hydroelectric potential but some locations have no water during the dry season, making hydro units completely inoperable, at least in certain provinces.[148]

In Vanuatu, a small but highly mobile population speaking many languages dispersed over many islands makes it difficult to build up and retain skills. Though a biomass gasification electrification scheme has some potential, two salient technical challenges exist. One is the lack of rural technical expertise to maintain gasifier hardware in a sustainable manner. Another is the lack of professionals able to choose systems, negotiate with suppliers, arrange training, and develop mechanisms for maintenance and financial management. A third is the difficulty of sustaining cooperative or community-based energy projects in Vanuatu. To improve local technical expertise, rural educational or vocational centers would need to integrate principles of bioenergy systems into their curricula, and household surveys would need to be conducted to ensure that the communities surrounding these projects would approve of their use of forest resources.[149]

9.1.2 Poor maintenance and performance

In India, repair and maintenance services tend to be unreliable, with relatively simple and minor things such as fixing transformers or even fuses taking weeks to months.[150] In Nepal, a prevalence of water with high rates of silt and lack of sufficient crews to conduct maintenance explain why the average capacity factor—the amount of time a dam is actually producing electricity—hovers around 59 percent.[151] As one study of Nepal concluded, "at the local level, rural communities lack minimal level of technical knowledge to operate and maintain established renewable technologies."[152] In PNG, a majority of their hydropower facilities are in excess of 35 years old and in states of disrepair, given infrequent maintenance (due in part to lack of parts, and in part to lack of expertise).[153] In Thailand, one academic investigation noted that "despite extensive experience" with renewable energy throughout the country, more than 60 percent of solar battery charging stations and 45 percent of solar water pumping systems have failed due to maintenance issues resulting from a lack of training, and to designs not suitable for the specific needs of Thai communities.[154] In Viet Nam, supply chains for renewable energy equipment are "weakly developed" leading to a lack of "operation and maintenance".[155]

9.1.3 Logistical challenges and project delays

In Nepal, another barrier is logistical problems connected to building facilities in remote locations, and having adequate maintenance support. For a hydroelectric facility to work well, geographic and water conditions must be optimal, but many of these sites are remote, at high altitude, and freeze over in the winter. Difficulty procuring technology and hiring experienced staff to install remote systems serve as obstacles.[156] And in Vanuatu, the ADB notes that infrastructure outside of main urban areas in Vanuatu is "of poor quality" or nonexistent, that airstrips and ports facilities in the outer islands are in poor repair, that roads often do not exist, and that cargo supply arrangements are intermittent.[157] These can create logistical hurdles to disseminating renewable energy equipment.

9.1.4 Dependence on imported technology

This impediment is also experienced in eight countries. As examples, in Bangladesh, one assessment documented lack of national quality standards for solar equipment, the limited nature of local manufacturing and assembly of SHS units, and the limited capacity to design, operate, and install solar systems as significant "technical barriers".[158] The World Bank has cautioned that Thailand still lacks a "landmark investment" in solar energy because the industry must rely on expensive foreign technology and does not have the capacity to develop it indigenously. As it concluded, "major barriers to development are the lack of technology, trouble connecting to the supply grid, expertise, and the availability of capital and private sector participation."[159]

9.1.5 Lack of adequate or reliable transmission and distribution

This barrier, though it affects at least five countries, comes in many different forms. One is high rates of losses and grid inefficiency. For instance, the Solomon Islands has some of the least efficient transmission and distribution grids in the entire Pacific, with 20 percent of their electricity sales "lost" in the network in 2009. Oddly, these losses are getting worse, rather than better, over time. In 2010, the Solomon Islands Electricity Authority (SIEA) reported losses of 29 percent, amounting to a loss of revenue of $4.8 to $6.4 million for the SIEA every year, representing about 30 percent of the SIEA's generation assets for that year.[160] This problem is only compounded by a poor bill collection efficiency that currently hovers around 70 percent, meaning the SIEA does not receive revenue from almost one-third of their customers.[161]

Another variant of this barrier is transmission networks that must shed load. The Cambodian grid is known for being unreliable for large industrial users and commercial enterprises such as hospitals and hotels, due to sudden power outages and fluctuations in voltage, convincing many establishments to invest in expensive backup generators and equipment.[162] In Nepal, the annual peak power demand of the Integrated Nepal Power System in fiscal 2011 was estimated to be 1,027 MW yet 448 MW of equivalent demand had to be shed. Experts in Nepal have called this load shedding detrimental with "the complete shutting down and relocation of industries, inability to attract new companies to Nepal, a deteriorating service and welfare sector including health and education, in short, the complete paralysis of the Nepali economy."[163]

A third variant is limited transmission infrastructure for "evacuating" renewable resources of electricity located too remotely or distantly from existing transmission lines. As the World Bank has noted, in India "much economically attractive wind and small hydropower potential remains untapped because of lack of adequate grid evacuation capacity and approach roads."[164] Similarly, in PNG, "the technical potential for renewable energy sources is enormous, but many of these resources are in remote locations with limited demand, and are not readily exploitable."[165] And in Sri Lanka, "inadequate absorptive capacity of the Sri Lankan power system (national grid) to accommodate renewable sources is considered as a major barrier."[166]

A final type of transmission challenge relates to high "aggregated transmission and commercial losses," a term that describes "lost" power due either to inefficiency or theft from illegal tapping of transmission lines. Nationwide in India, in 2011 these losses were greater than 31 percent, much higher than China (5 percent), Japan (5 percent), and the Republic of Korea (4 percent), and they created a significant burden on electric utilities, as functionally one-third of their electricity produces no revenue.[167]

9.1.6 Lack of water

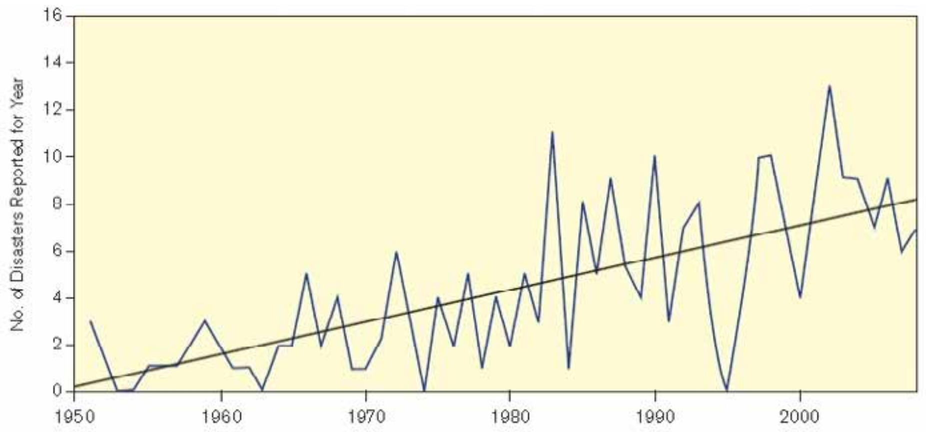
A final technical challenge relates to the lack of water. In 2012, for example, the Raichur Thermal Power Station in India had to shut down four of its eight coal fired units due to lack of water in the Krishna River. The loss of more than 800 MW of capacity left Karnataka State with erratic power supply. The plight of Karnataka State may reveal broad problems facing India's thermal plants. According to a 2012 report by HSBC Bank, most of India will be water stressed by 2050 and the World Resources Institute reports that the country's quantity and quality of fresh water is in decline due to climate change.[168] This issue of water conceivably exists or will exist in all countries that rely significantly on thermoelectric power plants, those dependent on fossil fuels or fission.

9.2 Economic and financial

9.2.1 Natural disasters and climate change

One significant economic challenge facing the energy sector of the 18 countries relates to the cost of natural disasters. This impediment is especially acute for Small Island Developing States (SIDS) in the Pacific Ocean, such as Fiji, Samoa, Solomon Islands, and Vanuatu, and it concerns unpredictable weather and the risk of future natural disasters accelerated by climate change. These countries are especially vulnerable to cyclones and storm-induced floods that can damage energy infrastructure and lower national incomes. Figure 18 shows that since the 1950s, the quantity and magnitude of natural disasters throughout the Pacific has increased significantly. Table 14 also shows how most Pacific islands have seen severe damage inflicted by such disasters.[169] These hurt the technical capacity of SIDS to expand energy access and implement energy programmes in myriad ways, from direct flooding and damage to power plants and transmission lines, to the disruption of the delivery of imported energy fuels, to the destruction of crops for biofuels, and to lowering the income base and adding to government debt.

Figure 18 Number of natural disasters Pacific Islands region (1950-2008)



Source: World Bank: Preparedness, Planning and Prevention (2009).

Consider the following examples. Fiji depends on hydroelectricity for almost half of its grid-connected power, yet hydro's share of electricity has fallen considerably from the 1980s (when it was above 90 percent) to today. This fall is not only due to increased thermal capacity coming online, but decreased reliability at hydro sites due to unexpected shortfalls in water, which saw a 15 percent increase in diesel fuel consumption from 2010 to 2011 alone.

The past five years have seen Samoa survive repeated economic shocks related to a global financial crisis, food and fuel crises, and the September 2009 tsunami. In 2008 and 2009, the economy shrunk by 5.1 percent and contracted a further 0.2 percent from 2009 to 2010. The tsunami was the worst natural disaster to strike Samoa since it declared independence in 1962.[170] It damaged the Electric Power Corporation's (EPC) generation and distribution assets in the southern and eastern coastal areas of Upolu, Manono, and Savii. Damages included toppled power poles and fittings, cracked transformers, and destroyed meters. The tsunami also damaged the headrace of the Fale ole Fee Hydroelectric Power Station, and caused a landslide which blocked the intake canal of the Alaoa Hydroelectric Station.[171] With assets of only $163 million and a net operating profit of $2.1 million per year, the EPC has little revenue to draw from to address these types of damages. Indeed, the Ministry of Natural Resources, Environment, and Meteorology has projected that sea level rises from climate change will threaten 70 percent of the country's population and infrastructure, which are situated in low-lying coastal areas. It also noted that "infrastructure assets" such as power plants "will be the most vulnerable given the cost incurred for construction and maintenance."[172]

In the Solomon Islands, the Ministry of Environment, Conservation and Meteorology has cautioned that "energy production, utilization, conversion and transportation" have and will continue to be negatively affected by "droughts, floods, fires, storm surges, and cyclones." Forecasted droughts are expected to reduce potential hydroelectricity capacity and also decrease the productivity of biofuel crops and coconut plantations. Flooding and cyclones are anticipated to affect both potential hydropower and the potential generation of solar PV and wind power, which could be susceptible to flooding induced landslides and direct damage from high wind speeds. Forest fires could ravage fuelwood and energy crops and storm surges can flood low-lying areas and delay the delivery of renewable energy equipment.[173] As a result, one article recently mused that "it is hard to imagine a country anywhere in the world that is more challenging in terms of infrastructure provision than the Solomon Islands."[174]

Unfortunately, it is not just SIDS that are at risk. In Bangladesh, floods, landslides, and tsunamis are among only a few of the recent events that have directly destroyed renewable energy equipment as well as cultivated and arable land thereby reducing the capital villagers have available to make the down payment for systems. Cyclone Sidr in 2007 destroyed hundreds of SHSs installed on the coast in a matter of hours and flooded thousands of hectares of arable land.

Climate change is threatening to make variability at hydroelectric sites worse, not better, throughout Bhutan and Nepal with one hydrological trend analysis of seasonal flows and extreme events showing that monsoon seasonal floods are decreasing, suggesting that the hydrograph is changing, ultimately minimizing the amount

Table 15 Economic and social impact of disasters

Country	No. of Disasters	Losses (US$ 2008)	Average Population Affected percent Disaster Years	All Years	Average Impact on GDP percent Disaster Years	All Years
American Samoa	6	237,214,770	5.81	0.61	7.76	0.82
Cook Islands	9	47,169,811	5.13	0.63	3.48	0.43
Fiji	43	1,276,747,934	5.39	2.74	3.48	0.78
French Polynesia	6	78,723,404	0.53	0.04	0.31	0.02
Federated States of Micronesia	8	11,915,993	6.20	0.65	0.82	0.09
Guam	10	3,294,869,936	1.97	0.28	10.13	1.42
Kiribati	4	0	29.19	1.54	0.00	0.00
Marshall Islands	3	0	6.40	0.22	0.00	0.00
New Caledonia	15	69,623,803	0.14	0.03	0.09	0.02
Niue	6	56,461,688	73.15	7.70	80.88	8.51
PNG	58	271,050,690	0.69	0.36	0.14	0.07
Samoa	11	930,837,187	21.15	3.71	16.97	2.98
Solomon Islands	21	39,215,686	2.93	0.98	0.52	0.17
Tokelau	4	4,877,822	39.70	2.79		
Tonga	12	129,344,561	21.32	3.37	5.76	0.91
Tuvalu	5	0	3.19	0.28	0.00	0.00
Vanuatu	36	406,402,255	5.33	2.06	3.78	1.46

Selected PICs (1950-2008).

Source: World Bank: Preparedness, Planning and Prevention (2009).

available for electricity generation.[175] Indeed, one assessment argued that given climatic uncertainty regarding water, and the risk of glacial lake outburst floods, Nepal may want to avoid reservoir-based hydro systems and instead focus only on microhydro.[176] In Viet Nam and the Philippines, droughts affect both countries during "El Niño" periods, which means that hydroelectricity production is under stress, affecting in particular peak power demand requirements and causing blackouts.

In Thailand, the number of people at risk from flooding in Bangkok is expected to rise from approximately 900,000 to more than 5 million by 2070, creating $39 billion to $1.1 trillion in economic losses.[177] The Electricity Generating Authority of Thailand (EGAT) already warns that "weather conditions" and "extreme weather events" are complicating their operations and inducing losses in revenue. Heavy rains and floods in the second half of 2011 led to a severe shortage of raw materials at industrial facilities, forcing EGAT to curtail supply. More seriously, rains and floods "significantly affected" most of EGAT's transmission system including the destruction of nine high voltage substations and more than 6,100 transmission towers.[178] Outside the realm of electricity, biofuel manufacturing, especially from oil palm, is vulnerable to climate variations, such as droughts, and requires heavy investments in irrigation and fertilizers.[179]

9.2.2 Distorted energy prices

Distorted prices are a major challenge for many countries. For some, the issue is low prices. In many countries natural gas, petrol, and electricity prices are artificially low due to subsidies that are generally unsustainable, inefficient in terms of equity goals and sometimes causing inequality, and a drag on GDP growth. This includes India, China, Indonesia and Viet Nam and therefore a very large part of Asia's population.

For others, the issue is high prices. Due to its current small size of domestic capacity, its high dependence on imported fuels, the prevalence of heavy fuel oil and diesel, and relatively high transmission losses, Cambodia's electricity is one of the most expensive in Southeast Asia, costing about 14.6 ¢/kWh in 2000 for Phnom Penh and 25.0 to 50.1 ¢/kWh in remote areas; this amount has risen to 18 ¢/kWh today and 77 ¢/kWh in the most remote areas. Many of the batteries that households rely on for lighting are charged at diesel generators, further adding to costs, and the country spent roughly $60 million importing electricity from Thailand and Viet Nam in 2009. Households simply cannot afford these high rates, even if electricity were to be made more available.[180]

In Fiji, half of total commercial energy must be imported, and oil imports totaled $700 million in 2008 and $1.1 billion in 2011, when it amounted to almost half of the country's entire import bill. Diesel fuel costs have recently soared by a factor of four from 2007 to 2011 in current dollars, causing a consequent increase in Fiji Electricity Authority electricity prices, since about half of their generation portfolio is diesel-fired. Similarly, the Solomon Islands has one of the highest electricity tariffs in the world, due to the inefficiency of its grid and its reliance on diesel imports. Electricity tariffs announced for October 2012 include a staggering 85 ¢/kWh for residential customers and 91.6 ¢/kWh for commercial customers. It may come as no surprise that the 2011 Pacific Infrastructure Performance Indicators report ranked the Solomon Islands last among all Pacific territories for low power consumption per capita—[181]electricity is simply too expensive to afford.

9.2.3 Difficulty doing business

Some countries in the Asia-Pacific did not perform well on the World Bank's "ease of doing business" survey. For instance, Cambodia ranks 138th in the world for the ease of doing business, potentially making it less attractive for investors.[182] India ranks 132nd out of 193 countries—hardly a positive score—with business concerns related to starting a business, dealing with permits, and enforcing contracts, while PNG ranks 101st. In Lao PDR, starting a new business requires seven procedures, takes 93 days, and costs 7.6 percent of income per capita. Also, for an entrepreneur in Lao PDR to connect a warehouse to electricity, it requires five procedures and takes 134 days.

9.2.4 Poverty and lack of capital

Low national incomes, lack of available capital, and poverty frequently make energy equipment too difficult to afford—even if it would save households and companies money and other benefits such as improvements in health and productivity. In Lao PDR, one review of a biogas plant programme supported by Netherlands Development

Organisation (SNV) revealed that the upfront costs of bio-digesters and access to credits and financing have been "the key barriers" to the success of that programme. After more than quadrupling the national electricity access rate from mainly grid expansion over the last 15 years, Lao PDR also faces an economic challenge to connect the remaining unconnected population who lives in very remote, hard-to-reach places including in mountainous areas. The current grid expansion's approach is becoming very expensive. The average cost of grid extension has nearly doubled from $450-550 per household seven years ago to approximately $900 in 2010. In Viet Nam, one significant barrier is "the relatively expensive nature of new technology for consumers. Most rural families have limited cash whilst fuel wood is generally free. This limits the uptake of improved technology and limits the willingness to take loans."[183]

9.2.5 Tariffs and power purchase agreements

Discriminatory electricity tariffs and power purchase agreements stand as another economic and financial impediment. In most PICs, electricity tariffs are set below real cost. In India, overly subsidized rates for farms have driven many electricity companies out of business, since they must serve these customers below cost.[184] In Malaysia, a national Small Renewable Energy Power Programme intended to encourage the diffusion of mini-hydro, solar, and biomass technologies (mostly landfill gas capture and distributed generation at palm oil mills) has failed to achieve its targets because electricity tariffs under the programme did not match true production costs, were not based on sound economics, and did not provide cost recovery for project developers.[185] In Viet Nam, electricity prices are capped and new projects proceed only with large subsidies from the government.[186]

9.2.6 Limited financing

Limited financing is another substantial barrier. In Fiji, the penetration of credit unions and microfinance institutions remains limited (at 2.5 percent) and the country's national debt stands at an official $3.5 billion in 2011, meaning little funds are available to finance or invest in renewable energy, efficiency, or access. The government is trying to address this barrier.[187]

In India, many state electricity boards and smaller energy companies have "significant financial problems", with many operating at a loss and unable to make a profit with electricity tariffs that do not enable full recovery of costs.[188] The World Bank has noted that India's regulatory framework "fails to adequately address utilities' long-term financial concerns."[189] Project developers consequently report difficulty finding credit and financing for renewable energy and energy efficiency projects. As one report recently put it, "the non-availability of sufficient credit facilities and the difficulties in obtaining required finances for energy-saving projects are strong deterrents to investments in energy efficiency in India."[190]

In Malaysia, financing for energy efficiency "remains a challenge due to limited successful cases" and costs of renewable energy technologies are still "considered high" and risky by financiers.[191]

In Nepal, inabilities to procure financing and foreign investment are major barriers. One assessment calculated that if you take all of the available capital in Nepali markets—that is for everything, not just energy—and directed it solely at building hydropower projects, you would not even have enough for 200 MW.[192] UNDP surveyed key lenders in the sector and noted that commercial banks and financial institutions are "generally not interested" in investing in energy.[193] A separate evaluation commented that Nepal lacked "long-term debt financing" for energy projects and that the major lenders, the Agricultural Development Bank and National Commercial Bank, have already "maxed out" their lending for microhydro, solar PV, and biogas.[194] A third study remarked that in Nepal, "financial institutions are not readily motivated to invest in renewable energy technologies because of the immature business models, market insecurity and implementation and usage risks."[195]

In PNG, the financial capacity of PNG Power Limited (PPL) is limited and controlled by the government, and developers there have argued that they will not take on projects unless returns on investment are greater than 10 percent.[196] This makes investing in electrification and expansion of access difficult because returns on investment are much lower and operate on longer timeframes. Moreover, PPL must operate at a profit because it funnels money back into government revenue needed to fund general government work.[197]

In the Solomon Islands, the government has defaulted on previous loan interest payments, actions that make it difficult, even today, to secure financing for energy projects, given that investors see the Solomon Islands as high risk.[198] As one study noted, "commercial finance is difficult to obtain on affordable terms."[199]

9.3 Political and institutional

9.3.1 Political instability

Political instability can also reduce investment and complicate efforts at energy planning and policymaking. For instance, Bangladesh has since 1971 seen a war, multiple famines, disease epidemics, killer cyclones, massive floods, military coups, and changes in government every two to three years, making it difficult to implement long-term energy plans and regulations.

In Nepal, civil unrest lasted 11 years. It stopped with the formal end of the monarchy in Nepal and the establishment of the "People's Republic of Nepal" in 2006. Yet as of November 2011, the government was still in "crisis" without an elected Prime Minister. As a result, experts have noted that "for the past three months, the economy has come to a grinding halt, nothing is happening, no funds have been allocated to Nepal Electricity Authority or to energy."[200] Although the new budget published in November 2010 allocated 16.69 billion Nepalese Rupees to power generation and transmission systems, the Independent Power Producers of Nepal already stated that it is insufficient to bring any projects online.

In the Solomon Islands, civil unrest and conflict in 2002 and 2003 saw national GDP decrease by 24 percent and government debt increase 40 percent.

9.3.2 Constrained institutional capacity

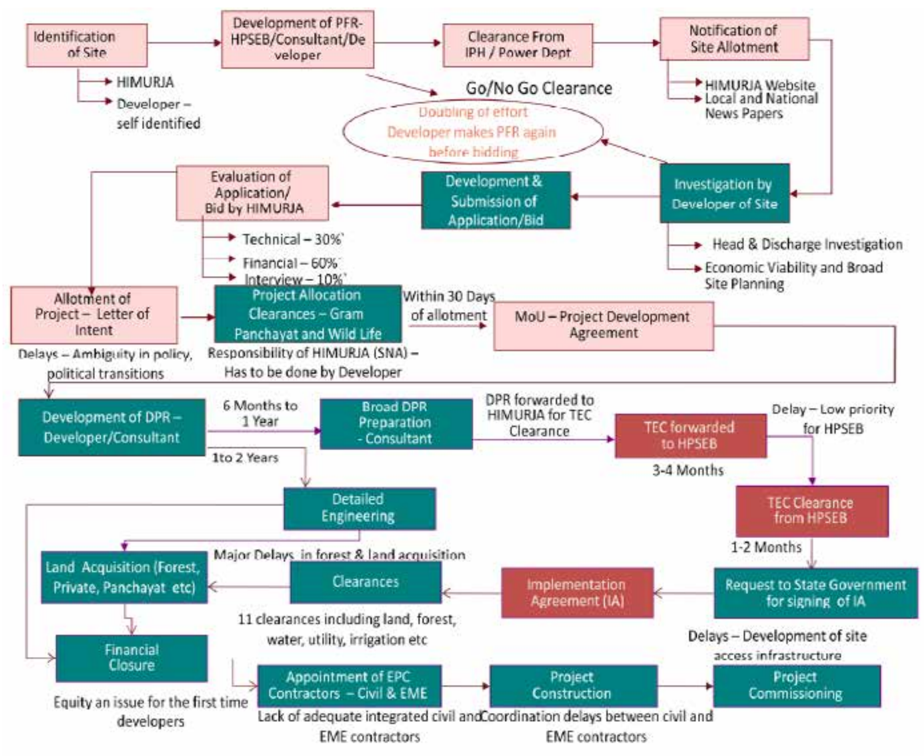
Constrained institutional capacity serves as a meaningful barrier. As two examples, consider Cambodia and Fiji. Legal and regulatory mechanisms in Cambodia for promoting renewables and efficiency have been called "weak" and "arbitrary".[201] The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) report confirmed some of these points when it noted that though the government seems interested in energy efficiency, they have not implemented specific legislation, have not created any supporting funds or incentives, and retain a "weak institutional capacity for planning, implementation and maintenance of energy efficiency policies and programmes."[202]

Fiji exhibits rapid turnover of experienced and well-educated personnel and a dependence on foreign expertise to conduct energy assessments and assist with energy planning. As one example of limited capacity, consider the current Renewable Energy Services Company (RESCO) Programme, which most households have reported being "unsatisfied" with.[203] Not a single household in Vunivao and less than 25 percent of households in Nakawakawa considered the maintenance element of the programme satisfactory. Some households reportedly went without electricity for almost 500 *days* as they waited for their systems to be repaired. As another indication of problems with capacity, there were hundreds of biogas digesters built in the 1980s of various designs, mostly floating dome types for piggeries, but they fell into disuse. Thousands of improved cookstoves were also built and sold in the 1980s but few exist today. This pattern of installing and then abandoning equipment does suggest the need for better institutional capacity in maintaining technology and managing rural energy programmes.

9.3.3 Fragmentation or gaps in regulation

Most critically, complicated energy policy landscapes and gaps in regulation can make it time consuming and difficult to pursue renewable energy or energy efficiency. In India, the IEA describes acquiring permits for land as "a slow and lengthy process" with "many key energy and infrastructure projects" not progressing due to "the lagging administrative process" and "excessive red tape".[204] The World Bank has noted that one negative result of India's regulatory environment is "unintended overlaps, reduced transparency and fiscal discipline, unnecessary complexity in claiming subsidies, and ineffective leverage for the amount spent on renewable energy development."[205] Consequently, Indian renewable energy projects suffer from an excessively long development cycle.[206] As one example of this, the World Bank estimates that 60 percent of a small hydropower project cycle time involves getting various government clearances from: (1) wildlife, fisheries, panchayat, irrigation, public health, and revenue departments; (2) the Structural Engineering Research Centre (for power purchase agreements); (3) forest center, pollution control board, industrial license, labor permits, state transmission utilities; (4) distribution companies' approval for interconnection and for usage of explosives for excavation; (5) state nodal agencies (for implementation agreement, infrastructure permission); and (5) approval from state utilities and transfer of land in cases involving tribal areas. As a result, a small hydropower project takes four to eight years from conception to commissioning, two to four times longer than it takes in China or Sri Lanka. Figure 19 graphically depicts the complicated licensing process for a small hydropower project in one Indian state.

Figure 19 Project development small hydropower project in Himachal Pradesh



Source: Sargsyan, Gevorg, Mikul Bhatia, Sudeshna Ghosh Banerjee, Krishnan Raghunathan, and Ruchi Soni. (2010). *Unleashing the Potential of Renewable Energy in India*. South Asia Energy Unit, Sustainable Development Department, World Bank. HIMURJA refers to the Himachal Pradesh Energy Development Agency. PFR-HPSEB refers to the Himachal Pradesh State Electricity Board Limited. IPH refers to the state Irrigation and Public Health Department. SNA refers to the Sangeet Natak Akademi. TEC refers to "techo-economic clearance". EME refers to "electrical and mechanical engineering". EPC refers to "engineering, procurement, and construction contract".

Other countries possess comparable regulatory environments. In Mongolia, institutional capacity is still limited within and between government planners, development agencies, *soum* centers, and retailers. As reported in the national rapid assessment and gap analysis (RA/GA), an "institutional and regulatory vacuum" remains, with no single government agency committed to advancing renewable energy. Although Mongolia continues to improve its regulatory framework to promote energy efficiency, its current energy planning processes suffers from inconsistent policies and poor coordination between different ministries and a lack of transparency.

In Nepal, UNDP has noted that "no single institution" could "provide the horizontal alignment and necessary focus on linkages between energy poverty" and give "overall direction to a collective pro-poor energy strategy".[207] UNDP also documented a lack of centralized energy planning, duplication of efforts resulting from lack of coordination, and disputes between local and national institutions over energy planning.

In Samoa, access to rivers on customary owned land and obtaining village support is often time consuming and full of uncertainties. Most villages dispute government claims of state ownership of rivers and water bodies, often resulting in protracted negotiations for compensation.[208] This complicates attempts to build new hydroelectric and biomass-based energy systems.

The Rural Electrification Unit within the Energy Division of the Solomon Islands is notoriously understaffed and underfunded, and "no dedicated agency is assigned to manage and promote rural electrification."[209]

In Thailand, notwithstanding a strong policy framework for renewable energy, some studies have identified a "lack of collaboration between agencies and companies" which can result in delays for many renewable energy projects.[210] Laws requiring public input and participation in project siting, especially for hydroelectric dams, may protect communities from projects they see as harmful but also result in meaningful delays on getting projects approved.[211]

In Vanuatu, friction exists between an electricity system predicated on concessions, which must make money, and electrification efforts, which cost money.[212]

In Viet Nam, a "primary gap" is "no comprehensive policy or plan for enhancing access to all forms of thermal energy for households, on its own or as part of wider national energy policies."[213]

9.3.4 Corruption and patronage

The analysis shows that corruption and political patronage can impede SE4ALL efforts. For instance, in Lao PDR, slow implementation of the anti-corruption decree issued in November 1999 by the Prime Minister's Office has corresponded with a rise in bribes, patronage, and corruption associated with energy projects. In Nepal, only 2 percent of the economy in Nepal is "formal", meaning the bulk of activity is untaxed and unregulated.[214]

9.3.5 Commitment to fossil fuels

Many Asian governments remain fully committed to fossil fuels, obviating a lasting commitment to SE4ALL. In Indonesia and Malaysia, fossil fuels have been cross-subsidized for decades, eroding the motive to invest significantly in alternatives. As one study noted, in Malaysia "there is still massive support for conventional energy sources in the forms of subsidies and export credits."[215] The result is a "lack of economies of scale for renewable energy" and "artificially low prices" for fossil fuel supply.

Comparably, in Mongolia, the Ministry of Energy has placed considerable emphasis on further expanding the production of coal, both for domestic use and exports. The production of coal is expected to more than double from 27 million tons today to 63 million tons by 2015, placing an abundance of cheap coal on the local market for use by power plants and herders, who will legitimately need some solid fuel for heating and cooking. The government has also announced plans to build the fifth power station in the capital city, a new 480 MW coal-fired facility near the Shivee Ovoo mine to provide electricity throughout the area as well as a 150 MW plant near Uhaahudag and an additional 450 MW facility at Oyu Tolgoi. With economic growth rates of 17.6 percent in 2011 and 12.3 percent in 2012, the government also expects that they will need to build more centralized plants around Ulaanbaatar and extend the grid to accommodate new commercial and industrial users.

Even in Sri Lanka, with its strong markets for renewable energy and the creation of its Sustainable Energy Authority, it is clear that the government's main goal seems to be to quickly restore development particularly in the northern and eastern parts of the country that were damaged by the civil war and kick start Sri Lanka's industrial development, including investing in energy infrastructure. Two new major coal power plants are currently under construction, one in Puttalam, Northwestern Province (900 MW), and the other in Trincomalee, Eastern Province (1,000 MW), which are seen as harbingers of economic growth for the country. In fact, these plants have become such potent national symbols that Sri Lanka now carries them on their currency. Moreover, with 88 percent of households electrified thus far and ambitious targets to achieve 100 percent electrification by late 2012 and early 2013,[216] energy access is seen as a political priority that has been accomplished.

9.3.6 Lack of private sector involvement

Some Asian energy sectors remain heavily dominated by public sector companies with little private sector participation. In India, for example, the electricity, oil, gas, and coal sectors all have less than 40 percent participation of the private sector. This has served as a significant deterrent to foreign investment in Indian energy infrastructure.[217] Indonesia and Malaysia, too, have energy sectors aligned closely with government-linked companies such as Pertamina, PLN, Petronas, and Tenaga Nasional Berhad (TNB). In the Philippines, renewable energy diffusion remains impeded by "restrictions on foreign ownership of renewable projects".[218]

9.4 Social and cultural

9.4.1 Stigmatization

Startup problems and lack of confidence can lead to a negative stigmatization of renewable energy projects in some cases. Given the challenges facing the government's Solar RESCO Programme mentioned above, the most significant social barrier in Fiji could now be a social stigma developing against renewable energy, particularly SHS, in rural areas. Researchers at Murdoch University and the University of Western Australia, for example, concluded that the programme was "seen by many stakeholders to suffer from a lack of well-developed planning and policy support" manifesting in "a lack of support infrastructure and in a weak monitoring and maintenance programme, which in turn give rise to significant technical problems."[219] More than half of respondents surveyed reported that monthly payments on energy had increased rather than decreased, and a strong majority stated both that SHS use had failed to produce positive economic change and that they did not result in new employment opportunities. This type of a stigmatization barrier could conceivably exist wherever failed energy access programmes have soured perceptions of renewable energy and/or electrification efforts.

9.4.2 Local opposition and protests

A separate social challenge to renewable energy encompasses local opposition. Sometimes, upstream and downstream villages in Bhutan, Nepal, and Sri Lanka cannot agree on how to share water resources or, in other cases, agree on how to distribute the costs of installing a hydroelectric facility or using its electricity.

9.4.3 Limited awareness and information

Shortages of information and limited awareness exist in many Asian countries. In Lao PDR, almost one-third of business owners and operators reported a lack of information on equipment brand names, types, and sizes related to renewable energy and energy efficiency devices.[220] In Mongolia, reliable information about the country's energy use is difficult to acquire.[221] In Nepal, one study warned of a "lack of awareness" about renewable energy in rural areas, with rural communities "unaware" of the benefits of renewables and the costs of depending on traditional energy.[222] In Viet Nam, "limited understanding" of renewable energy "at the local level" is reported as pervasive.[223]

9.4.4 Theft and vandalism

A somewhat unique challenge relates to an abnormally high frequency of theft and vandalism of solar panels and other individual renewable energy units within PNG. Such units are seen as a threat to the social fabric and identity of clans, tribes, and family groups. Introducing a solar panel into these types of homes can assault their communal value system, as it benefits only one household or community rather than the entire clan. Tribal communities can therefore react aggressively and negatively by stealing or destroying it.[224]

9.4.5 Social norms and consumer preferences

Often, cultural norms and consumer preferences need to be factored in the dissemination of renewable energy. In Bangladesh, an aversion to pigs prevents households from adopting biogas units that would run on pig waste. Other households refuse to purchase biogas cookstoves at all because they are uncomfortable with the idea of piping in gas from livestock and human excrement, which they see as "impure".[225] In Lao PDR, most cattle farmers and livestock owners do not pen their animals, making it difficult and time intensive to scour grasslands and fields to collect manure, especially compared to the relatively effortless task of collecting fuelwood.[226] In Mongolia and parts of rural China, nomadic herders remain mobile all year round, making it difficult to provide them with either electricity or modern energy services.

9.4.6 Entitlement mentality

Finally, some households perceive energy not as a commodity to be purchased, but as a gift or social necessity that they are entitled to for free. In Nepal, a social norm against collecting revenue for electricity further inhibits the profitability of hydro schemes. Many believe hydroelectric facilities should serve the community for free, and that poor families should not have to pay for electricity. The problem with this view is that it creates social opposition to charging rural households for hydroelectricity.[227] Correspondingly, in PNG many rural families have no savings, credit, debt, or even money or even money, and also expect electricity and fuel to be given to them for free by wealthier clan members or even political leaders.[228] In Sri Lanka, homes devastated by a longstanding civil war hold the government responsible and see free or low-cost provision of electricity as meeting their responsibility to repair the country.[229]

10 OVERCOMING BARRIERS AND CASE STUDIES

The presence of the barriers in Chapter Nine of the report should not imply that successful case studies of expanding energy access do not exist, or that investments in electrification, energy access, and renewable energy do not bring a suite of social, economic, and environmental benefits. However, the 24 distinct barriers clearly imply the need for policy intervention. Moreover, current projections suggest that the investment required to eliminate energy poverty by 2030 is $49 billion per year, only 3 percent of total global energy infrastructure investments yet well above the $14 billion that is presently being invested each year.[230] As the most recently available data reveal, there are 11 countries that have electrified less than half of their population—see table 16—and there are 21 countries that have more than half of their population dependent on traditional fuels for cooking.

Countries that have achieved success in electrification, energy efficiency and a share of renewables in the energy mix have often done so due to explicit and aggressive policies. Since its independence in 1957, Malaysia strived to achieve universal access to basic infrastructure services, and today has an electrification rate of 99.4 percent. This is to a large extent due to ambitious policy targets expressed in its consecutive five year National Development Plans, with appropriate development budget allocations. The *Four-Fuel Diversification Policy* introduced in 1981, aimed at reducing the over-dependence on a single fuel source and focus on four main sources of fuel, i.e., oil, hydropower, natural gas, and coal. A Fifth-Fuel Policy was introduced in 2000, focusing on incorporating renewable energy as next available fuel for power generation. In 2010 Malaysia approved a National Renewable Energy Policy and Action Plan for a more aggressive deployment of renewable energy in the country.

The Philippines has an electrification rate of 89.7 percent, and almost tripled their power generation between 1991 and 2011, from 25,649 GWh in 1991 to 69,050 GWh in 2011. Their positive electrification rate stems from an aggressive National Electrification Act passed in 1969 which entrusted efforts to Rural Electric Cooperatives (RECs), which involved local communities as key elements of electrification. Currently, a rural electrification programme with rigorous targets is being implemented by the National

Table 16 Electrification rates and traditional fuel dependence

Country	Electrification Rate (%)	Country	Population Dependent on Traditional Fuels (%)
Myanmar	13	Timor-Leste	98.7
Afghanistan	15.5	DPR Korea	97.7
Solomon Islands	16	Cambodia	95
PNG	17.6	Afghanistan	95
Timor-Leste	22	Lao PDR	95
Cambodia	24	Myanmar	95
DPR Korea	26	Solomon Islands	95
Vanuatu	27	PNG	90
Bangladesh	41	Bangladesh	89
Nepal	43.6	India	82
Lao PDR	55	Nepal	81
		Pakistan	81
		China	80
		Vanuatu	79
		Indonesia	72
		Thailand	72
		Samoa	70
		Viet Nam	70
		Bhutan	67
		Sri Lanka	67
		Mongolia	51

Source: Figures reorganized from those presented in the Introduction.

Electrification Administration (NEA) and the country's 110 electric cooperatives, of which more than 53,000 households have benefitted so far, according to NEA.

Looking to the future, what sorts of business and financial models are best suited to promote SE4ALL? What lessons do they tell us? And what particular case studies offer guidance in practice? This chapter discusses each question in turn.

10.1 Business and financial models for SE4ALL

The policies and models employed by institutions and governments to promote energy access can vary significantly. Based on an extensive, four-year assessment of 1,156 energy access and development programmes being implemented throughout the Asia Pacific, many of them mentioned in this report, ten approaches seem the most widespread: (1) a cash model, (2) a donation model, (3) a credit or microfinance model, (4) a mixed finance model, (5) a fee for service or ESCO model, (6) a technology improvement model, (7) a cooperative model, (8) a cross subsidization model, (9) a project finance model, and (10) a capacity building model.[231]

A "cash model" refers to when customers purchase the product paying the full cost. It is most commonly applied to SHSs and small hydro schemes, and the owners of such technologies are usually moderately wealthy private individuals and in some cases communities or public organizations.

A "donation model" is one where the technology is transferred to the community as a gift, usually from a private entity (part of their corporate social responsibility programme) or a development donor. It has been utilized for all types of renewable energy with varying degrees of quality and installation.

A "credit model" or "microfinance model" refers to when local dealers sell their products to rural clients on credit against collateral or personal guarantees. It is commonly applied to SHSs, biogas units, and improved cookstoves. Payment is done in installments, and this type of partnership has high installation expenses due to the transaction costs associated with acquiring credit and high to medium quality products. This model also excludes poor families without the ability to provide collateral.

A "mixed finance model" is when governments provide a fixed subsidy and the balance is borne by villagers or private firms. It is most commonly applied to microhydro schemes and SHSs, with ownership residing either with individuals or the community. The model requires high quality products from prequalified companies, and it has relatively high installation costs due to lengthy quality assurance procedures.

A "fee for service" model is one where renewable energy technology is owned, operated, and maintained by a supplying company, but the customer pays regular fees for using it. It, too, has been utilized for all types of renewable energy with varying degrees of quality and installation cost.

A "technology improvement" model attempts to "push" the supply of a given technology by improving its performance, often through research subsidies, product guarantees, warranties, technical standards, or improved manufacturing techniques. It has been largely used for SHSs.

A "cooperative" model refers to when households or investors band together to create their own cooperative which contributes all or some to the installation or operation of energy equipment. It is usually used for larger systems, such as solar micro-grids, commercial scale biogas units, or microhydro dams.

A "cross subsidization" model refers to when wealthier homes, or particular subclasses of electricity or energy customers, pay higher energy rates to produce money that then offsets the cost of expanding access to energy for poorer customers. It is usually applied to grid-extension efforts and occasionally to SHSs.

A "project finance model" supports small- and medium-scale projects with loans and financial assistance from commercial banks. These projects are often at the commercial or village scale and involve micro-grids or sales of electricity back to the national grid.

A "capacity building model" directs efforts not at technology per se, but at building the capacity of public institutions, private companies, or energy end-users themselves.

Many approaches use "hybrid" models that involve one or many of these approaches integrated together. Not all of these models appear to work well in Asia, and table 17 presents some of the most effective ones being used to expand energy access. The potential markets for energy access can become quite large. According to data from the World Resources Institute, providing energy services to the "bottom of the pyramid" in India, or the 114 million households that earn only $1 to $8 (adjusted for purchasing power parity) per day, represented a potential untapped market of more than $2 billion per year through small hydropower and biomass waste systems.[232]

Table 17 Successful business models for expanding energy access

Model	Description	Example	Primary Partners	Application	Technology	Dates	Cost (US$)	Accomplishments
Technology improvement and market development	A sort of "supply push" structure where the public-private partnership develops a renewable energy technology to reduce costs	China's Renewable Energy Development Program	World Bank, Global Environment Facility, National Development and Reform Commission, local solar manufacturers	Off-grid (nomadic herders)	Solar home systems	2002 to 2007	$316 million	Distributed more than 400,000 units in 5 years
End-user microfinance	A sort of "demand pull" which gives loans to energy users so that they can purchase renewable energy equipment	Grameen Shakti in Bangladesh	International Finance Corporation, Infrastructure Development Company Limited, Grameen Bank	Off-grid (rural households)	Solar home systems, biogas digesters, and improved cookstoves	1996 to 2010	-	Installed almost half a million solar home systems, 132,000 cookstoves, and 13,300 biogas plants among 3.1 million beneficiaries
Project finance	Where small- and medium-scale projects are supported with loans and financial assistance from commercial banks	Energy Services Delivery Project in Sri Lanka	World Bank, Global Environment Facility, Ceylon Electricity Board, and national banks	On-grid and off-grid	Solar home systems, grid-connected hydro, off-grid village hydro	1997 to 2002	$55.3 million	Installed 21,000 solar home systems and 350 kW of installed village hydro capacity in rural Sri Lanka, in addition to 31 MW of grid-connected mini-hydro capacity
Cooperative	Where communities own renewable energy systems themselves	Cinta Mekar Microhydro Project in Indonesia	Yayasan Ibeka, Hidropiranti Inti Bakti Swadaya, Directorate General of Energy Electricity Utilization, PLN, UNESCAP, Cinta Mekar Cooperative	On-grid	Microhydro	2004 to present	$225,000	Constructed a 120 kW microhydro scheme that has electrified homes and creates thousands of dollars of monthly revenue funneled back to the village

Model	Description	Example	Primary Partners	Application	Technology	Dates	Cost (US$)	Accomplishments
Community mobilization fund	Where revenues from renewable electricity or energy production are invested back into local communities	Microhydro Village Electrification Scheme in Nepal	World Bank, Government of Nepal, UNDP, Nepal Alternative Energy Promotion Center, District Development Communities, Village Development Communities, Microhydro Functional Groups	Off-grid	Microhydro	2004 to 2011	$5.5 million (original proposal)	Distributed 250 units benefitting 50,000 households in less than 10 years
ESCO "fee-for-service"	Where private sector enterprises purchase technology and then charge consumers only for the renewable energy "service" that results	Zambia's PV-ESCO Project	Ministry of Energy, Stockholm Environmental Institute, Swedish International Development Authority	Off-grid	Solar home systems	1999 to 2009	-	Three ESCOs currently lease the services of 400 solar panels and have hundreds of clients waitlisted
Cross subsidization	Where tariffs on one type of electricity are then funneled into a fund to support renewable energy	The Rural Electrification Project in Lao PDR	Electricité du Lao PDR, Ministry of Energy and Mines, World Bank, Global Environment Facility, Provincial Electrification Service Companies	On-grid and off-grid	Solar home systems and grid-connected hydroelectricity	2006 to 2009	$13.75 million	Electrified 36,700 previously off-grid homes and disbursed more than 9,000 solar home systems
Hybrid (end-user microfinance and ESCO "fee-for-service")	Where private sector enterprises purchase technology and then charge consumers only for the renewable energy "service" that results	India's Solar Lantern Project	Small-Scale Sustainable Infrastructure Fund, Solar Electric Light Company, local banks and entrepreneurs	Off-grid	Solar lanterns	2005 to present	-	Distributed 80,000 units across 25 separate cities

Source: Sovacool, B.K. (2013). Expanding Renewable Energy Access with Pro-Poor Public Private Partnerships in the Developing World. *Energy Strategy Reviews* 1(3), pp. 181–192.

10.2 Emerging lessons from recent energy access programmes

The success of these models, and the dire statistics presented in Chapter Nine about barriers, suggest that ordinary energy markets and the private sector will not by themselves quickly address energy poverty and expand energy access in countries such as those above. For example, most private or investor owned electric utilities tend to shy away from expanding access to underserved or poor areas because such expansion mitigates commercial profit. From their perspective, those on the lower rungs of the energy ladder share a number of common attributes independent of their country: lower income levels, low ability to pay, low levels of consumption, geographic dispersion, high system losses in getting them electricity, and high costs of connection and maintenance.

Public sector counterparts may view expanding energy access as a laudable goal, but can be limited in their ability to implement or finance projects, and are always under pressure to satisfy other urgent public needs related to jobs and economic growth, crime and corruption, public health, and national security, all of which tend to resonate more strongly with voters than "energy projects". National planners may hesitate to promote off-grid renewable energy projects since the technology often must be imported.[233]

As a result, the very poor "fall through the cracks" and are too politically distant and economically costly to provide with energy services. Furthermore, multilateral financial institutions such as the ADB and World Bank must demonstrate positive cost-benefit ratios for all of their projects, since they are indeed giving *loans* rather than *grants*, and many energy access projects have timelines that are too risky for these development partners. Thus, to ensure equal development and access for all, there is a need for specific programming to reach the poorest at the bottom of the ladder that are not served by commercial energy providers or large-scale energy projects that demand positive profit margins from an early point. Failure to do so prevents already disadvantaged families from participating in the Asian economic miracle; it also maintains the unequal distribution of wealth in societies.

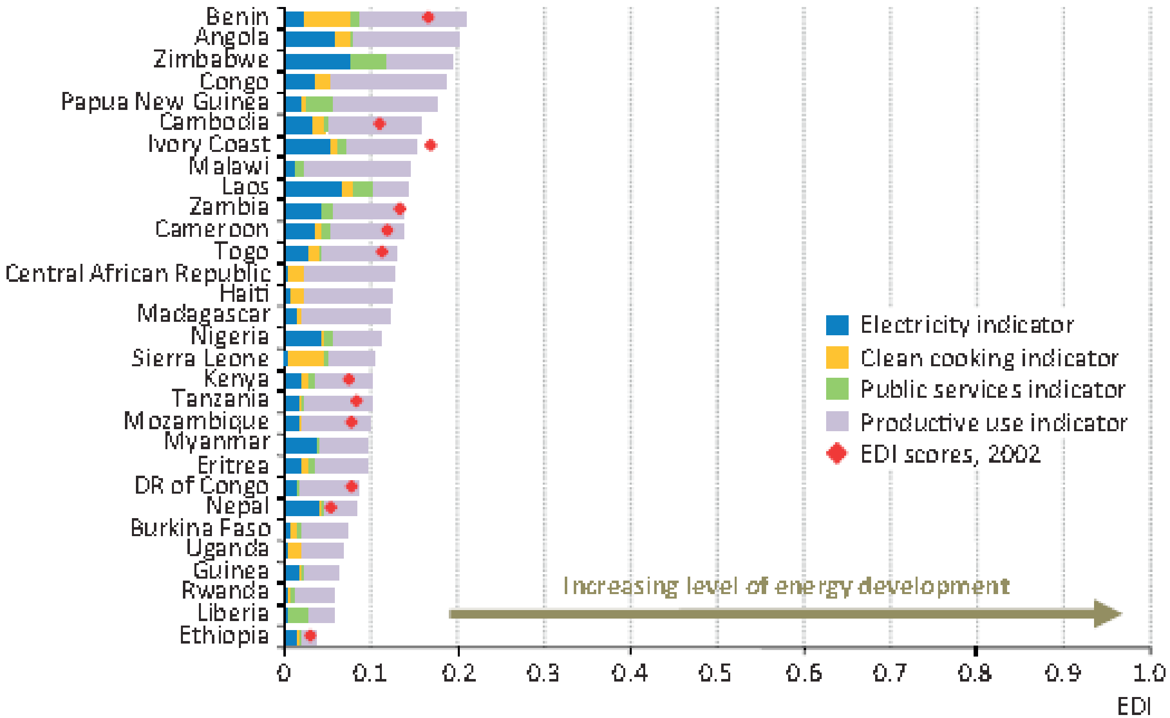
The most recent projections from the IEA subtly, but clearly, underscore that many of the poor are not likely to reach the goals of SE4ALL anytime soon. Using an Energy Development Index consisting of both household and community indicators, figure 20 presents the IEA's "bottom 30 countries", five of which reside in Asia-Pacific: Nepal, Myanmar, Lao PDR, Cambodia, and PNG. When projecting the future in their latest 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.[234] That same year, the number of people without clean cooking technologies in India will amount to *twice* the population of the United States, and overall the IEA forecast that 39 percent of people in the Asia-Pacific would lack access to modern cooking. The IEA also estimated that about $76 billion would be required to achieve universal access to clean cooking by 2030 (an average of $3.8 billion per year) contributing to almost $1 trillion needed for universal access to energy (an average of $49 billion per year). As of 2012, however, only 3 percent of this needed investment has been committed.

It is the poor households unlikely to be served by the private sector, government, or financial institutions—the energy poor that even the IEA projects will not gain access to modern energy by 2030—that development partners will need to consider serving. Put another way, there are certain high-impact opportunities that can help Asia-Pacific's poor leapfrog towards improved access to modern energy services.

10.3 Successful case studies

What case studies, then, offer instructive direction for how to structure, implement, and enforce SE4ALL programmes? This section of the chapter presents successful case studies spread across household thermal needs, rural electrification, energy efficiency, and renewable energy.

Figure 20 IEA's Energy Development Index (2002 and 2010)



Source: IEA World Energy Outlook 2012.

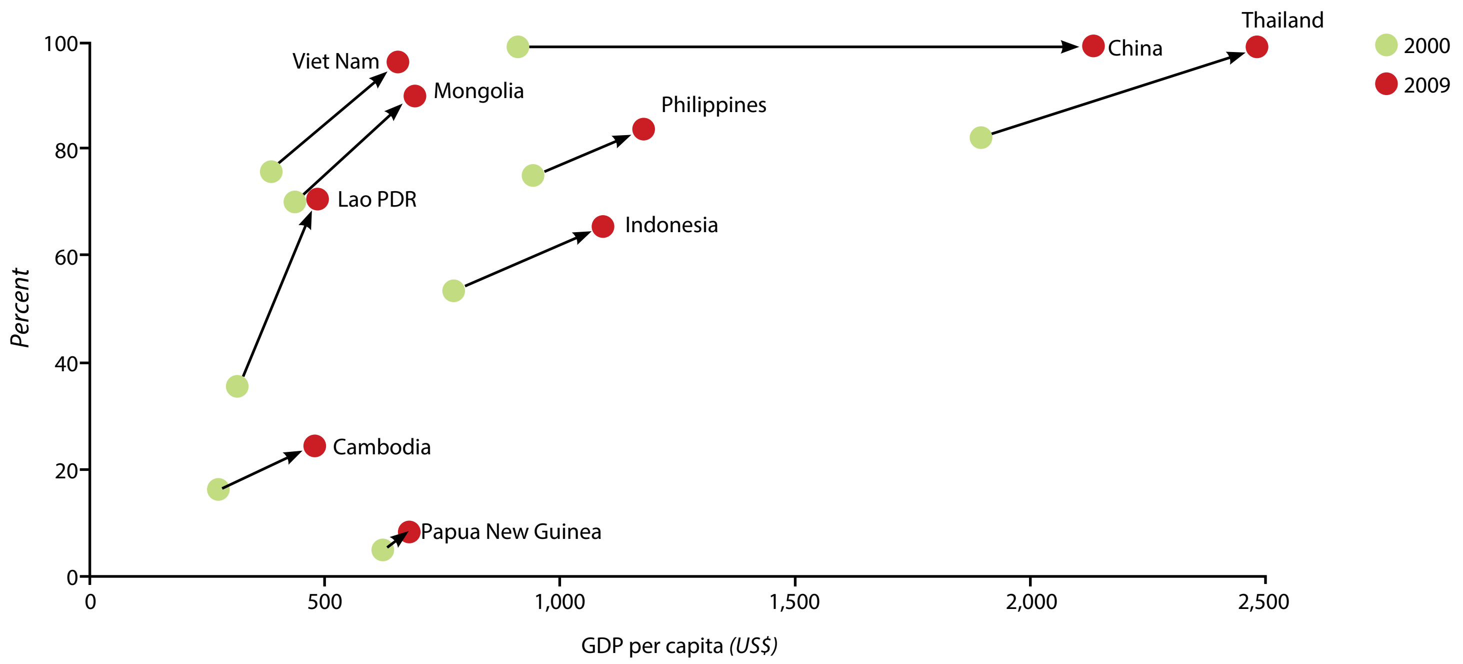
10.3.1 Household thermal needs

Overcoming the institutional and financial barrier: In 2006 and 2007, Indonesia created its "LPG Conversion Programme" to substitute liquefied petroleum gas for kerosene among Indonesian households. It appointed the Ministry of Energy and Mineral Resources to lead the programme and Pertamina, the state-owned oil and natural gas utility, as the sole programme executor. Its initial goal was to convert 42 million households and microbusinesses nationally over four years. Under the programme, every eligible household was given a 3 kilogram LPG canister, a coupon to fill that canister once for free, a single-burner stove, a hose, and a regulator. Over the programme implementation, Pertamina conducted market assessments, and built pressurized LPG terminals and filling stations to ensure LPG reliability. In less than three years, Pertamina had distributed initial packages to more than 44 million households and small-medium enterprises. Pertamina withdrew 5.3 million kiloliters of kerosene in 2009 and replaced it with 1.85 million tons of LPG, and Indonesia was able to save $3 *billion* in decreased kerosene subsidies as of May, 2010.

10.3.2 Rural electrification

Viet Nam, Lao PDR, Mongolia, Philippines, China, and Thailand, and arguably Bangladesh and Sri Lanka, provide some best practices examples for rural electrification. As figure 21 exhibits, these first six countries had the highest growth rates for electricity access from 2000 to 2009.

Figure 21 Growth in electricity access versus GDP (per capita, 2000-2009)



Source: World Bank. (2011). One Goal, Two Paths: Achieving Universal Access to Modern Energy in East Asia and the Pacific. Washington, DC: World Bank.

Overcoming political and institutional barriers: The Philippines has a high electrification rate at 89.7 percent, meaning less than 9.5 million people lack access to electricity. Their positive electrification rate stems from an aggressive National Electrification Act passed in 1969 which entrusted efforts to RECs, which involved local communities as key elements of electrification efforts and massive amounts of government funding in the 1970s, when 120 RECs served more than 1 million customers.[235] These cooperatives and the government's electrification strategy worked at electrifying homes, though independent assessments have indicated that many RECs face financial and operational challenges, are in debt, and that only 18.8 percent operate at a profit and are "financially viable".[236]

Overcoming the economic barrier: Over two-thirds of Lao PDR households today enjoy access to grid-quality electricity; a far cry from just one in six families having a connection in 1995. The coverage is envisaged to reach 90 percent by 2020. How did this come about? Firstly, the Lao PDR government put rural electrification as a priority in the National Growth and Poverty Eradication Strategy (2006-2010) and committed required resources. Then a comprehensive and sector-wide approach was adopted to carry out reform, strengthen institutions and build capacity, which resulted in expansion of generation capacity and distribution networks; improved operational efficiency; financial sustainability; and service quality. Both grid and off-grid solutions were used to expand the coverage. The government carried out tariff reform—including cross-subsidization in pricing—and provided subsidy incentives for financial sustainability of the utility and affordability of consumers. Focused capacity building was carried out in Electricité du Lao, the national utility, in planning, design, implementation, and operation.

On the ground, several innovative methods were used to improve the affordability for the consumers. A village screening process was put in place—including gender-sensitivity criteria and consultation process—to prioritize villages with clinics, schools, irrigation, and potential economic activities. A "Productive Use of Electricity" programme was launched to ensure income generation and extended social benefits. At the same time, a "Power to the Poor" programme was instituted to offer interest-free loans to the poor households to pay for the upfront cost of connection. When Power to the Poor was taken to already electrified villages, the coverage went up from 80 percent to 98 percent including the poor. Where off-grid solar systems were used to expand access, a hire-purchase scheme was implemented facilitating partial payments over a ten-year period making the systems accessible to the poor. Off-grid systems have covered about 2.5 percent of the households, particularly in remote, inaccessible regions.

The tariff reforms carried out by the government coupled with capital subsidies have attained an average energy price of $0.065/kWh against the cost of supply of $0.05/kWh. Systems losses went down to 13 percent in 2009 from 20 percent in 2005. Some of the key lessons from the Lao PDR experience are: Well-governed utilities can achieve fast expansion of access with the private sector playing a complementary role; strong commitment of government is critical; a combination of pricing and incentive mechanisms are necessary for financial sustainability and consumer affordability; strong commitment and capacity are a requisite for programme managers; and, innovative, customized solutions such as are often required to reach the poor.

Bangladesh and Sri Lanka also offer some interesting cases. In 1971, 3 percent of the total population of Bangladesh had access to electricity. Today, approximately 53 percent has access. This is a success story made possible by a rural electrification programme that was started in 1978. The programme created 70 rural cooperatives called *Pally Bidyut Samity* through which more than 50 million people are served. In Sri Lanka, an aggressive national electrification effort that has already seen more than 90 percent of households gain access to the grid with an ambitious target of universal access to electricity set to be meet between 2012 and 2015.

10.3.3 Energy efficiency

Overcoming institutional and economic barriers: India offers an exemplary model for how to promote energy efficiency. The Indian economy, for example, doubled in size from 2000 to 2007 and energy demand is expected to double nationwide from 2007 to 2030. The Government of India has therefore recognized the importance of energy efficiency, passing the National Mission for Enhanced Energy Efficiency in 2009, the second of eight Missions under India's National Action Plan on Climate Change. The Mission's goal is to save 5 percent of energy consumption by 2015, or almost 100 million metric tons of carbon dioxide per year.

This Mission is wide-ranging, and it involves the following schemes:

- Perform, Achieve, and Trade: calling for market mechanisms to enhance energy efficiency within large energy intensive industries;
- Market transformation: accelerating the shift to more efficient appliances and demand-side management programmes, supplemented with financing from the Clean Development Mechanism of the Kyoto Protocol;
- Energy Efficiency Project Financing: promoting fiscal incentives such as tax exemptions for ESCOs and creating a revolving fund to promote carbon finance;
- Power Sector Technology Strategy: promoting retrofits and upgrades at power plants and prototyping Integrated Gasification Combined Cycle clean coal power facilities;
- "Other initiatives" including the creation of public sector energy efficiency companies, state designated agencies, and enhancing public awareness.

An autonomous Bureau of Energy Efficiency also exists within the Ministry of Power, responsible for promoting energy efficiency and designing policy, and State Designated Agencies are statutory bodies set up by states to implement energy conservation measures at the state level. India has an energy efficiency labeling programme, launched in May 2006, and an Energy Building Conservation Code, launched in May 2007. As the IEA has noted, "energy efficiency has emerged as one of the key policy priorities in India's energy sector." [237] The IEA has also estimated that 42 percent of emissions reductions in India during 2010 to 2050 will come from energy efficiency improvements at power plants, industrial users, and homes.[238] Such potential for energy efficiency has been confirmed by multiple independent assessments as well.[239]

10.3.4 Renewable energy

Though many countries within the 18 have demonstrated remarkable success with renewable energy, two especially stand out: Nepal for its promotion of off-grid microhydro through the REDP and Thailand for its policy framework for renewable electricity.

Overcoming institutional barriers: UNDP's REDP in Nepal, now Renewable Energy for Rural Livelihood Programme, offers an excellent example of how to rapidly diffuse microhydroelectric facilities ranging from 10 kW to 100 kW, with an average plant size of 25 to 30 kW. Programme implementation was decentralized to local governments, with District Development Communities and Village Development Communities required to form Microhydro Functional Groups in each community. The Alternative Energy Promotion Center, an autonomous body established in 1996 under the Ministry of Science, Technology and Environment, was tasked with assuming overall management of the Programme.

The intended benefit was to provide customers currently dependent on kerosene and other fuels for lighting with reliable electricity. A secondary benefit came from the promotion of productive end use activities such as cereal milling, rice husking, and mustard seed processing as well as the replacement of manual implements for carpentry by electrical machines and tools, though to prevent deforestation project financing could not be used for sawmills. The REDP required that communities wishing to build microhydro facilities donate land for the construction of canals, penstocks, power houses, and distribution lines voluntarily. Furthermore, villagers were required to contribute labor for civil works related to microhydro units.

Tariffs for microhydro units were set by each Microhydro Functional Group, and were based on loan repayments, operation and maintenance costs, depreciation, and provision of a reserve fund for maintenance. Only schemes expected to yield positive Net Present Value were promoted.

Overcoming the technical barrier: One unique element of the REDP was its emphasis on being decentralized and community-led (local ownership of operations and maintenance). The programme provided extensive training in operations and maintenance for local operators and managers from each local community doing a microhydro project, assigned to each system, so that they would understand technical aspects of operation, bill collection, disconnecting for non-payment, record keeping, and accounting. Turbines and control systems are manufactured in Nepal, and maintenance support facilities and service centers within districts were established and strengthened to provide technical support. Another unique element was that part of REDP project funds was given to promote women's empowerment, skills enhancement, better management of technology, and income generation.

Emphasizing sustainability: From the beginning, REDP focused on financial sustainability of the renewable energy system it supported. Each micro hydro plant was provided financial support and technical assistance to make productive use of electricity and generate revenue to cover operation and maintenance costs. A Community Energy Fund (CEF) is established in each project. This fund focused on coupling hydropower with income generation schemes, and it offered $400,000 in total for the promotion of non-lighting uses of electricity such as agro-processing, poultry farming, carpentry workshops, bakeries, ice making, lift irrigation, and water supply. To support these activities, Rs 10,000 per kW of installed capacity was given (though capped at Rs 250,000 per plant). Resources from partner organizations and the local communities were mobilized through CEF to cover the financing of projects. The CEF also gave grants for power connections from microhydro schemes to members of vulnerable and marginalized communities. Schools, health posts, clinics and hospitals in micro hydro catchment areas are provided energy at a concessional rate decided by the community. REDP also promoted afforestation to not only offset trees felled for the construction of distribution poles but also to support the communities to have their own forest.

As a result of these combined efforts, microhydro system coverage grew under the REDP from only a few thousand homes in 25 districts in 2003 to 40 out of 50 targeted districts and 40,000 households in 2007 and more than 75,000 homes as of December 2012. Now, all 75 districts of Nepal have a District Energy and Environment Section to support communities to install and operate renewable energy systems. REDP started as a pilot project in 1996 and then expanded with the World Bank and UNDP funding in 2003 and is being mainstreamed through the National Rural and Renewable Energy Programme of Alternative Energy Promotion Centre. The Government of Nepal is planning to reach another 150,000 households by 2017 through the National Rural and Renewable Energy Programme.

Overcoming political and regulatory barriers: Thailand has done a noteworthy job promoting renewable sources of electricity. Indeed, the IEA has ranked Thailand's level of policy support for renewables as "high", ranking it more favorably than any other Southeast Asian country.[240] Researchers from Chulalongkorn University in Thailand have also estimated that the country could cost effectively expand renewable energy supply from 1,750 MW in 2009 to at least 5,605 MW by 2022.[241] Much of this potential is the result of Thailand's national feed-in tariff, coupled with the wide-ranging regulations and policy actions undertaken, as shown in table 18.[242]

Table 18 Major renewable-energy-related policies in Thailand

Year	Name	Description
2012	10-Year Alternative Energy Development Plan 2012-2021	Targets increasing the share of alternative energy by 25 percent within the next 10 years, resulting in replacement of some planned conventional (using fossil fuels such as coal-fired or gas-fired based) power plants by renewable power plants.
2009	Corporate Income Tax Exemption for Sale of Certified Emission Reductions	Sale of Certified Emissions Reductions exempt from corporate income tax.
2009	National feed-in tariff	Replaces earlier tariff schemes and offers competitive rates for renewable energy depending on the type of technology utilized ranging from 0.30 baht/kWh for biomass/biogas projects, to 8.0 baht/kWh for solar energy. In addition, there will be an extra 1.00 baht (US$0.03) per kWh tariff (or 1.50 baht [US$0.04] per kWh tariff in the case of wind and solar) for projects that replace diesel consumption in power generation in the relevant areas of the Provincial Electricity Authority (PEA). Seven-year tariff schemes from the commercial operation date of the project, for solar and wind 10 years.
2009	Thailand Energy Policy	Supports energy efficiency and renewable energy through a combination of awareness campaigns, financial incentives, research, and standardization.

Year	Name	Description
2008	ESCO Venture Capital Fund	Assists public and private sector energy efficiency and renewable energy projects through venture capital, equity investment, equipment leasing, carbon market operations, technical assistance, and credit guarantee facilities with an initial capital of 500 million baht (about $14.7 million), to address the issue of the lack of equity capital for small developers. The fund provides up to 50 percent of total equity, and support through equipment leasing. The fund has so far approved 17 projects, including a solar farm, biomass power plants, gasification projects, and lighting devices. The Fund should subsidize underprivileged consumers, rehabilitate localities, compensate people affected by power plant operations, and promote renewable energy. Revenue for the fund is provided by a levy on power generators through the electricity tariffs.
2008	Alternative Energy Development Plan 2008-2022	Sets the goal of increasing the share of Thai alternative energy to 20 percent by 2022. Short term (2008-2011) emphasizes promoting commercial alternative energy technologies and high-potential energy sources such as biofuels, co-generation from biomass and biogas; Midterm (2012-2016) is focusing on the development of the alternative energy technology industry, encouraging R&D to achieve economic viability and the development of a sustainable "green city" model. Long term (2017-2022) should enhance new alternative energy technologies (such as hydrogen and bio-hydrogenated systems), extend green city models throughout Thai communities, and encourage exports of biofuels and alternative energy technologies in the ASEAN region. Various incentives include provision of pricing subsidies/feed-in tariffs through the Small and Very Small Power Producer programmes using renewable energy, co-generation and microhydropower projects for instance, and tax and non-tax incentives.
2007	Tenth National Economic and Social Development Plan (2007 to 2011)	Thailand must increase efficiency and develop alternative energy sources to meet domestic demand. Thailand must maintain average elasticity of energy consumption no higher than 1:1 during the period of the Tenth Plan; increase renewable energy to 8 percent of total, and reduce the ratio of energy use to GDP.
2007	Thai Renewable Energy Development Plan	Attempts to increase solar thermal energy by 5 ktoe from 2007 to 2011 and reach 10,000 cubic meters of solar collectors by 2011, and promotes municipal solid waste, biomass, and biogas.
2001	Small Power Producer and Very Small Power Producer Programme	The Small Power Producer Programme allows private developers to build, own, and operate 10-90 MW power projects and to enter into power purchase agreements with EGAT. Solar energy projects originally received a subsidy of about $0.23 per kWh for 10 years from the start of commercial operations, which fell to about $0.19 at the end of 2009. The solar adder (feed-in) tariff has been hugely successful, with over 1,500 MW of signed power purchase agreements, and the government is no longer accepting new proposals. In the pilot round, about 300 MW of renewable power generation capacity is expected to be installed.

Source: UNDP Country Energy Review for Thailand 2012.

11 CONCLUSIONS

Three key conclusions emerge from the analysis presented in this report. First, though all three goals enshrined within SE4ALL are important, energy access emerges as the urgent priority with providing access to the bottom of the pyramid through the *Energy Plus* approach, emphasizing energy access for productive purposes as the central element. Second, SE4ALL's "bottom-up energy solutions", as documented throughout this report, can play crucial roles in enabling "energy empowerment"—enhancing the political, social, and educational strength of communities through the provision of modern energy services—and in recognising gender roles, and providing their specific needs improving health, and protecting the environment. As such, energy should be included as a primary goal in any global post-2015 development agenda. In reaching this goal, however, it must be recognized that all countries are different and programmes and policies must accommodate the specificity of each country's SE4ALL needs and aspirations. Third, in order to achieve the aim of expanding access in a region as diverse and heterogeneous as the Asia-Pacific, a regional knowledge hub can play a valuable role in guiding SE4ALL country actions. This hub can be established as a partnership or network and can conduct research, build capacity, assist in monitoring and evaluation, promote collaborations, and disseminate best practices.

11.1 Recognize energy access as the most urgent SE4ALL goal

The SE4ALL initiative encompasses three separate goals: universal access to modern energy services, energy efficiency, and renewable energy. Yet improving access represents the most immediate goal, as well as perhaps the largest opportunity for achieving the other goals. This is for, at least, three reasons:

- The ability of the poor to utilize energy for productive purposes for agriculture, enterprise, education, health, and public services does not only bring income to the poor that allows them to pay for and maintain the energy services; it also leads to wider human development impacts that enable the poor to move out of the vicious cycle of poverty;
- In terms of population in the Asia-Pacific, more than four *times* more people lack access to cleaner household cooking devices and depend on dangerous and polluting fuels (2.9 billion) than those that lack access to electricity (687 million). This dependence on traditional cooking devices and fuels produces more significant and severe immediate impacts such as millions of premature deaths, mostly among women and young children;
- Expanding access to lighting, cooking and productive energy uses through decentralised systems is cheaper and involves technologies of a smaller scale compared to electrification through grid extension.

This is not to say, however, that the other SE4ALL goals of renewable energy and energy efficiency are less important. Energy efficiency is equivalent to the "first" energy resource and cheaper as well as easier to achieve—it will produce quicker results than investments in supply-side options such as new power plants or transmission and distribution lines. Efficiency is cumulative, meaning an investment made today in energy efficiency can last for the next few decades, and even centuries. Efficiency more easily enables other SE4ALL goals to be achieved, similar to access. For example, improving the types of lamps and bulbs for a solar lantern or SHSs from incandescent to CFLs or even LEDs means solar systems can be of smaller capacities to provide equivalent qualities of light. Moreover, implementing demand-side management programmes to cut utility load lowers the difficulty of meeting national targets for renewable energy since those targets are often based on projected load. Similarly, improving the thermal efficiency of a household by installing better windows, insulation, and lighting devices as well as passive lighting lessens the needed size of household devices such as solar panels.

Investments in renewable energy and grid electrification can help attain the goals of access and efficiency. Electrification can eliminate the need for homes to rely on burning solid fuels for cooking and heating; electric lighting and electric kettles and rice boilers are only one example of appliances that can displace candles, kerosene lamps and traditional cookstoves. Renewable energy systems such as solar PVs and microhydro dams, moreover, can operate more efficiently/economically than diesel generators in certain markets and/or sites.

Furthermore, the importance of productive use of energy, as embodied in UNDP's "Energy Plus" approach, emphasises that communities should use energy for productive purposes and that improving the capacity and skills of households/ communities, government leadership and support, reliable access to finance and commercial markets, and better access to equipment and technology are needed to enable these productive uses of energy.[243]

The Energy Plus Approach also sits at the intersection of the three SE4All goals. It often integrates energy access and renewable energy goals by using technology for generating off-grid electricity that is selected based on locally available resources such as wind, hydro or biomass rather than fossil fuels. Energy efficiency is also a primary concern because electricity supply is often comparatively costly for the poor and limited in areas that have distributed or off-grid power generation systems. Adopting efficient technologies such as agricultural pumps, domestic lighting and appliances can substantially extend the periods that they can be used for. Similarly, the efficiency of both domestic and commercial stoves can have dramatic beneficial impacts for users.

Considering that SE4ALL is aiming to extend sustainable energy access to such a large proportion of the world that currently lacks it, the Energy Plus approach has a potentially vital role to play. The productive use of energy can help to ensure that those who gain energy access are able to afford and maintain it and do not fall back into energy poverty. Moreover, it will contribute to solutions which ensure that the carbon footprint of those who gain access in the coming years will be minimal.

11.2 Promote "bottom-up energy solutions" and recognize specific country needs

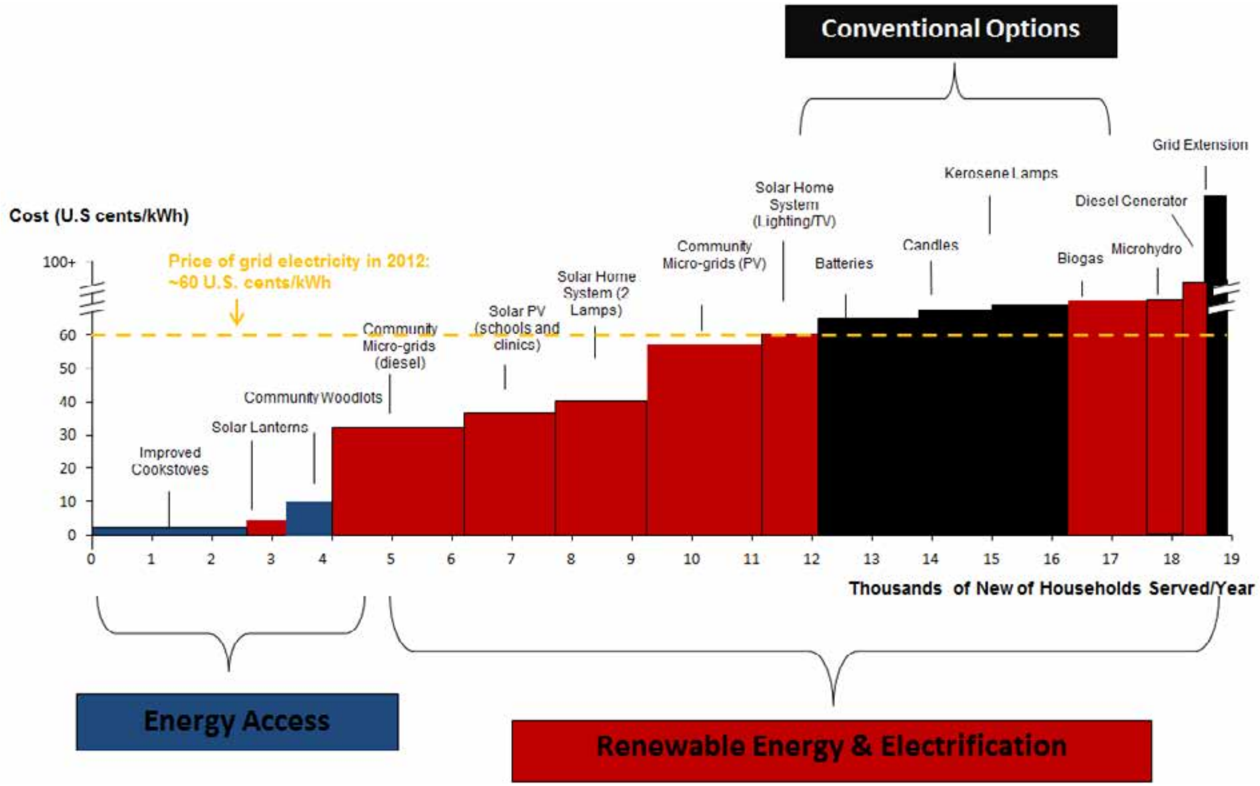
"Bottom-up energy solutions"—off-grid, small-scale, decentralized and community-based energy technologies rather than grid-connected, larger-scale, centralized, and privately owned and operated technologies—have the advantage of versatility, flexibility, and rapidity in terms of their introduction and dissemination within a given market, economy or community, as well as the benefit of responding to the immediate needs of end-users. They have further positive outcomes in terms of productive uses of energy, thus supporting income generation, health, agriculture, education, small business, and telecommunications. They should thus remain an elemental component of SE4ALL activities and programmes , targeting communities that are not served by the central grid or centralized distribution systems.[244]

The report has also shown that infrastructure investment solutions—larger-scale, grid-connected technologies, and extensions of national electricity grids—have a salient role to play as well, for they can often serve larger numbers of people at once. So does energy efficiency, which can cost-effectively curtail rapid increases in demand for electricity and energy.

However, though countries in the Asia-Pacific can certainly benefit from a combination of targeted "bottom-up energy solutions", centralized distribution systems and infrastructure investment solutions, and they can be grouped according to some of their needs, barriers, and potential solutions, each one is unique—and that specificity must be acknowledged when designing particular SE4ALL country action plans. In other words, countries differ in terms of the large-scale investments, reforms, and bottom-up energy solutions needed. As such, planners must fully recognize the specificity of each country in the Asia-Pacific—a region that is vastly diverse.

It could be, as the Country Rapid Assessment and Gap Analyses argue, that the best near-term option for helping Bangladesh meet SE4ALL targets is to ensure that the Sustainable Renewable Energy Development Authority would be able to spend $2 billion replacing diesel pumps with solar power, installing grid-connected solar PV power parks, building integrated systems, and electrifying health centers, educational institutions, unions, religious establishments, and railways stations. The best immediate energy development strategy for Bhutan, Cambodia, Lao PDR, and Nepal could be to focus on the encouragement of improved cookstoves and biomass gasifiers and digesters for household needs, and to harness microhydro and larger-scale hydroelectric dams to displace fossil fuels on the national grid. Indonesia and the Philippines should find ways to further tap their geothermal resources; Mongolia and Viet Nam their vast wind resources.

Figure 22 Energy access cost curve for Vanuatu



Note: The vertical access of the figure shows the cost for various options in US cents per kWh, with some (below the dotted orange line) costing less than grid electricity already. Others (above the dotted orange line) cost more than the grid, but are *all* cheaper than grid extension, which is cost prohibitive at more than $1.20 per kWh. The horizontal access of the figure shows the number of people served by each option (i.e., the larger the size of the square, the wider the bar, the more people served)—with improved cookstoves (about 2,500 people), batteries (1,900 people), and kerosene lamps (1,200 people) having the most potential, but only one of them—cookstoves—low costs of 3 to 4 cents per kWh, whereas solar lanterns cost about 5 cents per kWh, micro-grids vary from 40 to 58 cents per kWh, and biogas and microhydro units cost about 70 cents per kWh. Figure 22 does not show energy efficiency on the chart only because efficiency programmes are at a nascent stage of development in Vanuatu; if fully developed, they would likely fall competitively with the lowest cost energy access solutions.

For Fiji, the best option could be expanding upon the energy audits and retrofits being implemented and conducted at government offices and tourist hotels and resorts, starting an energy efficiency programme for commercial buildings, and promoting energy efficient lighting for households. In India, small hydropower and electricity from biomass and waste represent the cheapest technological solutions to be supplemented with the use of SHSs in areas remote from the grid where they can compete favourably with diesel prices. Malaysia, Sri Lanka, and Thailand should continue to support grid-connected renewables with their feed-in tariffs and comparatively strong policy frameworks. In PNG, the most immediate concern could be enabling PPL to properly maintain their fleet of power plants. Samoa, the Solomon Islands, and Vanuatu may benefit from implementing biogas projects, find alternatives to fuelwood based cooking, and promote solar lighting.

Indeed, it may be that entirely new tools need to be developed to assess the cost-effectiveness of SE4ALL options for particular countries. One novel tool developed in this report—albeit in limited form—is an energy access cost curve, a curve that shows household effectiveness for yearly investments in SE4ALL. Figure 22 presents such a curve for Vanuatu, and it illustrates that the total number of people that could be provided cost-effective energy access per year is 19,000. However, the figure reveals that the composition, configuration, cost, and number of people served by these measures vary, though it does suggest that the least costly four are improved cookstoves, solar lanterns, community woodlots, and diesel micro-grids.

These examples, and the particular cost curve for Vanuatu, suggest that no "one-size-fits-all" approach exists for achieving SE4ALL by 2030. Likewise, the draft SE4ALL 2013-2015 Strategic Work Programme discusses unique "steps for country engagement", acknowledging that each country has distinct needs.

11.3 Create a knowledge hub to increase partnerships, disseminate best practices and conduct further research

To improve coordination between development actors, governments, private sector, civil society, and other stakeholders, and to ensure successful implementation of the SE4ALL agenda, an Asia-Pacific regional knowledge hub should be established to share successful experiences, learn lessons, increase partnerships and collaborations as well as maximize impact of actions. The hub can be established as a partnership or network to serve as the center for coordination of country actions related to SE4ALL. It will communicate and encourage implementation of the initiatives of the Executive Committee and the Global Facilitation Team of SE4ALL, and ensure that at the country level, governments and all stakeholders have the means and knowledge necessary to implement their country action work plans and engage proactively in high impact actions to achieve the goals of SE4ALL.

Development actors and stakeholders need not reinvent the wheel. Instead, countries can learn from each other, and good (and bad) practices certainly exist. Development partners can play a key role creating a knowledge network to facilitate cross regional and cross country exchanges, draw out new innovative approaches and work, and carry forward the SE4ALL initiative. The global SE4ALL Practitioner Network on Energy Access and the Asia Equitable Energy Access Network offer valuable resources on which a regional hub could engage.

Apart from disseminating best practices, such a hub could also promote research. The specificity of country needs (second conclusion) implies that further research and tools are needed to help refine an understanding of both the energy requirements and cost-effective energy resources for reaching SE4ALL goals. The assessments initiated with the national Rapid Assessment and Gap Analyses and Country Energy Reviews could be supplemented, strengthened, and complemented with:

- Robust guidelines outlining methods for development partners, private sector, and civil society to implement energy access programmes in line with an Energy Plus Approach;
- Training and advising national actors in the design and provision of household surveys to generate basic data about energy use and consumption patterns, as well as the tools to conduct more rigorous resource assessments for renewable energy and energy efficiency;
- The development of new and innovative tools such as the energy access cost curve shown above to help determine which investments generate the best return per dollar expended, especially for the poorest communities that continue to "fall through the cracks";
- The development of an incubator programme targeted at startups in the "energy access for productive use" space, providing appropriate framework(s) for the scale up of various energy service delivery and business models, including pro-poor public-private partnerships; and,

- The facilitation of country level investor forums bringing together project proponents, developers, financiers, brokers and investors.

The hub could also build on the idea of "investment readiness" presented in the draft SE4ALL "2013-15 Strategic Work Programme", an attempt to identify the countries that are ready for private and international finance investments in sustainable energy. Though clearly a work in progress, the concept of "investment readiness" currently rests on a number of criteria including country track records of implementation capability, the existence of enabling policies and lead agencies, and a conducive "macro-economic environment," among others.

A third task for the hub would be monitoring and evaluation. For example, the knowledge network of the hub could independently review and assess participating countries and partners in sustainable energy access programmes, in reaching the three SE4ALL objectives through nationally set targets and goals. Such evaluations are useful for not only informing countries if they are accomplishing their goals, but also for increasing interaction and feedback among policy makers and practitioners.[245]

A fourth and final task for the hub would be drawing on the High Impact Opportunities (HIOs) of the SE4All initiative. Work in this area could consider providing advisory support for scalable and sustainable business and financial models that promote renewable energy, energy efficiency and affordable access. It could provide guidance on the design of robust policies, and the necessary enabling environment.

When these types of activities—circulation of good practices, partnerships, research, capacity building, monitoring and evaluation, designing more sustainable and affordable models of —are undertaken in a holistic manner, SE4ALL can become a reality.

APPENDIX I: KEY TERMS AND RESEARCH METHODS

Sources of information

A majority of factual claims in the report come from two sources: the Rapid Assessment and Gap Analyses (RA/GA) that were available at the time of writing, and UNDP APRC Country Energy Reviews for countries which had not yet completed or initiated the RA/GA process or had not opted-in to participate in SE4ALL. In total eight RA/GAs were available at the time this report was commissioned, and another ten Country Energy Reviews that were prepared by UNDP APRC.

The RA/GA is a review process intended to provide a brief look at a country's energy situation in the context of its economic and social development and poverty eradication. It also attempts to summarize progress, challenges, and opportunities vis-à-vis the three goals of SE4ALL and the major investments, policies, and enabling environments required to meet those goals. All national RA/GAs have been carried out following the standard SE4ALL template. All RA/GAs in the Asia-Pacific have been completed through a combination of support from governments and/or development partners, though the actual research and review process has varied from country to country.

Country Energy Reviews were prepared by UNDP APRC through desk-based literature reviews. This research followed the same template as the RA/GA template in order to collect similar information and for the purpose of easy comparison in the regional analysis. However, the research for these reviews was limited to secondary sources and was not able to undergo the same country consultation process as the RA/GAs.

Definition of key terms

Throughout the report, a few terms recur consistently, and deserve proper definition. These include:

Energy poverty: traditionally defined as either lack of access to electricity or dependence on traditional fuels

Energy access: defined by the IEA as "a household having reliable and affordable access to clean cooking facilities, a first connection to electricity (defined as a minimum level of electricity consumption), and then an increasing level of electricity consumption over time"

Electrification: the process of providing households, commercial enterprises, and industries with electricity connections to the national grid

Electrification rate: Number of people with access to electricity, expressed as a percentage of total population. It includes electricity sold commercially (both on-grid and off-grid) and self-generated electricity but not unauthorized connections.

Micro-grid: A localized or isolated grouping of 100 kW or less of electricity generation, distribution, storage, and consumption within a confined geographic radius of 3 to 8 kilometers

Mini-grid: A localized or isolated grouping of 10 MW or less of electricity generation, distribution, storage, and consumption within a confined geographic radius of 50 kilometers or less

Modern energy services: generally, meant here to imply the provision of cleaner cooking and electricity discussed in the definition of "energy access"

Off-grid: Homes or communities that do not have a connection to a national electricity network, micro-grid, or mini-grid

Poor/rural poor households: Households/populations living below the international poverty line of US$1.25 (in purchasing power parity terms) a day.

Traditional fuels: woody biomass, agricultural residues, kerosene, coal, charcoal, dung, and firewood

Purpose and scope of report

This report has been prepared with the aim of contributing to the implementation of the goals of the United Nations Secretary-General's SE4ALL initiative, and it provides a review of sustainable energy challenges and opportunities in selected countries across the Asia-Pacific. The information presented here has been compiled for the purpose of continuing a discussion amongst governments and development partners in the region, focused on how to proceed towards these goals together using the framework established under SE4ALL. The report also seeks to assist with the implementation of the following three strategic approaches given the three goals of SE4ALL:

- Support the development of a renewable energy roadmap to expand the rate of use of renewable energy systems and increase renewable energy-based capacities for energy security and energy self-sufficiency;
- Support the local development, manufacture, assembly of quality renewable energy technologies and equipment and support systems for sustainability, including formulation of a renewable energy research and development agenda; and
- Support towards climate-proofing, rehabilitating and improving energy systems and infrastructure, including assessment of local energy development plans.

At the time of writing, many countries had opted-in to the initiative and had undertaken preliminary assessments of their energy sectors. Steps were also being made to define how private sector participation and investment could support the development of the energy sector. The context of these developments presented a timely opportunity to carry out the comparative analysis presented here and to set a baseline for regional cooperation.

As of December 2012, 11 countries in the Asia-Pacific had decided to participate in SE4ALL and had completed, or were planning, the RA/GA expected from all participating countries. All of these countries were selected for analysis in this report.

In addition to these countries, China and India are members of the previous Governing Board and hence have been actively engaged in the SE4ALL Initiative. India was included in the analysis, as were Thailand and four additional Pacific island states (PNG, Samoa, the Solomon Islands, and Vanuatu), to provide greater representation to South Asia, South-East Asia and the PICs. The final pool of 18 countries, shown in table 19, were selected to give a more representative overview of energy issues across the region.

Table 19 Countries reviewed in this report

SE4ALL countries with RA/GA complete	SE4ALL countries without RA/GA or RA/GA in process	Non-SE4ALL countries
Bangladesh	Cambodia	India
Bhutan	Fiji	PNG
Indonesia	Nepal	Samoa
Lao PDR	Philippines	Solomon Islands
Malaysia		Thailand
Mongolia		Vanuatu
Sri Lanka		Viet Nam (draft RA/GA)

The reports are available upon request from registry.th@undp.org

Additional countries would have also been included, but this was curtailed by time and resource constraints, and as a result the sustainable energy issues of some of the countries with significant numbers of energy poor (such as China, Pakistan, and Myanmar) have not been addressed here. Nor does the report include a number of the Pacific island states that have indicated their support for SE4ALL through their adoption of the May 2012 Barbados Declaration on Achieving Sustainable Energy for All in Small Island Developing States, but who have not formally opted-in to the initiative. These include the Cook Islands, Marshall Islands, Nauru, Palau, Timor-Leste, Tonga, and Tuvalu.

Analysis

In sorting through all of the data available from the RA/GAs, Country Energy Reviews, and secondary literature, especially for the section on the barriers, this report relied on two key concepts: grounded theory, and the social science systems approach (sometimes known as the "socio-technical systems approach").

Grounded theory—also called "interpretive tacking", "grounded reading in data", and "the discovery of theory from data"—enables researchers to draw conclusions from vast amounts of data when no clear theory or concept exists to guide interpretation. Basically, being "grounded" means the research began without preformed hypotheses. Instead, the process forces researchers to develop a conceptual account from the "ground up", the analysis being "grounded" in the data collected itself.[246] A grounded approach works exceptionally well when few relevant theories yet exist to explain what is being studied, as was the situation with understanding the dynamics of SE4ALL in the Asia-Pacific.

The process of "grounding" and synthesizing data led the author to consider utilizing the social science systems approach, or socio-technical systems approach, to help guide the structuring of the section of the report on "Barriers and Impediments". In his seminal *Networks of Power: Electrification in Western Society*, MIT historian Thomas P. Hughes argued that the generation, transmission and distribution of electricity occurs within a technological system that extends beyond the engineering realm. Such a system is understood to include a "seamless web" of considerations that can be categorized as economic, educational, legal, administrative, and technical.[247]

Hughes, and the socio-technical systems approach that he spawned, argues that large technological systems are simultaneously social and technical—or socio-technical—in at least two senses. First, systems require social institutions and technical hardware to function. The electric utility system, for example, contains social institutions such as regulatory bodies and financing firms. At the same time, it encompasses physical objects such as electric generators, transmission substations, and cooling towers. Secondly, systems possess both physical and immaterial components. The electric utility system refers not just to physical artifacts such as steam turbines and distribution wires, but also immaterial or epistemic elements, such as the knowledge needed to repair a broken generator or to construct a new transmission line. Hughes uses this epistemic element of the electric utility system to explain why such systems vary between geographic regions; the different socio-technical environments in Britain, Germany, and the US produced distinct types of electric utility networks. Bringing this back to SE4ALL, the systems approach suggests that in order to reach commercial dissemination and consumer adoption, new technologies—in this case, renewable energy, energy efficiency, rural electrification technologies, and improved cookstoves—must simultaneously address technical, economic and financial, political and institutional, and social and cultural challenges.[248] It thus explains why Chapter Nine on "Barriers and Impediments" follows this structuring.

Review

The contents of this report were distributed for peer review in order to gain feedback on three main aspects of this report: the accuracy of the data used, whether the energy resources and renewable technologies listed were correctly prioritized, and relevance of the main conclusions drawn from the regional analysis. Comments were sought from other UNDP offices, regional development partners, and government colleagues where possible. While an attempt was made to verify all information included here, feedback was not able to be obtained from all of the countries reviewed. As a result, the data extracted from the eight RA/GAs and Country Energy Reviews was assumed to be current at the time of drafting.

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