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Sustainable Electrification for Asia and Africa

Gabrielle DESARNAUD

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Center for Energy

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Abstract

Access to electricity was one of the great forgotten aims of the Millennium Development Goals of 2000. While 1.2 billion people still depend – when indeed possible – on fossil fuels, biomass or candles for lighting, the electrification of developing countries is a catalyst for economic growth. It allows households to redistribute the long hours spent on the search for fuel to other purposes. Electrification favors the development of in-home micro-enterprises and child education. Above all, it gives the opportunity to substitute kerosene and diesel used in electricity generators for less harmful and cheaper energy.

In 2011, the United Nations launched the "Sustainable Energy for All" (SE4All) initiative, which finally brought together international organizations, development banks, as well as private and public actors around common and well-defined objectives, including universal electrification before 2030. In September 2015, promoting access to clean energy became one of the priority missions of the Sustainable Development Goals, which take over from the Millennium Development Goals. However, progress in electrification faces many challenges, linked to the institutional capacities of the countries concerned, unstable legislative and political contexts, a lack of reliable data, the limited financial capacities of populations in need, and demographic growth. Current investments are nowhere near the $32 billion per year required to meet the SE4All target, according to the International Energy Agency (IEA).

The extension of grids in developing countries, which is largely favored by the public opinion and political choices, does not always provide sufficient quality of service. Grid expansion requires investment in heavy and expensive infrastructure, and cannot be profitable in remote or sparsely populated areas. In addition, the United Nations is gradually demonstrating that in areas where connections exist, connected populations nevertheless suffer regular power outages. China's remarkable progress in extending its grids confirms that this solution is not always adapted to needs.

Innovative and promising projects are nevertheless flourishing, as shown in Bangladesh. During the last decade, new and renewable solutions for decentralized electricity generation have emerged, overcoming the technological barriers that hitherto rendered these systems too expensive,

complex and unreliable. Their development has been favored notably by the 75% drop in the price of photovoltaic cells since 2009 (IRENA, 2015) and by a 42% fall in the price of batteries since 2008. These systems are part of a new design of electrification based on a gradual move up the "energy ladder", the first level of which corresponds to a minimal access to electricity to operate a few lamps. While this approach does not lead to a quality of service similar to that theoretically achieved by access to a power grid, it has the advantage of rapidly providing a basic service to households and allowing them to achieve considerable savings.

Such off-grid systems and micro-grids are not yet very widespread. But they are gaining support in a context in which the design of our energy systems is being profoundly re-assessed, and which is pushing local governments to consider innovative and sustainable solutions. However, many barriers must be overcome to create the conditions for flourishing markets and private sector engagement.

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Introduction

The year 2015 was the end point of the Millennium Development Goals.[1] Since September 2000, they had federated some 193 nations in a common struggle against poverty. While spectacular progress has been made in some areas, the issue of access to energy was only addressed indirectly and not as a factor of human development. Over the last fifteen years, however, it has been shown that promoting access to energy not only makes it possible to act directly on poverty, but also to improve social conditions that are more difficult to evaluate, such as gender equality.

In 2013, 1.2 billion people still did not have access to electricity (IEA, 2015) and nearly 2.7 billion people were dependent on cooking fuels that were harmful to health and the environment.[2] Although international institutions such as the World Bank and the United Nations Development Program (UNDP) began seeking to improve access to electricity in the mid-1980s, real international efforts in this area only started 20 years later. In 2011, former UN Secretary General Kofi Annan launched the "Sustainable Energy for All" (SE4All) initiative, which today brings together 101 countries and the European Union, in order to achieve universal access to energy in a sustainable manner, by 2030. Setting this objective made it possible to raise the debate internationally, and to widen its scope considerably. A year later, electrification was formally identified at the Rio + 20 Conference as a critical dimension of the development process. The recent involvement of personalities like Jean-Louis Borloo in France on these issues is a strong political symbol that demonstrates a growing awareness of the issue. The Sustainable Development Goals, successors to the Millennium Development Goals[3], now include energy as an integral component of poverty. Access to energy for all by 2030 (including access to electricity) is henceforth a central objective.

1.The Millenium Development goals covered eight objectives that were adopted in 2000 by 193 member states of the United Nations, which agreed to achieve these goals by 2015. The goals sought to mobilize the international community around common objectives to fight poverty, the eradication of certain diseases, education, and equality between women and men (for further information see < https://en.wikipedia.org/wiki/Millennium_Development_Goals >).

2. Author's calculation using IAE Biomass Database, 2014.

3. The Sustainable Development Goals promoted by the United Nations have replaced the Millenium Development Goals. They take forward efforts to eradicate poverty and foster international development. These goals gather 17 objectives for the years 2015-2030, which now include clear environmental and energy aspects. For more information, see: <www.undp.org>.

But the year 2015 was also the year of climate negotiations, with the signing of a new international agreement in Paris, in December. The agendas of international institutions and multilateral development banks now recognize access to energy as a pillar of development. But, it is also important to highlight the issue of access to energy relative to the challenge of climate change. The global energy system is responsible for 60% of greenhouse gas emissions (IPCC, 2012), and the energy transition will also have to penetrate developing areas which still lack reliable and accessible energy services. The rise of electricity production systems that are disconnected from grids and based on renewable sources specifically allow electrification to be viewed from a new angle.

This research paper starts by setting out the issues concerning access to electricity and the constraints that until now have limited its progress. On the basis of two case studies, Part II then seeks to demonstrate that different approaches to electrification are possible and that decentralized energy sources let us conceptualize electrification in a different manner.

Energy Poverty in the Spotlight

Progress and Stagnation

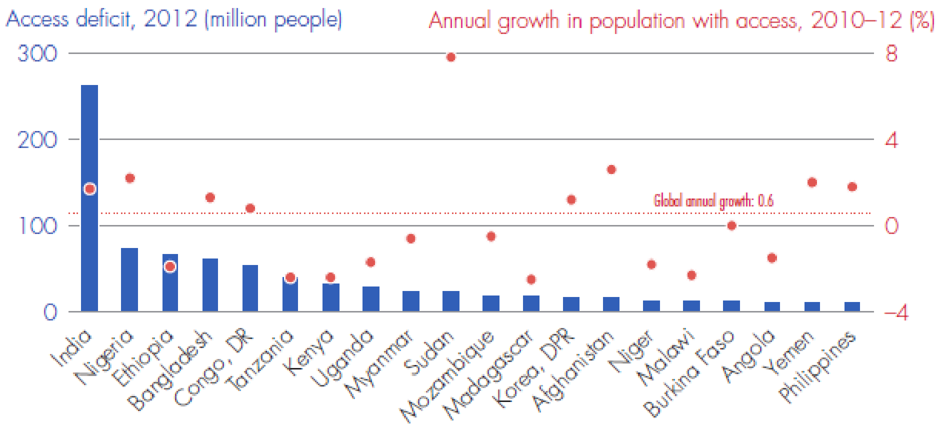
Energy poverty is a multidimensional reality. It refers both to access to electricity and modern ways of cooking. Having access to energy implies some conditions: it must be affordable, reliable and of high quality, in order to provide households with the minimum level of consumption for their needs to be met.

The challenge of energy access is more regularly addressed by governments, international institutions and companies in terms of access to electricity. This stems from the political nature of electricity projects, but also from its role in industrial and agricultural growth. This study focuses specifically on the access to electricity for households, given that electrification for community services (local government, hospitals, schools, etc.) generally follows the same development trends. The current precariousness of access to modern cooking is nevertheless still a factor of mortality, morbidity and severe poverty, while being accompanied by a considerable environmental impact.

Sub-Saharan Africa and Asia alone account for 95% of the world's population without access to electricity (IEA, 2015), or about 600 million people on each continent. But given its demographic size, the rate of electrification is much higher in Asia than in Africa.

Between 2010 and 2012, global electrification increased by 0.6% per year: some countries have significantly improved access to electricity for their populations, while others have regressed, mainly in Africa.

Figure 1: Growth in Access to Electricity by Country between 2010 and 2012, and Energy Poverty in 2012



Source: SE4All Global Tracking Framework 2015.

This is a tremendous step forward as 222 million people gained access to electricity during this period, with an additional 84 million more acquiring access in 2013 alone. However, according to the reference scenario of the World Energy Outlook 2015 (New Policies Scenario or NPS), 810 million people will still live without electricity by 2030, based on current energy policies or policies already clearly stated by governments. This estimate is however lower than the figure announced in 2012.[4]

Africa remains the most vulnerable region with a growth rate of electrification that is well below that of population growth, and where only 18% of the rural population has access to lighting (compared with 74% in rural Asia), while the continent's regional average is 32% (IEA, 2015).

Rural areas are the most disadvantaged, with a worldwide electrification rate barely reaching 68% in 2012, compared with 94% in urban areas (SE4All, 2015). However, the maintenance of quality electricity services in the cities is undermined by population growth and rural-urban migration. In Africa, only 37% of the urban population had access to electricity in 2014, with more than half living in slums without (or with a very precarious) access to electricity.[5] This proportion in itself represents a considerable challenge for electrification. But the fact that sub-Saharan Africa's urban population is set to triple by 2050 must also be taken into

4. The *World Energy Outlook 2012* forecast there would be 969 million people without access to electricity in 2030.
5. For more information see: <www.afdb.org>.

account, given an annual average growth rate of 3.4% which is far above the electrification growth rate.[6]

Moreover, it has recently been recognized that the definition of access to electricity is still imperfect. The assessment of the electrification rate of an area is based on the presence of electricity grids and the number of interconnections. It assumes that electricity generating units are connected to the grid and that there is indeed electricity production, so that access to electricity is assured. However, according to a UN study, some cities such as Kinshasa, which record high electrification rates (90%), yet provide electricity for a few hours a day only due to supply, maintenance or demand management problems (SE4All, 2015). This results in increased dependence on small generators which are often inefficient and fueled by kerosene or diesel at sky-high prices. As a result, households face substantially higher energy bills. New multifactor calculation methods (eight factors are taken into account in the UN's Global Tracking Framework approach) will take time to develop and give a precise picture of the situation. But they should allow for a more accurate assessment of the investments to be made, even where connections already exist. Thus, improving access to electricity in cities could turn out to be far more complex and costly than originally envisaged.

In order to measure better actual access to electricity, some analysts today use a more precise indicator than the electrification rate, namely the minimum level of electricity required per household. According to the IEA, the World Bank and the SE4All initiative, the minimum electricity required to use a few essential everyday devices (lamps, cell phones, fans, radios and/or televisions, depending on the duration of use) is around 250 kWh per year for a rural household and 500 kWh for an urban household.[7] In comparison, an African (excluding South Africa) consumes on average only 162 kWh per year (with enormous disparities within countries), compared with 7,000 kWh for the rest of the world (Africa Progress Panel, 2015). Several other estimates exist according to the criteria selected (ADB, 2015a). The Sierra Club, for example, considers that IEA standards exceed primary needs for urgent use such as lighting.[8] These could be met using a fraction of such kWh levels, provided highly efficient appliances are employed.

6. Calculation of the growth rate and the annual average growth rate using the data and estimations by the Department of Economic and Social Affairs – United Nations, see <http://esa.un.org>.

7. Households are assumed to have five members.

8. The Sierra Club is the oldest NGO dedicated to environmental protection. It was founded in the USA in 1892, and is today involved in promoting renewable energies.

Considerable Joint-Benefits

Electrification has only recently been recognized as a catalyst for economic development. It increases the agricultural yields of family farms, the number of hours spent in education, improves the pumping of water, the sanitary conditions for households, etc. But for the eight out of ten Africans who own a cell phone, it is also the guarantee of being able to communicate, and access the new sources of credit and payment which are experiencing phenomenal growth on the continent, thanks to mobile technologies. All these gains have a leverage effect on households' consumption and their standards of living. Each dollar invested in the electricity sector in sub-Saharan Africa could thus result in a subsequent rise of $15 in GDP (IEA, 2015a).

The cost of energy is particularly high in countries with inefficient infrastructure and energy-intensive alternatives. For example, northern Nigeria pays the highest price of electricity in the world (60 times more than a New Yorker), while on average an African household pays $10 per kWh (Africa Progress Panel, 2015).

The obsolescence of networks also weighs on companies. In Asia and sub-Saharan Africa, power outages can last up to 12 hours a day and result in an average loss of between 7% and 13% of working hours. The cost of these cuts averages $9,000 per year for companies in Africa, and more than twice as much in South Asia (Iarossi, 2009). In Asia, nearly 50% of manufacturing companies have a power generator, compared to 38% in Africa where acquisition costs are higher. In both cases, 60% of the companies whose production is destined for export have invested in a generator.[9] In 2012, these generators supplied 16 TWh of electricity in sub-Saharan Africa, at a total cost of $5 billion, leading to an average price per MWh of around $310 (IEA, 2014a).[10]

The potential effect of universal electrification on the world's climate is a major concern in developed countries, which are putting increasing pressure on developing countries to integrate their economic growth in the energy transition process. Work by the IEA shows that achieving universal electrification would lead to an increase in world energy demand by 2030 of only 1% more than in the reference scenario (NPS), and so lead to relatively low extra increases in CO_2 emissions (IEA, 2012). For example, India expanded its energy services massively between 1981 and 2011,

9. World Bank Enterprises Surveys. For more information see: <www.enterprisesurveys.org>.

10. Between $255/MWh (given a diesel price of $0.75/liter) and $330/MWh (with a diesel price of $1/liter).

supplying electricity to 650 million people. This electrification effort only contributed to a 3 to 4% increase in the country's CO_2 emissions, i.e. 50 million tons (Pachauri, 2014). To be sure, these estimates are extremely fragile. But according to the World Bank, additional emissions would be offset by increased energy efficiency gains, improved management of biomass resources and the retirement of low-efficiency generators. At the same time, renewables are set to grow significantly, particularly in Africa, where they will account for 44% of installed electricity capacity by 2040 (IEA, 2014a).[11]

Major Uncertainties over Investment Needs

According to the IEA reference scenario, investments of $14 billion per year should allow 1.7 billion people to access electricity by 2030. But given the expected rate of population growth during the next 15 years, the number of people without electricity in sub-Saharan Africa will increase by 11% by 2030. Achieving universal electrification would require an additional $602 billion in investment over the same period, in order to finance grid expansion and off-grid systems. These sums do not take into account the investments needed to renovate or replace the degraded distribution and transmission lines. Data on the quality of services provided in areas with high electrification rates (such as Kinshasa cited above) are still too disparate to assess reliably the extent of necessary renovations and improvements.

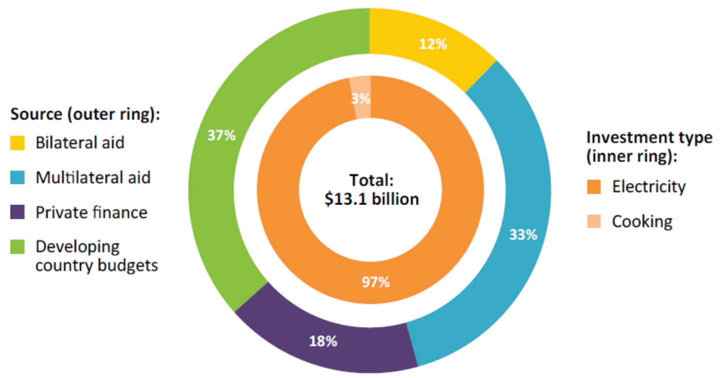
However, investments in projects related to energy access are still largely insufficient today. The SE4All initiative, for example, obtained $320 billion in commitments from development banks, companies, investment funds and NGOs, at the Rio+20 summit. But, only $32 billion of these investment promises relate to projects directly connected with access to energy. The remainder is devoted to energy efficiency and the development of renewable energies in projects that do not necessarily respond to the challenges of energy poverty, even if they contribute to this indirectly and over the long term (IEA, 2012). In 2013, only $12.7 billion was invested in electricity access projects.[12] This result is far below the annual $32 billion needed to attain 100% electrification in the next 15

11. Speech by Akinwumi A. Adesina (President of the ADB) at the High-Level Consultative Stakeholder Meeting, on the New Deal on Energy for Africa, in Abidjan (Côte d'Ivoire), available at: <www.afdb.org>.

12. Author's calculations based on the *World Energy Outlook* 2015 (p. 106), i.e. 3 % of $13.1 billion.

years.[13] Multilateral investment banks are the main contributors, followed by States, with the private sector much further behind.

Figure 1: Investments in Access to Energy by Type and Source in 2013



Source: World Energy Outlook 2015.

A certain number of initiatives do however illustrate a dynamic trend in the making. For example, the President of the African Development Bank (AfDB), Akinwumi Andesina, recently stressed that allocating 10% of the taxes collected on the African continent to the development of renewable energies (i.e. $500 billion a year) is essential to the success of the continent's electrification objectives.[14] It would also push African countries to take ownership of development projects on their soil.

Initiatives such as the Africa Progress Panel[15] and Energies for Africa[16] highlight the role of public funds, which must above all attract private sector finance. The US agency USAID has in fact shown that this approach can bear fruit even in poor markets: every dollar invested by the US government through Power Africa has raised three dollars of private sector investment.[17]

Moreover, a study by the Lawrence Berkeley Laboratory and the Sierra Club shows that progress in energy efficiency would provide acceptable energy access for only $14 billion per year through to 2030, when based on the development of decentralized, renewable energy systems (Craine & Mills, 2014).

13. Author's calculations based on IEA estimates: from 2011 to 2030, a further $602 billion are needed for universal electrification.
14 For further information see: <www.newtimes.co.rw>.
15. Chaired by former UN Secretary General Kofi Annan.
16. Foundation chaired by former French minister Jean-Louis Borloo.
17. For further information see: <www.usaid.gov>.

In Ghana, for example, the development of an energy efficiency policy based on minimum standards for electronic devices and the switch to compact fluorescent light bulbs[18] have saved the country an additional investment of $840 million in supplementary installed capacity. This spending would not have served to meet the needs of households without electricity, but only to overcome existing grid overloads (IEA, 2015).

Indeed, a 40 W solar panel can power a 25 W incandescent lamp for five hours. Replacing such a classic bulb with the most efficient devices on the market would instead allow powering two LEDs for five hours, as well as a television, a fan, a cell phone charger and a radio for three hours (Global Leap, 2015). While this approach is economically sound, it remains technically difficult to achieve in certain areas. Efficient electronic products and electrical appliances are more expensive and rarely supplied to markets in developing countries. The assumption that energy efficiency can provide home comforts with low-capacity, off-grid systems requires the development of whole market segments. These are non-existent in some developing countries, but do indeed present real business opportunities.

Other actors are more optimistic about the future of electrification, such as the Global Off-Grid Lighting Association (GOGLA).[19] In an open letter to the World Bank, GOGLA estimated that $500 million should be enough to allow this sector to move away from a philanthropy-based approach and to create a market for robust off-grid solutions.[20]

The issue of investment is therefore not fundamentally a question of the sums involved, but concerns rather the type of investment to be undertaken. Favoring the extension of networks into remote areas, with low population densities and where inhabitants have very low financing capacities, makes it hard for electrification projects to be profitable. Governance challenges and the lack of competent local administrations create additional risks for potential investors, despite encouraging economic prospects. This is notably so in the nascent sector of renewable, decentralized energies.

18. The efficiency spreads are large, but a compact fluorescent bulb uses about five times less electricity than an incandescent bulb providing the same light. It also lasts seven times as long. LED bulbs allow for up to 90% of energy to be saved compared to a conventional bulb, and has a lifetime 40 times longer. For further information see: <www.presse.ademe.fr>.

19. The association representing major industries and institutions of off-grid lighting, including IFC, d.light, Canadian Solar, Total, Philips, etc.

20. For more information see: <www.global-off-grid-lighting-association.org>.

Rethinking the Access to Electricity: Grid Extension or Decentralized Solutions

There are two approaches to addressing electricity poverty:

- The first suggests that investments must immediately provide a relatively high level of consumption. It involves extending national grids and increasing centralized generating units (using fossil or renewable fuels);
- The second favors gradual access based on the idea that a minimum level of electrification makes it possible to change households' lives and to achieve essential economic gains, while waiting to obtain access to a more complete service.

These two measures are more and more jointly developed by governments, yet numerous barriers limit the deployment of off-grid technologies.

Extending Grids: a Necessary but Limited Option

The extension of national electricity grids has long dominated energy policy in developing countries, but raises significant challenges.

First, access to grids is often linked to the installation of generating capacity using fossil fuels. Countries with large domestic coal resources, such as India, are likely to invest heavily in coal-fired power plants to supply a growing network. Although centralized renewable energies are becoming competitive in some areas, their large-scale deployment faces many obstacles, particularly in countries where electric grids are not suited to managing supply intermittency.

Second, extending grids is not an option that is always economically justifiable. Connecting to a grid may not be profitable in sparsely populated areas, and may be detrimental to the quality of supplies which can be ensured over the long term. Experience shows that developing countries favoring the extension of their national grids are not necessarily in a position to maintain them later, nor to increase generating capacity to supply newly connected households. Extending such electricity networks and strengthening them as populations grow is equally challenging.

Investment in new generating capacities and heavy infrastructure is essential and will provide the bulk of electricity supplies to urban centers. But aside the difficulties mentioned above, extending an electricity grid can take years. In contrast, off-grid and micro-grid power systems require flexible infrastructures that can be deployed easily. It is therefore essential to promote decentralized and sustainable systems in some areas, in order to avoid committing to centralized capacities that will delay access to energy for isolated households and will not be adapted to current environmental concerns.

China as an Example and Counter-Example

With its huge population size and a landmass of 9.6 million square kilometers, some 60 years have been necessary for China to achieve a 100% electrification rate in cities and 99% rate in the countryside. The government's particularly significant commitment to rural electrification from the 1980s onwards has played a decisive role in this success.

The electrification of China since the founding of the People's Republic of China in 1949 has been characterized by the increasing involvement of the government, which became the main investor and planner as of the early 2000s. The grid was then aging and poorly developed, particularly in rural areas, resulting in repeated power cuts. There is however little data available on the state of the Chinese electricity sector before 1950. The development policies of the 1950s gave priority to the security of supply for urban centers and for industrial uses. As a result, the gap between urban and rural electricity consumption widened to such an extent that rural areas accounted for only 0.66 % of China's national electricity consumption in 1957. Even in 1978, 50 % of the rural population still had no access to electricity, and only accounted for 13.3% of national demand (Yang, 2003).

In order to overcome the power insecurity of the grid, standardize electricity prices and electrify rural areas, the government launched a reform of the electricity sector in 1988, investing nearly $50 billion in a seven-year renovation program of the grid. This allowed losses on high voltage lines to be cut to 10%. In 1989, China had 100 GW of installed electricity capacity, which reached more than 900 GW in 2009, when the electrification rate exceeded 99%. Extension of the grid has long been China's favored option, even for rural electrification, and the country now operates the largest network of high voltage lines in the world. Where other solutions have been required, they have mainly been considered as temporary measures.

Between 1998 and 2010, the Chinese government invested no less than $58.7 billion in the construction of power plants in rural areas, with the support of the World Bank and the Global Environment Facility.[21] Despite the success of the extension of the grid and the willingness of the government to provide electricity services to its entire population, it was not possible to supply some mountainous and remote areas in this way. Other areas have suffered greatly from poor supplies. The "Brightness Program" launched by the Chinese government in 1996 then aimed at supplying electricity to 23 million people in remote areas using small hydraulic and solar systems. This was followed by the "Township Electrification Program" in 2002. In areas where hydraulic programs were implemented, the electrification rate rose from 40% in 1980 to almost 100% in 2008. The 10th Five-Year Plan allocated $17 billion to pursuing this strategy (Chen, 2009). The Golden Sun program has also deployed micro-grids with a capacity of 500 MW.

From 2001 to 2006, 4 million people gained first-time access to electricity through grid extension and the installation of decentralized renewable capacity, a sign of strong and sustained political will. The electrification of the countryside by extending the grid has nevertheless been extremely costly for the electricity generators which have had to meet a weak and dispersed demand while bearing the cost of long power lines. Prohibitive operational costs have discouraged potential private and foreign investors. However, the political and social implications of extending the network have motivated the pursuit of this strategy, despite excessive construction and maintenance costs, as well as transmission losses. The transmission costs collected were partly used for maintenance, but were insufficient (Luo, 2004).

Decentralized electrification programs have also had mixed results due to the poor assessment of needs, the limited involvement of beneficiary populations, the lack of maintenance programs, so that grid extension has remained the preferred option of local governments and populations.

In 2004, 2005 and 2011, power cuts were frequent and particularly long in the south of China, highlighting the challenges faced by this approach. Nor should the indispensable “war against pollution” resulting from this energy policy be forgotten. The human and environmental damage associated with the use of coal as a fuel for the low-efficiency thermal power plants built during the electrification period is considerable. It costs China a significant share of its GDP each year, according to the Chinese Academy of Sciences (Cole, 2014). Yet, it is important to recognize that the spectacular growth of

21. For more information: <news.xinhuanet.com>.

centralized output capacity based on renewable energies also raises numerous challenges for the Chinese network (connection delays, difficulties in managing intermittence, etc.). The priority given to developing the grid has supported the growth of urban and industrial centers, but the management of such infrastructures in the countryside remains a constant challenge that requires highly developed institutional means and capacities. It should also be noted that these programs were implemented at a time when off-grid and micro-grid systems were still underdeveloped and relatively inefficient, aside from small hydropower systems.

The Emergence of Decentralized Renewable Energy Systems

Technological advances and the gradual decline in the cost of micro-grids and off-grid systems using renewable energy have made these alternatives competitive and easier to deploy in rural areas than traditional grids. They are sometimes criticized for their lack of power, which limits the development of sustained economic activity. However, these new developments make it possible to climb the "energy ladder" and lead to considerable economic gains for the households. In situations of extreme energy poverty, the first kWhs have the most significant impact on households' standards of living. Thus, a clear correlation between the increase in electricity consumption and the improvement in the human development index (HDI) can be observed.[22] Above 2,500 kWh of consumption per year per person, however, further increases in electricity consumption affect the HDI very little (see Annex 2). Favoring the expansion of off-grid systems therefore improves the quality of life in a short period of time, even in suburban areas where the quality of service provided by grids is poor.

22. For more information see: <http://hdr.undp.org/>

Table 1: The Different Levels of the Energy Ladder, According to the Type of Appliances Used

Energy ladder level		Level 1	Level 2	Level 3	Level 4	Level 5
Functions accomplised by level of consumption		Simple lighting and telephone charging	Lighting, television and fans (if necessary)	L2 use + average power appliances	L3 use + high power appliance	L3 use + very high power appliance
Type of appliances	Indicative list	Appliances with very low consumption	Appliances with low consumption	Appliances with average consumption	Appliances with high consumption	Appliances with very high consumption
	Lighting	Occasional lighting	Overall home lighting	Overall home lighting	Overall home lighting	Overall home lighting
	Communi-cation	Cell phone charging, radio	L1+ television, computer	L1+L2+ printer	L1+L2+printer	L1+L2+printer
	Heating and air conditioning		Fans	L2 + air conditioning	L2 + air conditioning	L4 + air conditioning, heating*
	Refrigeration			Refrigerator	Refrigerator *	Refrigerator
	Mechanical appliances			Water pumps, food processors, washing machines	Water pumps, food processors, washing machines	Water pumps, food processors, washing machines
	Cooking			Rice cookers	L3 + Microwaves	L4 + Electric cookers
	Heating appliances				Irons, hair-driers	L4 + water boilers

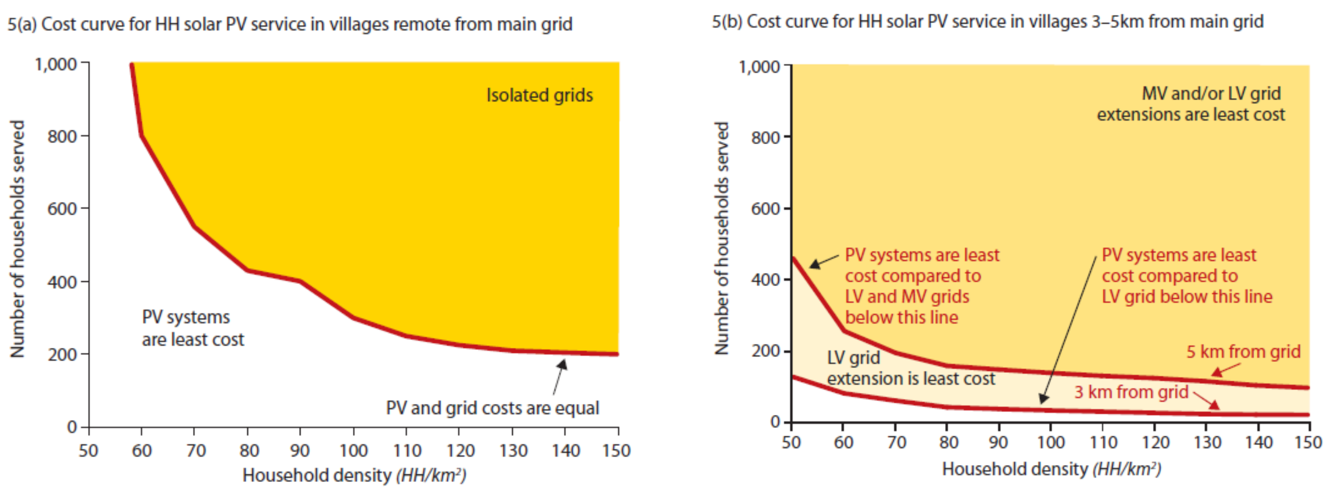
Annual consumption by level (kWh per year)	≤ 4,5	≥ 4,5	≥ 73	≥ 365	≥ 1 250	≥ 3 000

*Intermittent use

Source: Asian Development Bank, 2015.

Accordingly, 70% of households experiencing energy poverty in rural areas have an interest in turning to alternative solutions to access electricity by 2030 (IEA, 2013). For the IEA, remote rural areas could best be served by developing 65% on micro-grids and 35% on off-grid solutions. Renewable off-grid solutions could provide electricity at a cost of between 4% and 20% compared to grid connections (Carbon Tracker Initiative, 2014).[23] In 2011, the cost of supplying a household opting for an individual solar system in Southeast Asia ranged from $0.15 to $0.65 per kWh (World Bank, 2011), leading to a profit of up to $1/kWh. Since then, the price of these systems has fallen further while their efficiency has increased. Most developing countries already use decentralized kerosene or diesel backup systems (generators). But these are expensive, polluting and require fuel supplies that can be difficult to obtain. They are therefore mostly set to be replaced or adapted to function in combination with renewable micro-grids.

Figure 2: The Cost of Deploying Off-Grid Photovoltaic Solar Power Systems by Population Density and Grid Distance



Source: World Bank 2011.

23. For a consumption of 1.6 kWh/day, which is enough to cover basic lighting and the use of low-energy appliances (Table 1).

Some analysts predict that the market for off-grid, renewable electrification will grow at 26% per year to reach $12 billion in sales by 2030 (Craine, Mills et al., 2014). Annual sales of solar lamps have now risen to $200 million. However, A. T. Kerney estimates the potential for this market, which is still dominated by kerosene lamps, at almost $3 billion. The market for solar systems could reach $6 billion a year, and indeed much more taking into account the complementary markets for energy efficient radios, fans and televisions, which large companies in the sector are developing as part of their energy access programs. The private sector is betting on penetration rates of off-grid technologies reaching levels similar to those of mobile technologies in Africa, which have grown far beyond what had been anticipated. Many companies are indeed counting on the prevalence of mobile phones in the lives of Africans in order to offer innovative payment means, and thus allow households to pay their day-to-day electricity bills in small amounts.

The most significant projects have been launched by multilateral development banks, traditionally involved in infrastructure projects such as the International Finance Corporation.[24] The IFC aims to provide electricity to 250 million people by 2030, using decentralized solutions.[25]

Besides, the growing involvement of the private sector in the commercialization of small off-grid systems follows from technological breakthroughs that occurred in the late 2010s. These advances hold out possibilities for positive, albeit low, rates of return. Such private sector commitment is recent, but is bearing fruit locally, and favors above all an integrated approach, including business models specifically developed for realities in the field. Numerous multinational energy companies are on the board of directors of the SE4All initiative. They are also pursuing several projects to develop sustainable electrification solutions. Schneider Electric is participating in the Energy Access Ventures Fund initiative, in cooperation with several international agencies and development funds to provide €54 million to African SMEs in order to ensure access to electricity for 1 million households by 2020, using decentralized solutions.[26] Its Bipbop program is also supporting SMEs in their development models and electrical expertise, in order to ensure the sustainability of funded infrastructures. This latter question of training is essential to generating greater skills in Africa and to keep infrastructures in working order. Similarly, between 2011 and 2015, the "Awango by Total" program enabled

24. World Bank Group.

25. For further information see: <www.lightingafrica.org>.

26. For further information see: <www.proparco.fr>.

1 million households to invest in solar lamps which costs can be covered in a few months even by poor households. The program aims to multiply this figure by five by 2020.[27] While the program does not translate into full energy access, it does allow these households to climb onto the first rung of the energy ladder. The development of young companies in this sector is also increasingly visible and is above all a sign of a buoyant market.

Bangladesh as a Case Study

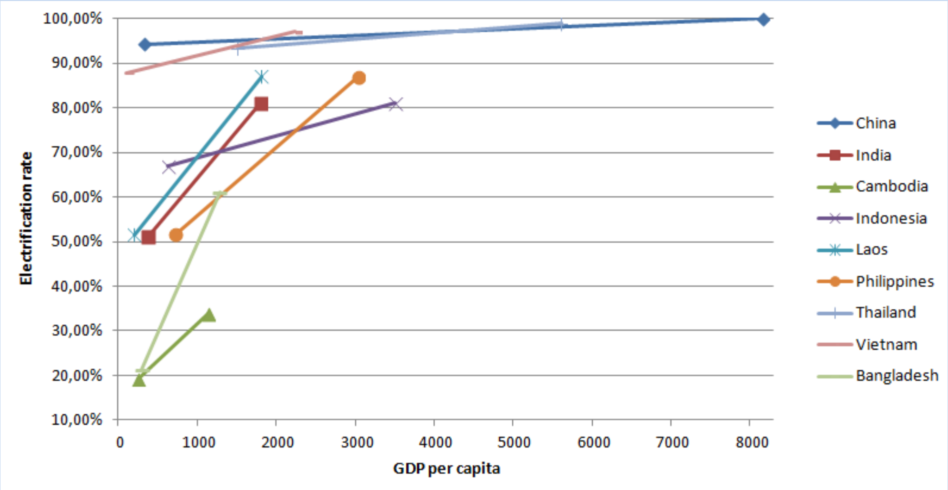
Despite recording economic growth of about 6% per year over the last decade, 43% of Bangladesh's population was still living below the $1.25 per day in 2010. Economic growth in recent years has led to a strong demand for services, particularly in the electricity sector. Installed capacity is approximately 6,500 MW, while demand peaks settle around 8,000 MW, resulting in regular blackouts that weigh on development. Moreover, while the electrification rate is 90% in urban areas, it only reaches 43% in rural areas, where four-fifths of the population lives.

The rural electrification program in Bangladesh was initiated as of 1977. At that time, the Rural Electrification Board estimated that Bangladesh would achieve near-100% electrification in half a century. However, with just over 400,000 new consumers connected to the grid each year, progress has been very slow, while the quality of service has deteriorated with new connections. In the early 2000s, it was considered essential to promote an innovative approach to electrify rural areas at reduced costs. In 2002, the World Bank introduced a pilot scheme to install 50,000 domestic solar systems within six years, in a country in which the market was still in its infancy. By March 2014, 2.9 million had been installed, providing a basic electrification service to more than 15 million inhabitants, with a renewable capacity of 130 MW. In recent years, learning gains have resulted in the installation of 50,000 systems per year. From 2012, the project was able to extend its skills to pumping systems, solar irrigation and micro-grids.

An impact study in 2013 confirmed the benefits of this approach: households that took advantage of solar installations were able to reallocate their energy budget to other consumption items significantly (H. Samad et al., 2013). Food expenditure increased by more than 9% per person and non-food items by almost 5%.

27. For further information see: <fr.total.com>.

Figure 3: The Electrification Rate *vs.* GDP Per Capita in 1990 and 2012



Source: Graph by author based on the IEA Electricity Database 2014 and data from the World Bank.

The above graph also shows that the country's electrification rate tripled from 1990 to 2012, while per capita GDP did not even double. Bangladesh witnessed the highest rate of electrification of all developing Asia.

The success of this off-grid electrification has been based on factors that are unique to Bangladesh. But it is also due to the adoption of a flexible and adaptive approach by the team in charge of the program. For instance, the country already had an extensive network of microfinance institutions which have been chosen as the main vector of the program implementation on the ground. They have been then trained in the specificities of solar systems and played a crucial role in the success of the program. Their knowledge of local conditions, the trust of inhabitants and their experience in development made them extremely efficient partners, requiring little investment in accompaniment and training. In addition, Bangladesh's population density is very high (1,200 inhabitants per km^2), even in rural areas, leading to economies of scale in installation and maintenance.

An upstream campaign fostering awareness, accompanied by a system of guarantees and qualitative standards for the proposed facilities, was essential to the acceptance of the program. The purchase of a solar system was accompanied by the repurchase guarantee of the IDCOL in the event that homes were finally connected to the grid.[28] This guarantee has rarely been used, as households that were fortunate enough to be connected to the grid often preferred to keep their solar power system in order to overcome grid instability.

The program was able to adapt to technological developments throughout its duration, in order to reflect market trends. Initially, only systems above 40 Wp were offered in order to ensure the satisfaction of clients.[29] Today, systems as small as 10 Wp are also available to the beneficiaries. The 30 Wp solar systems (to power a few lamps and a color television), now as efficient as the 50 Wp systems proposed in 2003, are the most popular ones, reflecting technological changes and energy efficiency gains by lamps and electronic appliances. The standards established by the program have been continually revised to ensure the continuous availability of the most effective products.

A tailored financial package has enabled microfinance entities to increase market capacities while reducing their risk, thanks to the support of a major financial institution. Families provide 10-15% of the system price on the basis of a microcredit ($300 in Bangladesh for a 40 Wp system, in 2014), the remainder of which is paid in two or three years (at an interest rate of 12-15%). Between 60% and 80% of the loans granted to households by the microfinance institutions can be backed by IDCOL, in exchange for a five-year repayment at a rate of between 6% and 9%. In addition, lower systems prices, energy efficiency gains and improved household incomes reduced subsidies for the poorest households from $90 per system in 2003 to $20 in 2014, while they have been totally scrapped for other households. At the same time, households can benefit from maintenance contracts and training in basic maintenance. The program has enabled Bangladesh to expand significantly its renewable energy production sector (all components are now produced locally), and the country now has the world's sixth largest labor force in the sector (R. Elahi *et al.*, 2014).

28. Infrastructure Development Company Limited: a financial institution created by the government of Bangladesh in 1998, in order to finance infrastructure and renewable energy projects.

29. The *watt-peak* unit measures the maximum power which can be provided under standard conditions. This unit makes it possible in particular to compare the yields of photovoltaic materials and of installations of different sizes.

Lessons from the Case Studies

- Any electrification program needs the support of committed national and local institutions to be efficient over the long term. It must be supported by a strong political will to act in favor of the poorest, as it has been the case in China and Bangladesh. The involvement of a local partner or a network of small partners is also important to steer the project on the ground. This has been a role that IDCOL and microcredit institutions in Bangladesh have taken on successfully.
- Grid extension following from the addition of centralized capacities, be they renewable or not, does not necessarily benefit populations in need. Some large projects that were presented as being of major interest to populations without electricity access have sometimes served political interests above all.[30] The development of off-grid renewable solutions represents a great opportunity with potential for low-income populations, as the companies and associations that market such solutions have direct access to customers. The instrumentalization of these electrification programs seems more difficult given the current market structures.
- While it is recognized that decentralized systems must primarily equip rural areas, the Bangladesh example shows that they provide an interesting alternative to an unreliable grid in heavily populated areas, particularly in suburban areas and shanty towns, in which strong population growth hampers the development of heavy infrastructure. Indeed, high population densities make it possible to achieve significant economies of scale on feasibility studies, installation, the training of inhabitants and the maintenance of facilities.

30. The Inga I and II dams (1.7 GW) can only operate at 40% capacity due to a lack of maintenance. The electrification rate in the Democratic Republic of Congo is one of the lowest in the world, with only 9% of households having access to electricity and half of businesses using backup generators. Despite this, corruption and the priority given to the mining industry have greatly limited the positive impact of this hydropower production on the local populations. The Inga III project has been criticized all the more because over half of its planned capacity (2.5 MW) is destined for South Africa, especially its mining industry. See: <http://foreignpolicy.com>, or <www.internationalrivers.org>.

- When the country opts for off-grid systems and micro-renewable grids, then providing information and training sessions for the target populations are essential in order to specify needs, expectations, engage communities in projects and win their confidence in new systems. These preliminary steps were neglected in China, resulting in the deterioration and abandonment of many systems.
- A number of guarantees and services must be offered. Poor quality products (including systems using high-polluting, low-life lead-acid batteries with low heat resistance) diminish market potential. Products should be guaranteed for at least two years, in order to obtain the trust of the households and provide them with a return on investment. Maintenance services must be available in exchange for low pay-back for several years after installation.
- Original and appropriate means of payment to poor populations need to be developed. Several solutions have already been developed and some are better suited than others to the habits of the populations concerned. In Bangladesh, microcredit has proved its worth, thanks to the existence of a network of institutions and associations that are already well-established and known by the population. In Africa, the systems of prepayment for small, daily sums of money for the use of equipment lent by companies marketing off-grid systems seem more appropriate. Lease-purchase contracts are also possible. The cost of a renewable decentralized system must be less than, or equal to, the cost that households would be willing to pay for alternative energy sources.
- Regulatory standardization at regional levels is necessary to generate economies of scale. The almost non-existent legislative framework for this type of investment makes the future of markets uncertain, so that the private sector is reluctant to invest (EUEI, 2014). Some tax systems, for example, make importing solar power equipment extremely expensive. The disparity of legal frameworks imposes significant learning curves on companies wishing to expand their activities and does not allow for the spreading of administrative costs from one country to another. This severely limits the possibility for the private sector to expect satisfactory returns on investment. Thus, most projects cannot be launched without public subsidies and are supported by NGOs, whereas most companies already operating in markets benefit from parallel activities capable of bearing a risky investment.

Conclusion

International institutions have clearly identified the problem of access to electricity since the 1990s. But it took two decades to bring this challenge to the forefront of the global arena. Although $1.6 trillion was invested in the energy sector in 2013, access to energy actually made little progress in meeting needs.

The real obstacles do not seem to be linked to the amount of funding to be committed. The IEA itself recalls that achieving universal access to electricity by 2030 would only account for a small share of overall investment needs in the energy sector, while companies operating in the sector are calling in particular for international institutions to support developing countries in building institutional capacities and appropriate regulatory frameworks.

Some models do attempt to evaluate the possibility of electrification using renewable energies alone. However, the most realistic path includes a certain amount of fossil fuels, in particular for increasing electricity generating capacity in urban centers. That said, continuous improvements in the efficiency and flexibility achieved by off-grid systems and micro-renewable grids also suggest they can be used much more widely than is commonly accepted. Many city dwellers are indeed connected to the grid, but are unable to benefit from its services. At the same time, the cost of services associated with the installation of decentralized systems is decreasing strongly in densely populated areas. The impact on climate change of the progress in accessing energy throughout the world will be greatly tempered as electrification moves to using renewable solutions.

Major work in extending grids remains indispensable and has proved its virtues. However, the challenge today is twofold. Electrification must not only respond to pressing health and social needs, but also be achieved in a sustainable manner and respond the imperatives of the energy transition. It is not by chance that we are witnessing a new awareness of the problem, precisely at a time when climate issues occupy the political and media debate. As international climate negotiations have led to particularly significant mobilization, the context is favorable for addressing these issues. The room for maneuver of developing countries is much greater than for those countries whose energy systems are already developed, but have not yet been amortized. Private sector actors who are beginning to address this issue seem to have understood that the electrification offers overall economic returns which are far superior to the sums invested in its development.

Off-grid systems and micro-renewable grids may provide an opportunity to maximize the benefits of electrification. They enable rapid action in favor of long-term, sound and sustainable development and the first kWh they generate really makes a difference. To the extent that off-grid systems and micro-renewable grids are directly addressed to households, they also offer the opportunity to circumvent institutional abuses in some countries, which undermine electrification projects through corruption and political ambitions that do not always serve the most vulnerable.

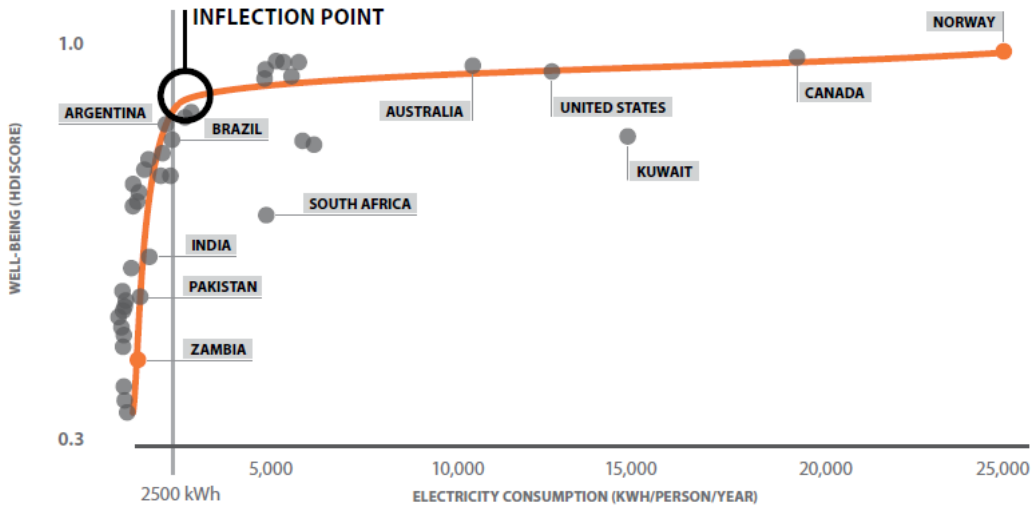
Annexes

Annex 1: Off-Grid Options in Renewables for Remote Regions

Energy service	Sources of off-grid energy already used	Examples of off-grid renewable energy sources
Lighting and other small energy needs for homes, schools, street lighting, vaccine storage, etc.	- Candles - Kerosene - Batteries - Refrigerators using kerosene - Recharging batteries with occasional grid connection	- Hydraulic systems (micro and pico) - Biogas from family digesters - Small gas fires - Micro solar/wind power grids - Individual solar power systems - Solar powered refrigerators solaires
Communications (televisions, radios, cellphones)	- Recharging with occasional grid connection	
Energy for small- and micro-enterprises	- Backup diesel-powered electricity generators	- Micro-grids based on micro-hydraulic, gasifier and large digester systems
Water pumping (food & agriculture)	- Diesel powered pumps and generators	- Mechanical pumps with windmills - Small solar-powered pumps - Micro-grids based on micro-hydraulic, gasifier and large digester systems

Source: REN21, "Renewable Energy Policy Network for the 21st Century" (2010).

Annex 2: The Correlation between Electricity Consumption and the Human Development Index



Source: Power for All.

The level of electricity consumption contributes enormously to increasing the HDI, below a consumption level of 2,500 kWh per person per year. The inflection point after 2,500 kWh shows that, beyond this zone, the link between increases in consumption and improvements in the HDI is less significant (K. Hamilton, Brahmbhatt, 2014).

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