Renewable Energy Potential in Nigeria

Low-carbon approaches to tackling Nigeria's energy poverty

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Cover photo: Solar water pump, NDWC

Executive summary

Renewable energy has considerable potential in Nigeria, and could bridge the major energy gaps in rural areas, particularly northern Nigeria. The scale of opportunities is only just becoming apparent as new grid technologies such as concentrated solar power are emerging as in competitors with conventional power generation.

Changes in technology also mean that solar power, with the correct financing, could bring transformational change to household energy needs. Robust small lighting products starting at under $30 mean that low-income households can benefit, although financing even modest capital costs remains an issue at all levels. Progress in lighting indicates advances that can be made in addressing other needs, given continuing improvements in efficiency and affordability.

The scale of renewable-energy potential is much larger than the public or policymakers realise. Recent studies credibly put concentrated solar thermal power potential in Nigeria at over 427,000MW. Present levels of power generation of around 5000MW meet only a fraction of demand, and renewable energy could play an escalating role. Large-scale renewable power generation could prove transformational, but small consumer- and household-level systems could offer energy independence for the majority with presently limited or zero access to reliable electricity.

The experience of the small number of renewable energy developers in Nigeria over the last decade is crucial to the emergence of viable markets. For the industry to grow, both practitioners and government need to absorb lessons on correct adaption, servicing, installation and efficiency in new technologies. Without incorporating this experience, there is a strong risk of continuing the underperformance which has resulted in near market failure in recent years. Considerable education of consumers and policymakers will also be required for existing negative perceptions to be converted into sound decisions on energy choices.

The cost per unit of power of renewable energy ($0.26–0.50/kWh) remains markedly higher than that of grid electricity ($0.10–0.15/kWh), which is the main reason for subsidies and feed-in tariffs in most countries. Much of the planning and incentives overseas are based around climate change commitments and trends where the rapidly falling cost of renewable energy will make it competitive without subsidies within a decade. In Nigeria, immediate renewable-energy competitiveness is more likely because reliance on generators and kerosene puts the real cost of energy needs in many areas at over $0.50/kWh.

Finance for renewable energy remains a huge issue because the majority of costs for years of use are incurred immediately at installation. The high cost of loans in Nigeria, with interest rates over 20 per cent, is an immediate disincentive to energy investments which would recoup costs over even relatively short periods (perhaps 1–3 years). This is a concern at all levels—for poor families seeking to raise $30 for basic lighting, or for households and businesses which would need to invest many thousands of dollars.

Major improvements in energy efficiency and the cost of renewable-energy products have meant that the amount of capital needed for key applications has declined dramatically. Adapting renewable energy for water boreholes, lighting, refrigeration of medical supplies, and IT uses for rural areas has rapidly become more affordable. There is still a need for capital investment but costs have often fallen by more than 75 per cent in the last five years. Key steps are still needed to link capital, market development and reliability but growth overseas demonstrates that these are steps which could bring about swift changes.

Wide-ranging changes are needed for Nigeria to realise its renewable-energy potential. These changes require application together, and with adequate resources. The following key recommendations reflect the critical need for a holistic approach to change.

Key recommendations

Develop integrated renewable energy planning and investment
The federal government needs to reinforce its existing initiatives by developing both an integrated renewable-energy plan and a systematic major increase in investment in research, market development and regulation of renewable energy.

Provide incentives for renewable energy uptake
Government should also consider incentives, probably through a feed-in tariff, for at least one major pilot of solar thermal power generation in northern Nigeria.

Ensure sufficient and affordable capital financing
Low-interest capital financing for renewable energy needs to be systematically expanded, with increases in available capital matching growth in the industry.

Improve public understanding of renewable energy
Renewable-industry actors and government need to make a significant investment in public education that will improve consumer and policy choices and overcome existing prejudices against the industry.

Cultivate collaboration between renewable energy developers and policymakers
Policymakers and renewable-energy developers need to work closely together to develop best practice options for services in rural areas—particularly for education, health centres and water provision.

Educate on energy use and efficiency
Energy use, particularly energy efficiency and renewable energy, needs to be a core part of the education system as swiftly as possible, with a view to changing public behaviour and expanding participation in a growing renewable-energy sector.

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1 Introduction: potential for sustainable energy development

Popular perception of renewable energy in Nigeria tends to focus on solar and occasionally wind power. Renewables have a relatively short history in Nigeria, especially in the public view. However, renewable energy from hydropower has actually been at the core of Nigeria's grid electricity production since the 1960s. Until very recently, the Kanji and Jebba Dams (1300MW) accounted for around 50 per cent of Nigeria's stable power sources, only recently being overtaken by gas power stations whose role continues to be constrained by the poor state of the national grid and unstable gas supplies.

Power supplies are very limited in Nigeria: electricity from the grid is available to only around 50 per cent of the population, and even then is erratic. This has been at the core of early renewable-energy development in Nigeria. It has provided a strong incentive to find something more stable and that does not result in the constant drain of cash associated with the high costs of power from the 'stand-by' generators which have become the main source of power for many basic rural services.

Wind and solar power in Nigeria are poorly understood by the public and even policymakers. The successes are much less well known than the shortcomings, which have been all too visible with failed solar street-light schemes dotted across Nigeria's major cities. In the public mind, solar power installations have largely joined the many failed projects initiated by government—testimonies to poorly installed technology associated with patronage and corruption.

Yet the successes for renewable energy in Nigeria should give pause to its critics. The small but growing number of solar energy projects that have been faithfully implemented have delivered far greater stability in service than comparable interventions. They also offer the most elusive of gains in rural Nigeria—plausible long-term sustainability. In the areas of vaccine storage, rural water supply and lighting for those on the lowest incomes, there are global innovations and improvements in affordability at a remarkable pace that can be adapted for Nigeria.

Renewable energy should never be considered in isolation. Progress in the field goes hand in hand with improved energy efficiency, which has been vital in driving down costs and making new applications feasible. Compared with the existing costs of power in Nigeria (mainly generators), there is a very strong case for quite radical interventions. This is also in contrast with other developing countries which have a more stable grid electricity supply.

This paper seeks mainly to explore some familiar but poorly understood territory—primarily solar power and energy efficiency, with their implications and potential for Nigeria. It links to work on the power sector, which highlights some of the weaknesses for proposed rapid privatisation, with all the associated risks for those in rural areas and on low incomes.

Coverage of wind, hydro, and biomass power in this paper is very limited—not because they do not share potential but because further work is needed before they can be usefully assessed for Nigeria. The short discussion of energy policy and the recent scenario planning by a team working for the World Bank highlights the (perhaps surprising to many) strong potential for low-carbon energy growth in Nigeria. This is based on the potential for broad development of renewable energy, particularly in northern Nigeria.

2 Early days: niche applications for rural Nigeria

There have been various explorations of renewable energy in Nigeria since the 1990s, with almost all the early experience being in photovoltaic (PV) panel solar power. The four applications of solar power featured in this section are included because as models they have provided key lessons showing how renewable technologies might best be adapted to local needs.

In each case, the models developed are the result of years of iterative improvements by individual organisations or partnerships drawing on both experience and new technology. Only a limited part of the evolution can be properly captured here, given limited space, and it is important to note the role of innovators—both socially progressive companies and NGOs—that have made persistent efforts to demonstrate these new technologies in real-life rural environments.

2.1 Solar water pumping: a model of simplicity

The provision of drinkable water has been a longstanding problem in Nigeria, with reliance in many regions on water pumped from boreholes that are privately owned, or sponsored or developed by government. In all of these cases, there has been perpetual instability because of the cost of operating boreholes when grid electricity is either unreliable or entirely absent. Boreholes in rural areas are normally reliant on generators, which are expensive to maintain and operate. Failures of water supply within relatively short time periods are very widespread in many parts of the country, particularly the Niger Delta.

The Niger Delta Wetlands Centre (NDWC) has been experimenting with solar-powered water boreholes since the mid-1990s. Part of the motivation is to mount a direct challenge to the region's reputation for being 'too cloudy' for effective use of solar power. The Centre has been able to demonstrate model water boreholes developed around several key principles and provide direct evidence against the "too cloudy" hypothesis.

The design of the NDWC borehole water supplies relies on simplicity at all stages. Many solar systems use on a combination of panels, charge controllers, batteries and inverters to capture, store and then use solar-powered electricity. Each of the key components has some requirements for maintenance and vulnerability to failure. This is a significant challenge in an environment where planning and resources for maintenance can be very poor, and knowledge of new technologies such as solar power is limited.

The NDWC response was to balance competing issues to arrive at a design that was as simple and as robust as possible. By opting for a system that could pump sufficient drinking water during the daytime, they were able to opt for a DC (direct current) system that eliminated the need for both batteries and inverters. This immediately removed two components that were most expensive and most vulnerable to failure. As a compensating measure, the system pays attention to likely overall demand for water, with tank and daytime pumping and storage capacity adjusted accordingly.

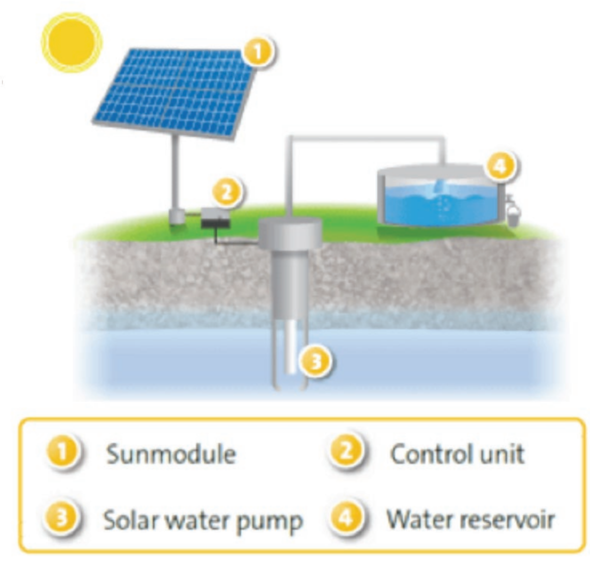

Figure 2.1: Basic components of a DC solar water-pumping system

Source: la.solarworld.com

There are a number of strengths of the system, which are now well proven:

- Investment in quality components is rewarded with extraordinary durability.
- Maintenance costs are low enough to be viable in rural areas.
- There is a continuous fall in the costs of major components, primarily solar panels.
- Efficiency of both pumps and panels continues to improve.

However there are also outstanding issues which have been highlighted:

- Low maintenance is not maintenance free—some trained support is still essential.
- Initial capital costs are still significantly higher than generator/grid systems.
- Capacity needs matching to demand management—systems will pump only within their storage capacity for a 24-hour period and will not 'top up' overnight.

Present position

The potential of this technology is well proven in one of the least sunny parts of Nigeria but several areas need addressing if the technology is to reach its full potential. Many of these have to do with financing, which is discussed in Section 6 of this paper, while eliminating sub-standard installations is considered in Section 5.

After a period that included sponsoring many disastrous installations, the Niger Delta Development Commission appears to have adopted the simplified design first promoted in the region by NDWC as standard practice in rural areas. However, many other government agencies and departments continue to fund either generator-based schemes (despite their consistently high failure rate) or very poorly designed solar systems. There is also very limited exploration of 'right-sizing' drinking-water supply designs to community needs, with a tendency towards single large hubs regardless of practical need.

With shrinking payback periods (see Section 6.4), in which savings on fuel costs fully recoup the extra capital cost between 18 months and 3 years, it seems obvious that the technology should become standard for 'off-grid' or poorly supported locations across Nigeria. Such a decision would also justify the modest investments needed in research to improve the match of system size to needs, and the relatively low cost of regional technical support (see also Section 2.2).

2.2 Small-scale solar lighting products

As with other solar applications, there have been experiments for some years in solar lighting in Nigeria, but these have met with modest success at best. The aim of the few projects seen by the author has been to provide lighting alternatives to kerosene lanterns, and small generators for households on relatively low incomes.

The early systems relied on DC lighting with relatively very small solar panels supported by batteries which could also provide power to small appliances such as radios. They appear to have suffered from the full range of challenges confronting early solar pilots in Nigeria: limited beneficiary buy-in, difficulties in maintenance and supply chains, relatively high cost in the short run, and questions about the aspirations of beneficiaries with a range of needs. Nigeria was never really exposed to the early solar lanterns that started at $100 upwards, with performance markedly below that of products available today.

In the past three years, there has been a dramatic increase in lighting options, affordability and commitment by developers focusing on other parts of Africa, with some laudable innovation also within Nigeria. This has been based on the development of affordable and robust LED lighting attachments, better battery options, along with dramatic falls in the cost of solar-panel components. New products are compact, with battery and LED life spans measured in years (most batteries now being 3–5-year lithium variations), and small portable solar panels smaller than a shoebox.

Sun King
by Greenlight Planet

Power Pack Junior
by Barefoot

Figure 2.2: Examples of small-scale solar lighting

The new generation of products presently entering the market is swiftly creating a full range of choices for households and small businesses—from sturdy kerosene lamp replacements where price is kept to a minimum (as low as $15 retail) to an upper end that may reach $500 for a system capable of stronger lighting across several rooms, also powering a laptop and mobile phones.

There is improving targeting of design to specific potential needs. One design in conjunction with the Federal Ministry for the Environment is targeted specifically at small hairdressing salons, which have an obvious modest power need where designs can compete with a small generator. The World Bank 'Lighting Africa' programme supporting the emergence of this new generation of products has tried to address issues of quality by having a robust quality assurance programme which can give consumers a high degree of confidence about reliability. The technology changes and their potential are discussed in more depth in Section 3.1 of this report.

Present position

In Nigeria, solar lighting for households has shifted from a marginal experiment with serious cost issues to one of significant potential. Collaborations and innovation driven by international initiatives have resulted in exponential growth for small companies operating in other parts of Africa, and a limited but growing appreciation of the potential market and benefits in Nigeria.

The most obvious potential beneficiaries of this new generation of products in Nigeria are the large proportion of the 70 million Nigerians estimated to have no access to grid electricity. The prospect of reliable night-time lighting for both households and small services, without a constant cash drain, is potentially transformational for many lives. Yet the new products are making a modest start in Nigeria.

Even though household-level products have improved radically and come dramatically down in cost, they still require marketing, supply chains, product support and matching with both the means and needs of consumers. Other countries have seen a number of potential methods applied to addressing these challenges, from micro-finance to hire purchase. These solutions are not impossible in Nigeria but have often proved more difficult than in other low-income countries.

Assuming that the present assessments of these products is correct—that over their lifespan they offer transformational changes—then the limiting factors again become finance (see Section 6) and the development of a small consumer industry. The radical simplification and reduction in cost of solar lighting products also means that something new could be encouraged to develop in Nigeria—modular mixing of small solar products that can be matched and upgraded according to need, budget and the changing situation of households. Crucially, small solar products have reached a point where they represent modest but durable assets that are relatively portable and have a very significant lifespan.

2.3 Refrigeration (vaccines and medical stores)

Early solar-power applications in refrigeration serve a vital niche health need, as with solar-powered water pumps. However, both applications also present affordable household options as a key aspiration for an overwhelming majority of Nigerians.

For some years in Nigeria, several companies have been installing solar-powered vaccine fridges able to maintain a stable service in rural areas where the resources for fuel and maintenance are predictably very weak. KXN Nigeria won an Ashden innovation award in 2008 for its installation of solar-powered fridges across central and northern Nigeria.

Since starting in 2002, the company reports installing 767 fridge systems in health centres central to the campaign to eliminate polio. The fridges were compact and even then consumed only 60 watts of electricity thanks to insulation upgrades. In 2009, KXN estimated costs per system (including solar and fridge) of around $11,000. This included costs for a specialist company operating in a remote area. An equivalent rural generator-based system would have cost at least $2500–3000, although fuel costs over time would be prohibitive, to ensure the constant temperatures needed for storage. The cost of system failure (or simply running out of fuel), of up to $5400 for a full batch of medicine stored in a single fridge, indicates the powerful incentives for stable power supply.

Interviews with other consultants highlighted successful trials of regional maintenance contracts —where a service provider covered a zone of several states for any fault that arose. This was combined with training on-site staff in coping with the most basic faults and at the time was deemed highly successful. The workload on the service providers was modest because systems proved highly reliable and basic problems were amenable to solutions provided through a remote help desk. Yet cost was obviously a factor limiting this technology to this specialist application, and a full system of panels, batteries and inverters was required.

More recently a UK company, Surechill, has demonstrated dramatic gains in combining further improvements in design and efficiency. It is marketing a fridge which can withstand 43°C for 7 seven days without any source of power, and requires only a 350W solar panel array (just over two standard panels) for completely off-grid operation. As with the innovations in other areas, the efficiency gains here mean that the need for battery and inverter components is also radically reduced. Consequently, this has produced a radical drop in overall cost. Even at introductory prices, Surechill solar units appear set to be about one-third of the cost of previously installed systems.

As with the example of IT centres (Section 2.4), the efficiency gains in solar-powered refrigeration do raise the question of whether many of the benefits could be achieved with a smaller petrol or diesel generator. If a good, well-maintained generator was part of the system, the short-term costs would be lower but the capital investment required for a solar alternative has also dropped to a far less intimidating level. Solar options would still cost more initially, but would win over time compared to a generator. A solar system would require markedly smaller investments in either case compared to a few years previously, but the stability and lack of daily inputs required for a good-quality system remains a winning factor for solar power.

Present situation

Solar power continues to be a major factor in the provision of stable fridges and supply chains for vaccines. Yet interviews with both solar practitioners and health organisations highlight lessons that appear to have been lost over time. There is a significant failure rate of fridge systems, and persistent concerns around maintenance.

Some of the issues are reminders that solar systems are not the only components requiring maintenance—with basic fridge maintenance and replacement being an obvious issue. Yet there are also cases of solar components failing for the most mundane of reasons (such as dust or leaves on panels), and earlier regional support systems have not been maintained. There is an obvious need to consolidate lessons from earlier years and to take advantage of new technology.

New technology and basic improvements well away from the solar field—more efficient commercially available fridges and freezers—suggest another basic rethink. Just a few years ago, refrigeration for medium-income households was regarded as prohibitively expensive. Now that readily available freezers are offering a basic ‘stay cold’ provision of several days, the mathematics of what small home-solar systems can do needs re-examining and explaining to the public. The gains made by companies pushing the boundaries of innovative design suggest that even more significant gains should be available within the relatively short timeframes that characterise advancements in renewable technologies.

2.4 Off-grid IT centres

The IT sector provides striking examples of the improvement in options for systems supported by renewable energy. There has been a longstanding desire to improve access to information technology and the internet for Nigerians, particularly for those on modest incomes and living in rural areas. The social inclusion, education, access to information and governance gains that should result are all seen as significant in reducing inequality gaps in Nigeria.

However, the problems with maintaining IT centres, particularly in rural areas, have been very similar to those of other small rural infrastructure projects, only worsened by the sensitive nature of the equipment. The cost of power from generators, maintenance of equipment, and damage from power spikes, and general wear and tear, have led to a very high failure rate within a relatively short period. Yet, when an NGO running the STAND governance project in the Niger Delta sought an off-grid solar option using conventional personal computers in 2006, the proposed cost was prohibitive—in the region of $120,000 for powering a relatively small centre.

Just three years later, the successor project manager, SDN, who inherited the same project, was able to opt for a pilot based on newly developed low-energy computers specifically designed for difficult rural conditions. Aleutia PC systems have reduced the energy consumption of a base unit for a PC to around 9W (from around 200–300W in 2006) while flat-screen monitors have more than halved energy consumption for screens. Without even the advantage of recent falls in solar-panel prices, costs for a complete centre fell by over 75 per cent to under $25,000 while the ruggedness of the computers allowed a five-year warranty.

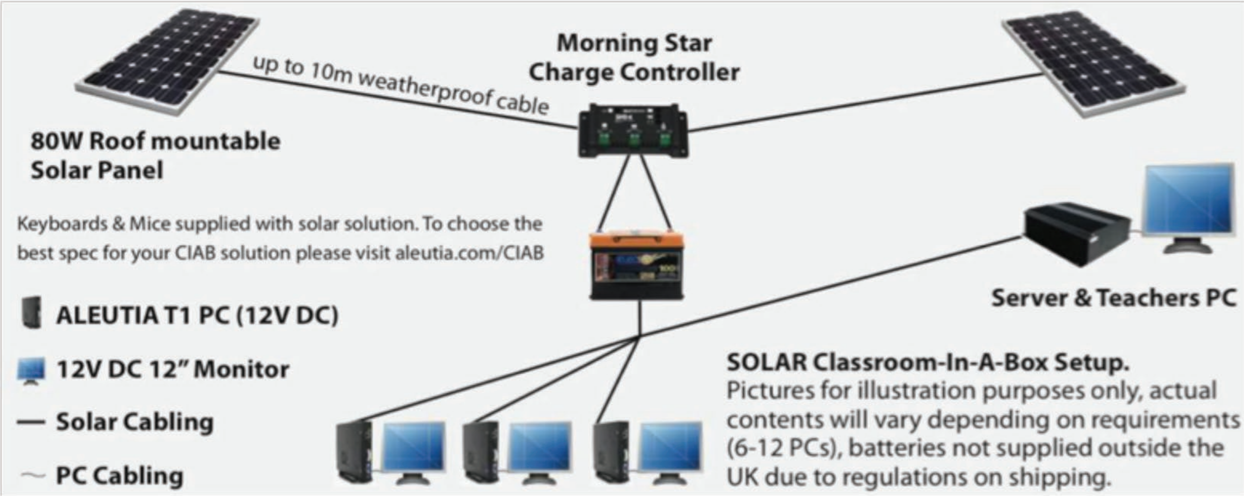

Figure 2.3: The Aleutia computer classroom system

Note: Power use for 6 desktops is 180W (approximately the power use of a single conventional PC).
Source: presentation by Jeremy Weate, Aleutia Nigeria (for more details, see http://www.aleutia.com/solar-lab).

Present situation

There have been several IT centres using the same technology in different parts of the Niger Delta and a few pilots in other parts of the country. Capital and energy demands of systems have fallen further, making it feasible to install stand-alone systems based around a single modest solar panel. Yet, as in other areas of solar technology, wider uptake has been limited.

The potential of solar combinations in IT seems even more clear-cut than in other areas. Continuing advances in the efficiency of computing mean that carefully designed IT centres and classrooms could run on very modest solar systems. Careful selection of hardware could also mean extremely low maintenance and would be likely to reduce the components needed. In schools, there is the potential to make this part of an invaluable exercise in education about energy use and renewable resources.

Many states and agencies are investing considerable sums in IT centres for schools and institutions in both urban and rural areas. These projects often fail early due to limited initial contracting and poor maintenance. The combination of solid-state technology and solar power offers solutions to many of the most common problems. However, progress will require a level of public-sector commitment to the technology and a number of supporting steps. These should include a continued development of the match already occurred in solar lighting—a full combination of efficient, robust and affordable components to deliver overall products of extraordinary value. For laptops and tablets, the match on efficiency is straightforward (with high-end products already available overseas). In Nigeria, there is a need for further refinement of the mix of durable computing, affordable batteries, and carefully matched solar power.

2.5 Lessons from early pilots

All of the pilots and early experiences in Nigeria share characteristics of obvious technical capacity and unfulfilled potential. A significant part of this obviously has to do with finance and market development, yet it is worth reiterating the common factors linking these applications.

- Refined design, with emphasis on simplified combinations of well-protected components that wherever possible are robust and solid state.
- Improving technology and solar efficiency continue to make solar products and systems more affordable and reliable.
- Relatively economical maintenance capacity and basic training for end users remains essential to sustainable performance.
- Education of government and agency managers of development budgets is likely to be critical to market development (see Section 6 for more discussion).
- Access to applied technologies from other countries should be a higher priority, so that adaption for use within Nigeria can be hastened.

3 A bright future for renewable energy in Nigeria?

Despite the slow start for reliable renewable energy technologies in Nigeria, there is reason to be optimistic about their potential. This section discusses markedly different levels of the same technology—from consumer-level products through to grid-level generation. The examples in this section are intended to highlight developments, and capture only some of the changes taking place. Recent progress suggests that the fundamentals and range of options for renewable energy in Nigeria are far stronger than has been realised by most policymakers and the public, and that dealing with obstacles caused by market and finance issues (Sections 5 and 6) should take on renewed urgency.

3.1 Technology for consumer-level products

The improvements in technology described in the pilots and specialist project applications of Section 2 are occurring more broadly and extremely fast. Solar lanterns and household lighting now actively promoted for those on low incomes highlight the pace of change. In 2009, the technology was being promoted with some enthusiasm by development organisations and small specialist companies. The cost of a single lantern was \$100–\$500—difficult to justify for low-income households.

Just three years, in 2012, the technology has consolidated around a dramatically lower price, almost unbreakable LED lighting, and battery life that can genuinely be claimed to be in the range of 3–5 years and still improving. The cost of entry-level products is now around \$25 and the 'payback' period for the capital costs of these products compared with the daily cost of kerosene lanterns is now justifiably being asserted at well under one year, making a whole range of new financing options feasible.

Figure 3.1: Low-cost solar-powered lighting

Notes: LED lights: extended life and more robust. Lithium batteries: with guarantees of up to five years.
Photo: author (Barefoot Power 1W light).

The dramatic progress in lighting is based on developments in different aspects of the end product:

- improved quality and price of solar panels
- complete change in lighting technology
- new generations of affordable lithium batteries
- elimination of components—where stand-alone systems can run directly from batteries without inverters or replacement bulbs.

In addition to these improvements, there has already been one other key change in the market—the emergence of a range of competing products of varying power which provide a choice for households. There is little question that households using basic kerosene lanterns faced a lighting deficit, with lighting inadequate to complete basic tasks. The new generation of solar lighting products offers everything from a significant improvement on kerosene lanterns through to small stand-alone systems suitable for permanent use across a small house. As products and markets improve, we can expect further gains in matching affordable lighting options with actual needs.

At this level, major gains in affordability are being made by eliminating additional demands—there is no need for expensive (and energy-consuming) inverters, and new batteries have improved reliability and portability. The simultaneous improvement in the efficiency of lighting products and solar power has made products markedly more accessible. The opportunity for meeting other needs in a similar fashion appears to be growing. There are improvements in the efficiency of a significant range of products used in households and small-scale services, with electronic products making particularly strong and consistent gains in efficiency.

The current everyday circumstances of most households and small businesses in Nigeria are that they use small computers, LED televisions, radios, and lighting powered by a petrol or diesel generator. Section 4 will make the case that petrol generators cost well over 50 cents per kWh—well above the costs of unsubsidised solar power over even part of its lifetime.

3.2 Large-scale generation potential of 'solar thermal'

Because Nigeria has significant oil and gas supplies (plus substantial coal deposits), renewable energy potential for power generation has been little considered. All of the pilots described here have focused on stand-alone designs, with only the most isolated attempts to explore village-size installations.

Figure 3.2, showing the intensity of solar radiation globally, was used by Lumina Decision Systems in an outline of solar thermal power in Nigeria for a World Bank study. It puts Nigeria on a rough par with Spain—the largest developer of solar thermal power outside the United States. Southern and eastern Nigeria have extended periods of significant cloud cover, which reduces the intensity of solar radiation significantly. This does not mean that solar power is not viable in southern Nigeria. Solar power has relatively

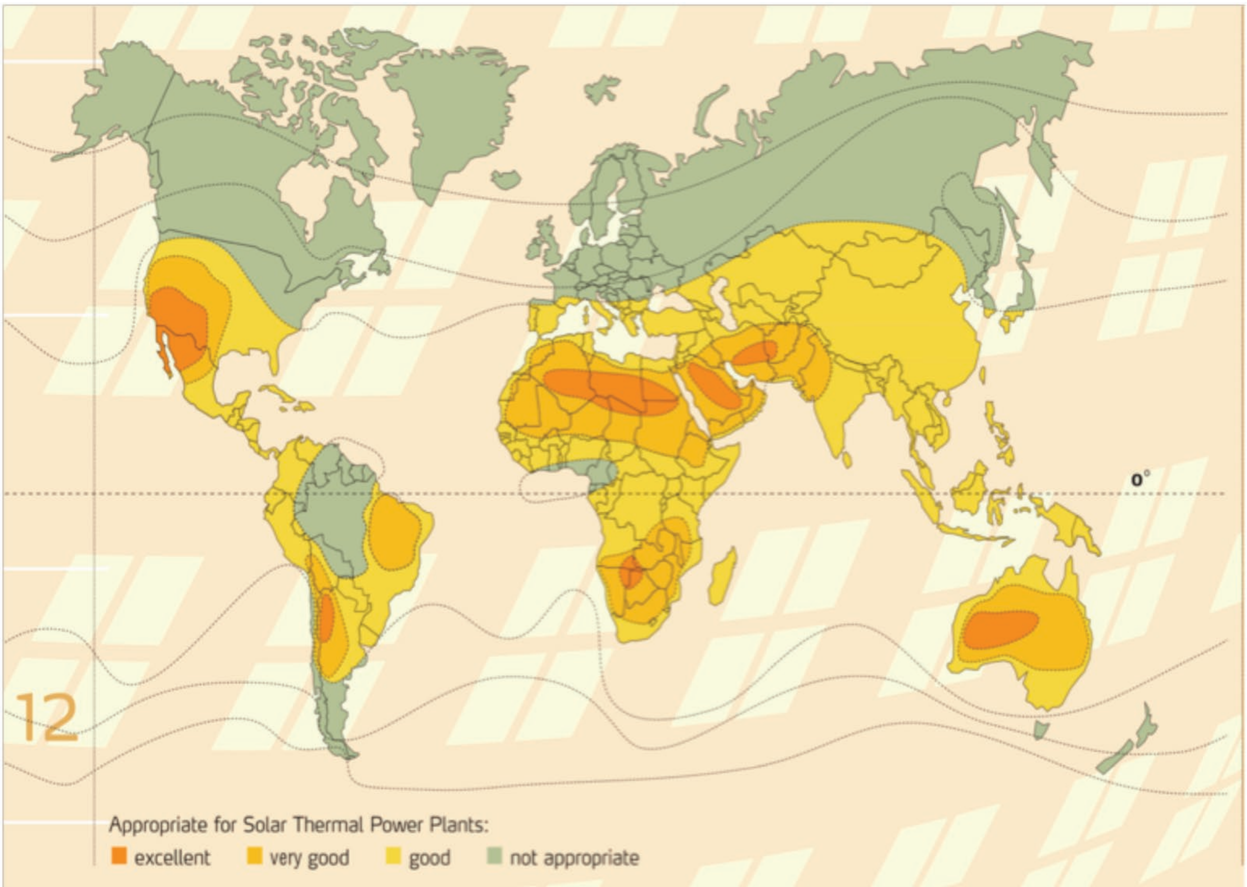

Figure 3.2: Global opportunities for solar thermal power plants

Source: Nigeria Low Carbon Plan: Power Sector: Interim Presentation October 2011, The World Bank, Nigeria.
Note: More detailed mapping and data can be found at http://re.jrc.ec.europa.eu/pvgis/countries/countries-europe.htm.

high-energy processes and needs, using mirrors and concentration of light, while solar PV panels can tolerate a wider range of daily conditions, and have been successfully demonstrated in southern Nigeria.

Solar thermal power is a classic example of an emerging renewable energy technology where its history is very short but confidence is extraordinarily high about its direction and ultimate potential. In a relatively short time it has broken ground on two key challenges—bringing the cost of generation down markedly and also developing efficient energy storage that can deliver power overnight. Solar based around PV panels faces the obvious generation challenge of only being able to provide direct power during daylight, and at night-time is restricted to the relatively expensive option of batteries.

Thermal solar is able to use intensely heated salts to provide an energy source for the same turbines it uses during the day to provide stable and continuous power. The technology is sufficiently young that its cost is still based on few data points and a sharp trend in reducing costs that is assumed to continue. However, the confidence in the technology has already led to the development of the extraordinary Desertec project in the Sahara desert. European companies are already sufficiently confident of pricing trends to plan for a massive installation across northern Africa with high-voltage delivery of power all the way to Europe. The first investments of over $1.5bn are already committed in Morocco, with new-generation transmission costs already regarded as 'modest' additional costs.

The analysis of Nigeria for the World Bank went on to estimate that if 5 per cent of suitable land in central and northern Nigeria was designated for solar thermal then there was a theoretical potential of 42,700MW of power production. However, in practice, the current installed capacity of this technology worldwide is less than 20,000MW.

Cost is the main factor preventing a broad leap to this technology but progress has been as remarkable as with the best of other solar technologies. Pilot plants in 2004 were costing as much as $0.45/ kWh while third-generation systems just a few years later are costing $0.17–0.20/kWh. Although not yet competitive with efficiently installed gas or coal (see Section 6), this is already far below the costs most Nigerian consumers and businesses face for operating predominantly on household generators.

Put simply, northern Nigeria and the Middle Belt appear to be sitting on an energy reserve of massive potential, which is becoming economically viable at a remarkable pace. Given that it is precisely these regions for which power distribution from southern Nigeria would be more expensive and complicated, there is an overwhelming case for in-depth exploration of the region's energy potential. The argument for this is strengthened further by the wide geographical cover of solar thermal potential. In many cases, it should be possible to conceive minimal transmission distances and relatively swift construction compared to gas plants relying on either long pipelines or lengthy transmission grids.

One cautionary note—the anticipated competitiveness of solar thermal plants is based around installations of medium to large scale. The cost-efficiency gains are estimated at as much as 50 per cent scaling from small pilots through to cumulative installations of around 5000MW. This does not detract from its overall potential, but does make it clear for now that there must be preparation for the technology to be treated as a major capital investment.

3.3 Other renewable energy sources

Away from the familiarity of solar PV, other renewable energy sources receive very little thought or attention. Nigeria's strongest source of renewable energy by present size—hydropower—has been the cornerstone of grid-powered generation for decades. In the present context, analysts are able to point to some significant hydropower sources and even some plans, such as the dam for the Mambilla plateau in eastern Nigeria, but the large investments and lead times have been cause for pessimism about their development.

Possibly the most significant change that can be anticipated in the short to medium term with hydropower is an obvious and urgent need to overhaul existing hydro-generation. Turbines in current use are critically aged and producing little more than 50 per cent of their potential.

The least well-understood source of renewable energy in Nigeria definitely seems to be wind power. Until recently Nigeria was thought of by both local and international policymakers as 'not a windy country' but this conclusion is based on a very limited dataset. There has been a relative lack of accessible data to give this support or to contradict it.

In 2005, Lahmeyer International assessed wind speeds in 10 locations in Nigeria, finding average wind speeds of 4–5 metres per second at 30 metres height (implying 5–6m/s at 80 metres height). These are moderate speeds that can certainly justify installations in locations at the upper end of this range, especially those with the most stable conditions. The relative lack of excitement about wind power seems to stem from the fact that these figures do not indicate the massive resources that exist in some 'windier' countries. The potential for wind power in Nigeria is obviously more modest than the massive potential indicated for solar thermal power.

Given the strengthening price-competitiveness of wind power, improving 'niche' applications at modest wind speeds, and the relative ease with which it can be deployed in modular size, wind power deserves better research and pilot deployment in Nigeria. Detailed mapping would provide answers about its potential for rural areas, particularly in combination with other power sources. Mapping available in countries such as the UK shows the level of variation that occurs once highly averaged figures are abandoned in favour of specific local data. While the potential for large-scale generation might be restricted to a few locations, the 'off-grid' potential of wind power in isolated areas, particularly the coastal Niger delta, has simply not been explored.

There is a relatively large wind pilot project being installed in Kano State of 30MW, and a further pilot being developed in Katsina State. These have the potential to provide the first locally accessible evidence of how grid-level wind power operates in local conditions for Nigerian policymakers and the public on the potential role of wind power.

Yet, even more important should be the piloting of smaller schemes for rural areas that are beyond the grid. Often not considered by large-scale mapping exercises, generating combinations could moderate seasonal fluctuations and other constraints. The most successful of these globally is wind power combined with diesel generation for when wind speeds are low. The proliferation of large 'community' diesel generators in the Niger delta provides an obvious place to examine alternatives to the status quo where fuel-supply problems often mean that electricity provision from the generators is occasional rather than reliable. It may be for the same communities that solar and wind are a plausible combination, given that their seasonal strengths complement each other's weaknesses.

3.4 Exploring new territory

If there is anything that should be learnt from the past two decades of hesitantly exploring renewable energy in Nigeria, it is the value of keeping an open mind to the progress of new and improved technology. The fossil-fuel industry is approaching its venerable fiftieth year in Nigeria, while it is only in the last decade that renewable energy other than hydro has even broken into consideration at the margins.

Section 6 will discuss the falling cost of renewable energy, as new technology becomes more accessible and rapidly more efficient. Yet it is far from the cost alone of generation that is driving new possibilities. The following section will discuss one aspect of the key changes that have developed alongside renewable energy—the leaps in energy efficiency in a wide range of devices from computers to air conditioners.

4 Renewable energy, households and efficiency

The previous sections have discussed the potential of specialist applications of renewable energy and large-scale generation, yet it is the 'mass household market' of Nigeria's population of 160 million where the majority of energy is consumed. With such varied needs, it is not possible to analyse here the domestic energy demand of Nigeria, but it is possible to highlight some of the vital themes that should be explored when considering renewable energy.

The consumer-level products highlighted in Section 3 provide some hints of the direction that affordable mass-market products could take. This direction will be influenced by some of the improvements in technology that we have already highlighted, and some of the vital and constantly shifting context of generation and demand that is discussed below.

4.1 Energy needs and aspirations

There is relatively little agreed data on household-level demand and energy needs in Nigeria but there is at least consensus that the scale of the issue is substantial. To give an example of the scale of divergence, we need look only at estimates of suppressed demand for grid electricity. Taking an end-point for aspirations of around 1KW demand per person—around what is found in many developed countries—then Nigeria has a theoretical level of demand of around 160,000MW of generation, against the comparatively tiny level under 5000MW presently being generated.

The prospect of matching demand and supply, even before taking into account industrial needs, appears overwhelming and far from the 'stable power supply' promised by political actors for the next few years. The issues of power generation and plans are discussed in an forthcoming paper by Lai Yahaya but Figure 4.1 is intended to illustrate the likelihood of an ongoing major gap between demand and supply of power in Nigeria.

Data for 'off-grid'-generator power consumption (and demand) in Nigeria are notable for their extraordinary

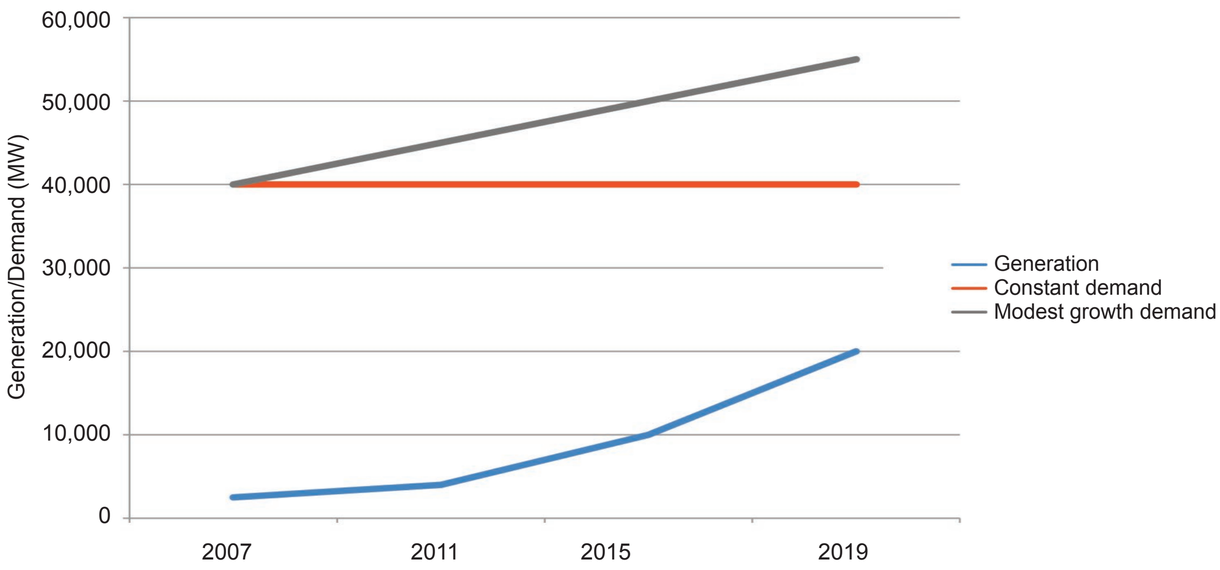

Figure 4.1: Estimated electricity demand in Nigeria

Source: author.

range in estimates. While official figures put demand at 20,000MW, other estimates for a population of over 160 million people put demand much higher. Although it has stronger industrial development South Africa with a population of 50 million people is a useful indicator, with generation capacity of 40,000MW barely meeting demand. Figure 4.1 highlights the ongoing gap if 2007 demand was as low as 40,000MW with just three per cent annual growth in power demand. The gap obviously becomes more dramatic if a starting point of 60,000MW is treated as a more accurate estimate of demand.

Actual suppressed demand is of course much more complicated than a single headline equation. Much of Nigeria's population certainly cannot yet afford the consumer goods that would routinely carry energy consumption to Western levels or beyond. Nor would they readily be able to afford the cost of the overall increase in energy consumption. It is this that has led to estimates of suppressed energy demands of anywhere between 20,000MW and 80,000MW, with all of the analysis relying on disturbingly small amounts of data.

At household level, there are two conclusions that can be drawn from the limited data. First, the shortfall in energy supplies for the vast majority of the population will remain very substantial for the next decade and beyond. Second, the real cost of power will remain that of the business and household generators which have costs of $0.50/kWh and upwards. Power-sector reforms will play a vital role in the economic growth that will come from more grid-electricity generation but there will not be enough power to go around, and many areas will effectively remain locked out or facing substantial rationing.

Within this context of power rationing, and sourcing energy from other options, Nigerian households will continue to prioritise a mix of what appears affordable and accessible. In reality, the question of affordability will be determined by factors beyond the control of most consumers— primarily the reliability of power supply to their area.

4.2 Not a 'single market'

For the purposes of this paper, it is possible to describe three basic tiers of energy consumer who could consider the option of going completely or mostly over to solar power.

1. Households and businesses 'beyond the grid'. Consumers in rural areas, where there is no prospect of reliable grid power within around three years, have only one source of competition for renewable energy—petrol and diesel generators. With cost structures of $0.5/kWh or considerably higher for generators, renewable energy can be immediately competitive despite high initial capital costs.

2. Those 'on the fringe' of the grid. Despite a paucity of truly reliable data, it is clear that for much of the country being on the grid means an unpredictable provision of power that could vary from anything between a few hours per week to 4 hours per day. A very large part of the population is in this group. Again renewable energy is competitive for this group, because grid supply is so limited and unreliable. There is also the possibility that 'optional' heavier-energy-demand tasks can be set aside for grid electricity, thus significantly reducing the size of a solar system needed to support other needs.

3. Those 'only partially blacked out'. In cities such as Lagos and Abuja there are parts of the city that can reasonably expect 8–12 hours of electricity per day on a fairly predictable basis, compared to the rest of the country. Realistically, this group is most likely to benefit from an efficient inverter and battery backup system,[1] which would take advantage of the cheaper cost of grid power while still providing markedly better and cheaper options than a generator when grid power is not available.

1 As with full renewable-energy systems, backup inverters still require a significant capital investment with reliable small home systems starting at N300,000 ($2000), with higher costs if refrigeration and other heavier appliances are to be supported.

Table 4.1: Changing energy efficiency for household products in Nigeria

Power consumption (watts)			
Product	**2002**	**2012**	**Maximum efficiency (for a solar installation)**
Lighting	600 (6 bulbs, 100W each)	120 (CFL bulbs)	80 (LED lighting]
Television	300	50 (flatscreen)	20 (LED flatscreen)
Fridge	500	300	150 or lower (energy-efficient versions)
Fans	150 (3@50W each)	150	120
Total	**1550**	**620**	**370**

4.3 Household choices, energy efficiency and renewables

The choices that households will make about consumer products to meet their needs will have profound effects on both the level of energy demand in Nigeria and the relevance of renewable energy. In simple terms, one of the most critical barriers to the wider use of solar power in countries like Nigeria is the high capital cost at the outset. As has been seen in specialised pilot applications, choices of more efficient products to meet need will have a dramatic impact on the cost of a complete system.

At consumer level, savings made by energy efficiency or by focusing on lower-energy-consuming needs make an impact at every level of a solar power system: fewer panels are required, a smaller inverter is needed, and the number of batteries is also dramatically reduced. Therefore, it is not hard to see how energy-efficiency improvements over the last decade have dramatically improved the odds of modest solar installations meeting household needs. Table 4.1[2] outlines changes that are relatively accessible in Nigerian markets.

For moderate-income households, using appliances as shown in Table 4.1, energy needs have reduced by almost two-thirds for those using new versions of what are now very normal consumer items. The gains are variable, but in some cases progress in items such as computers and lighting it has led to predictions that major advances will occur almost as swiftly as has become the norm in computing power.[3]

The final column of Table 4.1 indicates the reductions that can be made with some additional investment—even if still difficult to obtain in Nigeria where choices remain very limited. The above options do not deal with the occasional demand from heavy-use devices such as irons, kettles and water heating, but dramatically highlight the potential drop in energy needs to meet a core set of day-to-day demands.

The table also highlights another pair of issues: the need for consumers to be aware of their energy options, and the importance of affordable 'high-efficiency' technologies. Without more efficient products in use for local needs, these gains could remain theoretical for many households and small businesses. The ready availability of more efficient products is also critical for consumers considering the option of 'going solar'.

4.4 Consumer education, choices and supply chains

It is possible to see a clear opportunity for renewable energy at household level in large parts of Nigeria. Major falls in the price of solar power and in energy needs provide a powerful combination to compete with generators. Yet these remain only two vital pieces of the more complicated puzzle of consumer choices.

Fundamentally, there will be no significant move towards renewable options unless there are visible and accessible packages that meet household needs. Putting the capital costs aside, there is still only a minimal number of retailers of household solar systems in the market, and their reliability is highly variable. While the supply of energy-efficient products is moderately better, the level of consumer and distributor awareness about the energy value of these products is low or often non-existent.

2 Figures for energy use are drawn by the author from 'average' commercially available products in Nigeria.

3 On the gains made in efficiency of computer products, many of which are now driving the revolution in smart phones and mobile computing, see http://www.extremetech.com/computing/95913-koomeys-law-replacing-moores-focus-on-power-with-efficiency.

There appears presently to be a simple ‘catch 22’ trap in effect. The capital costs of solar systems are restricting the development of supply chains in solar and efficient products that would give consumers the options they need to adopt affordable combinations that suit their needs. Yet it is strengthened supply chains, consumer education, and access to the latest affordable innovations that will provide a further step down in cost that could drive significant demand.

Policymakers, vendors, donors and investors obviously have a common interest in breaking this ‘catch 22’ situation. Their task is not made easier by the present situation. The next section of this paper describes a badly damaged market for renewable-energy products. Yet the basic path would seem reasonably clear—technology has changed and been significantly proven. What remains is the market research, further adaptation and combination of products to match this with the needs of a very diverse population.

5 A broken market?

With the progress demonstrated by niche solar applications and the rapid advancement of energy efficiency and cost savings, one might expect Nigeria's renewable-energy market to be growing rapidly. Instead, the Nigerian solar market is better described as one in which isolated pockets of success are swamped by a swathe of government-sponsored projects that have an extraordinarily high failure rate. Instead of a robust market growing in confidence, there is a nascent industry held back by a reputation that has worsened considerably over the past five years, particularly in southern Nigeria.

In addition, there is a broad reluctance on the part of private consumers to commit to renewable-energy systems (or even inverter-battery backup combinations) because of the high capital outlay. This interplays with a lack of available evidence for ordinary consumers that their investment is likely to be successful. Finding reliable vendors and installers for solar equipment (and evidence of successful models) is difficult and time consuming. This is further complicated by the absence in most cases of reliable warranties or service providers who can provide both good-quality products and maintenance. This section looks at some of the prime causes of a collapse in market confidence, and some of the possible remedies.

5.1 Patronage contracting

The high capital outlay of solar projects has made them relatively attractive to government agencies that prefer large projects and make investments with very little knowledge of what is required in terms of goals, contractors and technical basics. This lack of concern and accountability seems explicable only as a continuation of the patronage contracting phenomenon, wherein the interest of administrators and contractors lies in maximising profit.

Project completion or even short-term sustainability appear to be fluid requirements where 'what you can get away with' influences implementation much more than best practice. Sadly, this is a condition that is not unique to solar power. It is a symptom of development contracting where many of the key actors are more interested in patronage and questionable contracting opportunities than in the end result (Figure 5.1).

Figure 5.1: Solar water project, Delta State, incorrectly installed

Note: This solar system was installed by a contractor to SPDC. It appears to be otherwise functional but was installed at a 15° tilt away from the sun. Image courtesy Niger Delta Wetlands Centre.

Known examples include:

- The Niger Delta Development Commission where dozens of large solar water projects (costing more than $300,000 each) have been commissioned since 2006. Short surveys suggest that the vast majority of this first phase of projects were never completed or failed shortly after installation.
- Millennium Development Goals projects. This presidency agency either contracts out development projects or works in collaboration with states. Concerns have been expressed by reviewers that the majority of projects appear to be failing within a short period with poor quality implementation and maintenance the most common problem.[4]

These shortcomings are not unique to large federal government agencies but also feature in a number of sweeping state initiatives in Nigeria. For example, Nassarawa state commissioned 147 solar water projects in 2004 seeking to provide one to each ward within the

4 Interview with consultant who asked not to be named due to the status of reviews carried out

local governments of the state. A review[5] by Iceberg Consulting commissioned by the state government found that 83 per cent had failed.The reasons for failure are similar to those that the reader will see cited more than once in this report:

- poor technical system design and installation
- inappropriate procurement of both borehole and solar array installation
- little or no training given to the end users in the community
- lack of maintenance.

The practice of poor work carried out through patronage contracting continues, with only limited responses to obvious problems. As with many development projects in Nigeria, there is no effective monitoring of services delivered or consequences for those who have sponsored large numbers of failed projects.

The damage to the perception of renewable energy, both within government and among the public, is substantial. There is an increasing number of communities with experience of a failed solar project of one kind or another, probably significantly outstripping the number of communities with positive experiences where their system is still functioning well after several years of use.

5.2 Difficulties with solar street lighting

Solar street lighting projects have done more damage to the perceptions of renewable energy in Nigeria than any other shortcoming of the young industry. Since around 2003, they became fashionable with state governments as a quick fix for the lack of lighting in urban areas due to failing grid electricity. However, the systems installed typically used cheap and poorly integrated components, underestimated the demand on batteries, and suffered from poor installation and low maintenance.

Most of the designs seen in Nigeria have housed batteries in a metal box on the street-light pole. In tropical areas, this can be a disastrous choice because battery life is usually seriously affected by high temperatures. Many systems will probably have died simply because their batteries were cooked by the very solar energy they were intended to store. Most state-installed systems are reported to have failed in around six months. In Rivers State and Bayelsa, most solar systems installed around 2006 were removed and replaced by standard lighting after failing within 12–18 months. In other states, failed solar street lights remain as silent testimony on how to get solar installation wrong.

Effective solar street lights are challenging but not impossible. The light demanded is at the upper end of what solar power can deliver without excessive cost, although this has improved markedly with the advent of LED lighting. Two rare cases that demonstrated this in Nigeria are lighting at FERMA in Abuja and a complementary system installed by Iceberg Consulting in 2003 in Nasarrawa state that is still functioning eight years later.[6]

5.3 Variable quality of installers and vendors

The marketplace for renewable energy seems feeble at best when compared to other areas with significant grid shortcomings such as Kenya. The massive generator market that has been established over decades in Nigeria to provide generation from the smallest scale of less than 1kva through to support for major hotels also highlights the massive growth that is required if renewable energy is to be a significant part of the overall energy mix in Nigeria.

Until very recently, the few renewable/solar vendors that could be found in the major cities seemed to rely almost exclusively on contracts from government (or oil companies) for installations which they are often under-qualified to complete well. Vendors often seem to be a mixture of the inexperienced with good but sometimes naïve intentions, or quite cynical outfits who have little concern about their products as long as they can limp past an initial inspection and official commissioning. There are good-quality installers and vendors, but they are rare and often very hard to find for those without existing networks.

This weak standing is not helped by the reluctance of private individuals to spend the required funds to secure a small home system or other similar options. In fact, two of the solar vendors visited by the author admitted that they did not have solar systems installed in their homes because of the expense (despite living in cities where grid electricity was often available for as little as 2–4 hours per day).

5 The review with detailed examination of each borehole is available on request from Iceberg Consulting

6 Interview with Louis Gyoh (Iceberg Consulting) January 2012

The challenge for the public and potential sponsors of renewable installations in finding good, experienced practitioners is considerable. Because of the hesitant start of renewable energy in Nigeria, those with 5–10 years experience in the industry seem to be both rare and relatively isolated. On several occasions while preparing this paper the author encountered well-intentioned individuals with the resources to invest in at least small solar installations but relatively little idea where to find a suitable company to complete the work.

There are only limited associations of solar or renewable practitioners in Nigeria, often through other bodies. The Ministry for the Environment's renewable energy programme keeps a database of actors but this does not overcome the relative isolation of practitioners in a very small industry within a very large country.

5.4 Lessons and market therapy

The damage done to the market by the wave of failed sponsored solar projects in the last decade, along with some questionable small products, cannot be easily or quickly fixed. As much of the damage is to perceptions, this suggests one obvious area for attention—highly visible 'best practice' projects which are specifically placed both to demonstrate the best of new technology and to change public perceptions.

Government has a vital role to play here as it could provide venues and sites for installations that will be seen on a daily basis. The government retains a competent core focal point for its engagement on renewable energy at the Ministry for the Environment. It would seem reasonable to expect that projects driven and monitored for their lasting quality and ability to change mindsets could come from here.

Other steps to address the problems in the market require a careful combination of market analysis, specific education of consumers, capital support to a fledgling industry, improved vendor visibility, and the use of regulation to build confidence in the market. Such efforts to build 'an industry' can easily go awry or have unintended consequences. It is vital therefore that these steps are carefully developed in close collaboration with practitioners who have already proven themselves.

The next section of this paper explores one vital element of market development—finance needs for an industry in which capital investment upfront is a defining feature. The key messages in Section 7 then describe a number of broad steps, which together would make a very significant impact on the market failings that have occurred to date. If these issues are addressed together as a coherent strategy, then this opens a clear path towards a strengthening market in renewable energy.

6 Financing renewable energy in Nigeria

The financing of renewable energy projects is seen by both practitioners and commentators as the single largest barrier to the expansion of improved uptake of renewable energy. Even those close to the small industry have held back on adopting systems because of the high capital cost and the relatively long 'payback' time in a difficult environment. This section will discuss some of the evolving issues in terms of capital costs and the consequent financing needs implied for households.

6.1 'Right-sizing' capital costs

Whatever the level of income of consumers, the relatively high capital costs of solar products has been seen as a crucial barrier to uptake of the new technology. In both small-home and business systems, the gap is significant in what remains an overwhelmingly cash economy. This applies at all levels in the market. A householder may be considering a solar lantern costing N3000 with no energy inputs versus a kerosene lantern of N300 with constant fuel needs. Another example is the choice between an investment of N40,000 for a generator versus a small solar/inverter combination of N200,000. In all cases, the challenge of finding the initial capital for solar systems is considerable.

In making choices like these, the gains for consumers must be crystal clear for them to make a major commitment to renewable options. In most cases, this suggests that the process of matching some of a consumer's energy needs with the most efficient of renewable options is crucial to winning both 'buy-in' and meaningful gains.

6.2 The reducing core costs of solar PV

Presently, with a very small market and only modest turnover, it seems unlikely that the gains in reduced cost of solar PV electricity have fully reached Nigeria. It seems equally unlikely that these costs will have been fully factored into the calculations being done by vendors and installers of solar equipment.

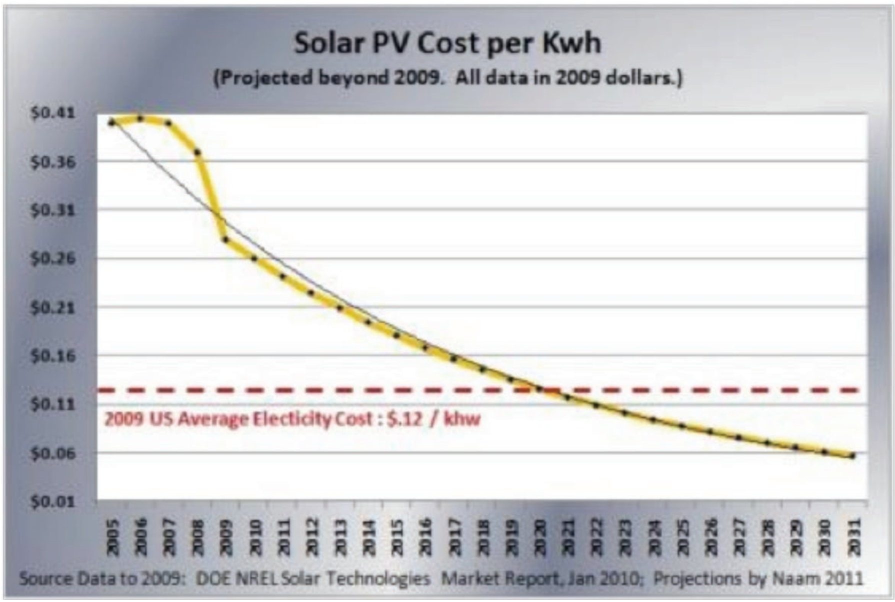

Figure 6.1: Projected costs of solar PV versus conventional electricity, 2005–2031

Source: Nigeria Low Carbon Plan: Power Sector—Interim Presentation, October 2011.

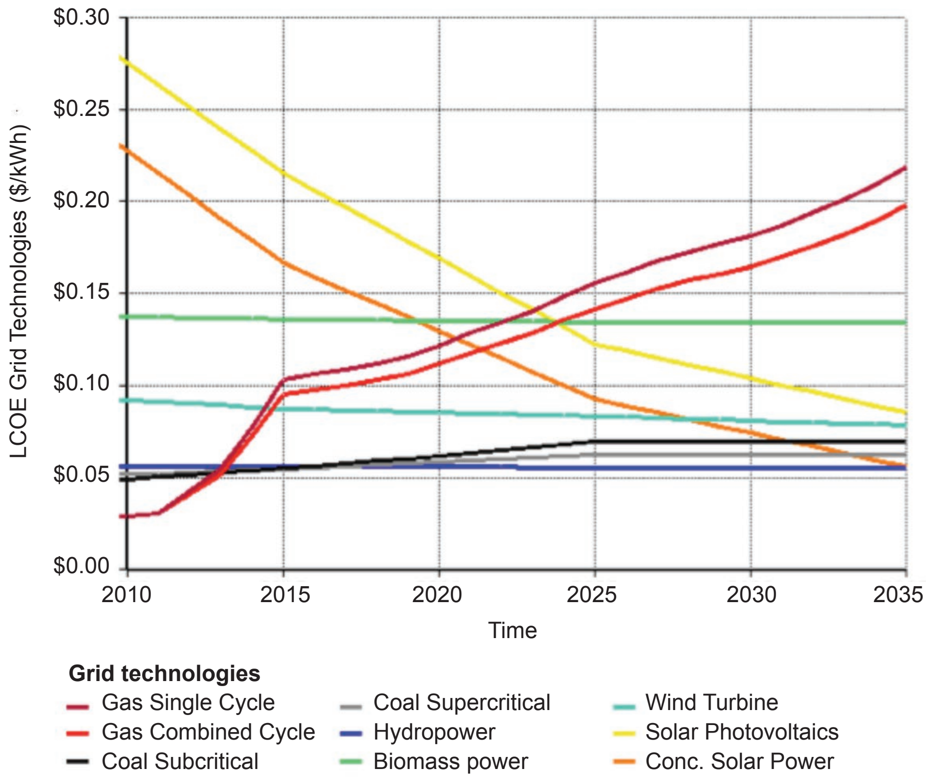

Figure 6.2: Projected costs of different energy sources, 2010–2035

Source: Nigeria Low Carbon Plan: Power Sector—Interim Presentation, October 2011.

However, the drop in prices has accelerated over the past four years. While there is some margin in the degree of optimism indicated in Figures 6.1 and 6.2, comparing PV to other energy sources, the message is the same: the marked improvement in solar technology means that the question is when rather than if solar power will be more competitive than existing fuels.

Figures 6.1 and 6.2[7] both highlight two common themes. The first is the continuing drop in renewable energy core costs. The impact of this at household level can be overstated (see Section 6.3) but the scale of the fall in costs is still good news at both macro and micro scales. It has implications in business planning even for the short term—where it underlines the importance of installers being able to access the best of current products and the need for their customers to be aware of options that give them the best of latest developments.

7 Figure 6.2 is a good example of the many estimates of trends in power prices but it is important to note that it aggregates 'typical' costs rather than highlighting real local conditions. Due to the high cost of generation infrastructure projects in Nigeria, conventional power costs can be assumed to be significantly higher, with a high reliance on gas for generation.

Second, both figures compare renewable to existing grid power alternatives. With so little access to grid power in Nigeria however, reliable grid power is not a realistic option for most Nigerians. Section 6.4 attempts to provide some context for the comparison between renewable electricity and the main realistic competition of generators.

6.3 Installation costs

For smaller projects, whether in Europe or Africa, the fall in the price of solar panels and reduced energy needs have further highlighted one core issue. It is not the theoretical efficiency of a panel that is the greatest determinant of cost and value, but the installation cost of a system. This makes labour costs and sector efficiency all the more relevant in estimating likely benefits for consumers.

In Nigeria, the very small size of the renewable sector appears likely to hold good-quality installation costs higher than in other countries, at least in the short term. Yet this also draws attention to another key goal. With labour costs lower in Nigeria than in many of the countries for which installation comparisons are done, it seems vital to develop technicians who can provide a professional and affordable service. Underlining this are the increasing number of analyses arguing that most jobs associated with renewable energy are in installation and maintenance rather than the increasingly automated manufacturing sector.

In addition to cost- and energy-efficiency, quality is also as important in terms of reliable components. There are several hazards in Nigeria that can easily damage equipment, making renewable energy capital items a markedly more expensive option if difficult repairs or replacements are required. Investment in some additional protection against risks ranging from lightning to accidental damage or abuse have proven to be of very high value to pilot projects, and the same principle seems likely to apply to most consumer situations.

Finally, these costs emphasise why some smaller ‘product’ solutions have obvious advantages where they are appropriate. Good-quality solar lanterns or small DC lighting systems do not require specialist installation skills and, with LED lighting, are exceptionally resistant to damage and abuse. Therefore, small modular applications obviously have a major lead in being able to take advantage of recent gains.

6.4 The competition: generators and kerosene

In comparing the costs of renewable energy, one crucial factor often not taken fully into account is the extraordinarily high cost that most Nigerian consumers currently pay for lighting and electricity. With surveys arguing that 50 per cent of the population have no access to grid electricity[8], and that many more people have access for just a few hours per week, the main energy sources for a very large group lie elsewhere.

Obtaining full spending and cost estimates are challenging. Almost all consumers ration their use of generators, lanterns and alternatives, while there is considerable variability in the efficiency of the systems in use. Further, some estimates do not account for the costs of poor-quality fuel (reducing generator life), gathering fuel, and unpredictable price changes and shortages. Yet better analysis of these costs for most consumers will probably help convince them that a well-designed solar system will save them vital amounts of money over time—whether against the running costs of a generator or the daily cost of kerosene for lanterns.

When considering the case for household consumers, Bermuda and other island nations give a good indicative cost of isolated areas relying on diesel. This area is embarking on a huge drive for energy efficiency and increased use of solar power, partly as a reaction to grid power costing $0.45/kWh. Those engaged on rural projects can further note detailed data from a comprehensive review in Namibia,[9] which tracked plunging payback times as well as performance levels consistent with the experiences of NDWC in the Niger Delta. In both cases, data from earlier than 2010 indicated that the point at which the higher capital investment for solar systems resulted in net savings was under three years and growing shorter. Savings after this point would represent a considerable gain for communities and investors.

6.5 Feed-in tariffs

Both NERC[10] and federal government representatives in Nigeria have stated their commitment (without details) to setting a renewable energy feed-in tariff that will help the sector to grow. In most countries with developed renewable energy capacity “feed in tarrifs” include payments that homes and small businesses can receive for power that they generate in excess of their own needs and feed back into the electricity grid. However, most analysts and stakeholders in the power sector, in informal discussions, have dismissed this idea as impractical in Nigeria given the fragile and confused state of the existing grid. This is almost certainly true for small installations or households, but may not be so easily disregarded for larger businesses that could support significant renewable generation.

If the federal government acknowledges that renewable energy has a strong economic case for development in the medium term, especially in northern Nigeria, then feed-in tariffs that give the industry an incentive to develop should be carefully considered. In Europe, where many of these technologies enjoy less natural advantage, the feed-in advantages are significant. The United Kingdom is in the process of reducing its green feed-in tariff to a still generous 21 pence (52 Naira) per kWh, from over 40p (104N).

8 World Bank worldwide energy assessment 2010 http://data.worldbank.org/country/nigeria

9 http://www.self.org/SELF_White_Paper_-_Solar_vs_Diesel.pdf

10 Nigeria Electricity Regulatory Commission, which has the mandate for setting tariffs, licensing power generation and protecting consumer interests.

Such a tariff might seem extreme in Nigeria, where most analysts expect the gross tariff (before any temporary mitigation) to jump from its present 10N to between 20 and 30 Naira per kWh. Yet conventional estimates of generator costs at around 70–80N ($0.45–0.50) emphasise the need to examine the broad context of cost-benefit analyses. It is also worth considering that some of the challenges of renewable power could well be presented as merits in the context of Nigeria's difficult power situation (Table 6.1).

There are other risks in the concept of a feed-in tariff for Nigeria. Fuel subsidies have proven disastrous channels for contract abuse and fraud. Any feed-in tariff would have to operate with outstanding transparency in a challenging market context. Overall, there may be a strong case for feed-in tariffs to promote swift deployment of large-scale generation of renewable energy in northern Nigeria. This would certainly have the potential to bring about rapidly increasing access to power. However, the benefits would be sustainable only if lessons about management of power, contracting and oversight could be fully absorbed. The emergence of a more credible NERC is a key first step, but the crucial factor is likely to be significant movement on broader power-sector reforms.

6.6 Access to capital

Access to capital at affordable interest rates is crucial to enable investment in renewable energy—at household level or in large-scale generation. The great majority of costs associated with any system of renewable power generation are in advance. In systems with batteries, there are also significant costs after 5 years (when the batteries need replacing) but other components such as panels are expected to last 15–20 years or more. This longevity is fundamental to the calculation of power cost from renewable energy systems, and at the core of justifying the higher costs when first installing systems.

Adequate capital becomes the critical issue for bridging the 'payback period' in funding renewable projects. This is basically the length of time required for savings from 'free' renewable electricity to overtake the costs of grid/generator power, with its constant bills or demands for fuel. However, if the main source of capital is loan financing and interest rates are excessively high, the loan costs become a major factor in the overall cost

Table 6.1: Challenges and responses on the costs of renewable energy in Nigeria

Challenge	Response
High initial capital cost of installing renewable energy—whether wind, solar PV, hydro, or solar thermal.	The upfront capital investment cost has some advantages in Nigeria—there are no questions about the ongoing financial and stability issues of fuel and pipelines.
Solar and wind power are clearly better suited to specific parts of Nigeria for the most competitive solutions.	The areas with overwhelming solar potential (northern Nigeria) are very poorly served at present, and seem likely to face very high transmission costs from growing power generation areas in the Niger Delta.
Renewable energy installations have tended to be relatively small compared to conventional grid generation.	Smaller installations near to target communities should mean faster deployment and much lower transmission losses than distant gas-powered options.
Grid-level renewable energy is not an 'always on' generation solution. Both solar and wind require complementary generation.	Nigeria's power shortages are so acute that this may be an acceptable shortcoming initially. As the grid improves, Nigeria has a wide range of sources that should complement renewable sources well.
The feed-in tariffs used as a tool in other countries could prove expensive at a time when Nigeria has difficulties funding infrastructure.	If structured correctly, a green feed-in tariff could prove attractive to agencies such as the World Bank, with a good potential match in the longer term between affordable interest rates and economically sensible green outcomes. The existing cost of power to the private consumer is extremely high, making even the more expensive renewable options competitive.

of converting to renewable energy. With commercially available interest rates starting at around 25 per cent per year (plus tough guarantee requirements), this is a major issue in Nigeria.

The need for affordable loans has been recognised for some time in Nigeria. There is an evolving commitment through the Bank of Industry to provide loans at low interest (7 per cent per year, or less). However, this is far from fully realised at present, with blockages both in the provision of financing and in uptake.

In addition to low-interest capital, several other key actions need to be taken in tandem. Renewable energy developers need to produce far more detailed costings and realistic payback periods for the full possible range of installations, from generation level to household systems. For household or stand-alone systems, this is not too complicated but publicly available data remain scarce. More information on consumers' willingness and ability to pay bills is desperately needed, for both potential investors and customers for renewable systems to see clearly the likely costs and benefits. Loans will be utilised only when improved access to capital is combined with credible information and choices.

7 Some key messages and recommendations

According to the Nigerian federal government:

> In view of the high capital costs and long lead times required to develop commercial power generation through solar, wind, nuclear and biomass, the Federal Government will focus its development efforts on hydro, coal and natural gas. The potential of natural gas, in particular, will be prioritised and incentives will be provided to investors to exploit this resource to its fullest potential.[11]

The purpose of this paper is to explore existing renewable energy in Nigeria, examine some of the reasons for the sector's under-development compared to other countries, and discuss emerging evidence of the potential of renewable energy for a critical emerging role. Some of the arising suggestions are relatively easy to summarise:

- Pilot initiatives have demonstrated both the potential of renewable energy in Nigeria and some of the ongoing challenges.
- Continuing shifts in technology and costs have created major opportunities for both small- and large-scale interventions.
- Carefully designed work on markets, education, and finance are now well justified investments for renewable energy to meet its potential in Nigeria.

Unfortunately, the practical steps required for a better energy future for Nigeria with a strong renewable sector are much more difficult to distil into a short number of bullet points. Although headlines for some key steps can be clearly stated, the process is likely to involve assembling a complex jigsaw of actors, finance, education, and technology. Some of these issues can be pursued independently but many require good co-ordination and collaboration. The spectacular failures of dubious solar projects involving significant government spending demonstrate that renewable energy still requires fundamental competence in planning and development to succeed.

This section does not attempt to describe fully the detailed steps for assembling a 'jigsaw' of policy responses, but identifies broad headlines under which it might be possible to group key areas for action. Aside from suggesting a change in policy stance at the core of government, it suggests the relatively early steps that might be feasible with modest government commitment which could deliver real gains to Nigerian households and promote broader buy-in to this fast-developing area. It seems likely that a foundation of success at this level might prove crucial to broader support for major next steps—such as competent investment decisions in larger-scale solar power generation.

Within these limits, this section concludes with selected key recommendations that need to be read as early steps in an ongoing process.

7.1 Time for a shift in energy policy

The evidence from emerging research makes it clear that Nigeria has a greater pool of renewable energy resources than has previously been recognised. Furthermore, the international evidence is that these resources are becoming competitive with existing power sources at a remarkable pace. Nigeria's present extraordinarily high-cost energy options mean that renewable energy is already competitive or an obvious winner in many specific situations—including targeted assistance to those on the lowest of incomes.

There is a need for energy policy to acknowledge that the dismissal of renewable energy as a short-to-medium-term option in the official *Energy Road Map* (as quoted above) was a fundamental mistake. This does not mean that renewable energy can be rushed to centre stage but that there is a need for systematic policy, research and financial support for the development of the renewable-energy sector. An attempt was made to lay out such a path in 2005 with the Renewable Energy Masterplan which was never adopted. Swiftly developing *and implementing* an

11 *Roadmap for the Power Sector 2010*, page 10. http://www.nigeriapowerreform.org/index.php/downloads

updated plan for strategic investments in renewable energy, which incorporates the lessons of the past decade, is a crucial first step.

7.2 Understanding and educating the market

Despite the importance of government policy, it is also crucial for government and other actors to understand that many of the best energy solutions will occur in the marketplace—where often the role of government may be only to minimise complications. For many needs, renewable energy is already competitive with existing sources, and the remaining issue is to align needs, solutions and affordable capital. However, progress will be limited unless both the customers for energy and the providers have a much better understanding of both needs and viable energy solutions.

For market-driven demand to play its role, a highly visible range of pilots and education programmes seems to be vital before widespread uptake by justifiably sceptical consumers. There is a need for research that breaks down household needs, incomes and aspirations. The diverse situations of rural and urban households with massive differences in income and cost of living mean that there needs to be a matching range in renewable-energy solutions that can be much more easily matched to individual situations. It is on the basis of this data that renewable-energy providers and vendors should be able to provide products and systems that fit with real-world needs.

7.3 Cultivating developers, educators and partners

This is much easier said than done—especially in a political climate which emphasises local content in industry. However, as noted in the Renewable Energy Masterplan of 2005, there is a need for strategic investment in both research and business development that can elaborate and consolidate opportunities for an industry in its infancy.

There is a base of local knowledge valuable in developing practical projects. This could usefully be paired with international experience, which can help Nigerian businesses and government to match the rapid pace of overseas technical advances.

7.4 Matching capital growth to emerging capacity

Government-led financing in the power sector has a troubled history in Nigeria, and disastrous levels of corruption in the fuel sector have given subsidies a very bad reputation. Yet, as highlighted in Section 6 above, there is a pressing need for capital for both consumer- and grid-level products. Research for this paper with solar industry practitioners and consumers suggests there is no magic bullet on the issue of financing, but that the following will be useful to note:

- Additional capital should not be considered in isolation—it will be far more effective in the context of other measures.
- Business mentoring and strategy support seem to be sorely needed for small and medium-sized businesses. This should be pursued in close collaboration with expanding the capital available to businesses.
- In some consumer areas, capital support for payment by instalment seems viable—particularly for civil servants and those on a stable income
- Subsidies for consumer products should not be dismissed outright. New technologies appear to be offering better options for accountability and assurance that benefits are reaching their intended target.

Possibly the key role for government is to fund a strategy in which available capital will grow in line with the renewable industry reaching verifiable milestones. Those investing additional effort in renewable energy need to be confident that, as they develop, affordable finance will continue to be available.

7.5 Incentives for efficiency and demand reduction

The roadmap for the power sector in Nigeria, and almost all industry thinking, is presently geared towards massively increasing supply. However, it has been well demonstrated that the most economical way to meet overall power needs is to reduce demand where this is possible without compromising the experience of customers. Put simply, reducing the consumption of a million consumers by 10 per cent (or say just 500 watts of peak demand) can be swifter and radically more economical than building another 500MW thermal plant.

For renewable energy, it seems worthwhile to consider seemingly radical options—regulatory incentives for small systems, or even village-level schemes that go 'off grid' entirely or maintain a very limited connection. While technically divorced from the mainstream power sector, those taking this option are making a small but significant contribution to reducing overall demand with a corresponding improvement in the prospects of stable supply to those on the grid. Providing some additional incentives to an emerging area may well help speed the emergence of sensible off-grid installations, which still face the higher costs of an emerging technology and will often be considered for relatively remote rural areas with associated challenges. As noted above, improving the efficiency of key appliances markedly reduces the capital cost of a solar system of any size, creating a virtuous circle of demand and market development.

7.6 Supply chains, customs and regulation

The tiny size of the renewable industry in Nigeria creates significant problems for installers, especially when combined with the prevalence of sub-standard products of key types such as batteries and inverters. Importation is an area in which there has been theoretical progress with a zero tariff but in reality the number of barriers for inexperienced importers are many and costly. The recent experience of a 'Light Up Africa' vendor is instructive. Customs officers first chose to interpret integrated solar lights as lanterns (a 35 per cent tariff) and then proceeded to follow up with a range of other charges which brought the cost of importation to 100 per cent of original cost.

This situation seems to be unexceptional but is partly derived from entrepreneurs with limited business experience who may also lack the networks to overcome such hurdles efficiently. If low-income Nigerians are to be assisted by renewable-energy technologies, it seems vital that relevant arms of government actively recognise this as an area for encouragement, requiring the sympathetic interpretation of regulations at every stage.

It would also seem to be an appropriate time for government to consider a broad interpretation of solar and energy-efficient products, so that there is an incentive for mutually reinforcing products to enter the mass market belatedly in Nigeria. Suitable candidates would seem to be all deep-cycle batteries, inverters, energy-efficient fridges, low-energy air coolers, low-energy light bulbs (especially LEDs), and other low-energy devices as they emerge.

With the growing problem of sub-standard components, it would be tempting to suggest that Nigeria should impose standards on solar products that are imported. However, in the current environment both customs and other government agencies lack the capacity to test or certify products credibly. This should be an area for carefully planned development where regulation follows only when government can demonstrably implement policies both fairly and effectively without unreasonably increasing cost for legitimate suppliers. In the interim, this makes the role of non-government actors in establishing credible brands and reputations even more important.

State governments, whose rural communities and low-income residents stand to benefit from appropriate low-energy products, should consider reducing business costs for renewable-energy companies as markedly as possible. The multiple local charges and frequently unnecessary harassment of small business by various arms of local government is a significant barrier to small and medium-sized businesses in the renewables industry. Reducing such barriers would create a welcome incentive for rapid expansion.

Finally, government could play a vital regulatory role looking towards the future. Building standards in Nigeria are poorly enforced but seem to be evolving in some areas. Nigeria should consider building standards that, without imposing unreasonable cost, provide both pressure and support for the adoption of low-energy principles at every stage of construction. These regulations could be progressively advanced as various options become more feasible and readily accessible at affordable prices.

7.7 Government as a promoter of renewable energy

One of the main thrusts of the power-sector reforms is to remove government as an actor in the operational and much of the ownership sense, leaving its role primarily as one of regulation. This is a strategy founded on the state's disastrous role in managing the sector and investment over the past four decades. Therefore, promoting government involvement in the renewable-energy sector should be pursued with caution.

There are obvious areas in which government could address financial gaps. This would probably best be in close collaboration with unquestionably qualified partners using models that adopt the many lessons of international experience from the past two decades. These areas include:

- high capital cost of small home/business installations, and difficulty in obtaining affordable finance
- investment support for new technologies where private investors may lack experience and confidence (solar thermal being a classic example)
- capital costs for proven renewable technologies such as solar PV and wind power in appropriate locations.

The federal government already sponsors a significant amount of solar PV installations through the Energy Commission of Nigeria, NDDC and other agencies. However, as elaborated in Section 5, there is an urgent need to review the quality and medium-term outcomes of these pilots. There is still value in government-sponsored pilots to help establish these new technologies but it must come with a radically lower failure rate than is presently the norm.

Given the size of the federal and state governments (including their services) in the Nigerian economy, there are obvious benefits from programmes for state bodies to adopt renewable and low-energy technologies progressively. In some areas there have been hesitant steps in this direction, such as policies to adopt low-energy lighting, but there is a great deal more to do.

As state services tend to suffer from chronic shortages of funds for power (being as dependent as other actors on generators), there are obvious multiple benefits in converting more services to renewable energy wherever feasible. Given recent history, the critical area is ensuring that any conversion is both cost-effective and handled by reputable companies that have the latitude to recommend designs suitable for particular local conditions.

There are two initial steps:

1. Pilot partnerships that establish best practice for several key areas (e.g. schools, health centres, government buildings) of varying scale *in highly visible locations*.
2. Swift research that identifies appropriate priorities and quick wins for renewables and energy-efficient options, along with key guiding principles for next steps.

There is a major role for government in both supporting and directly participating in public education on energy. If any of the potential gains for renewable energy and increased efficiency are to be widely realised, then communities, businesses, and the public need to be much better informed about the principles of energy use. The secondary-school education scheme started by the Lagos State Government with an online component and focus on energy efficiency[12] is a laudable example of a simple initiative that could have multiple positive ripple effects. Integrating education on energy issues, and particularly renewable energy, into school curriculums and massively expanding the volume of accessible written material seems to be an entirely appropriate role for government.

Education initiatives should not be limited to schools however, as there is also a wide range of adult audiences. Creative steps such as partnerships with churches and mosques to demonstrate renewable energy options should also be considered along with other potential areas for promotion.

Government must consider the place of renewable energy in the tertiary sector where credible investment is needed in both education and research. Practitioners have rightly identified the urgent need for capable technicians, which will only grow if the sector is encouraged to develop. However, with the case for expansion there is also a credible case for investment in all of the following:

- trade training for technicians that targets those with some existing electrical experience (generator vendors and repairers)
- professional development for solar and renewable engineers—until local capacity develops, this will certainly require overseas scholarships
- supporting credible institutions that can research renewable energy with an early focus on appropriate adoption of best available technologies for Nigeria
- careful fostering of local manufacturing, repair and support facilities that should evolve with growing experience of new technologies.

12 Although the main promotion has closed samples of the Lagos Electricity Board campaign can be found at http://www.lseb.gov.ng/content/campaign-materials

7.8 Key recommendations

Develop integrated renewable energy planning and investment

The federal government needs to reinforce its existing initiatives by developing both an integrated renewable-energy plan and a systematic major increase in investment in research, market development and regulation of renewable energy.

Provide incentives for renewable energy uptake

Government should also consider incentives, probably through a feed-in tariff, for at least one major pilot of solar thermal power generation in northern Nigeria.

Ensure sufficient and affordable capital financing

Low-interest capital financing for renewable energy needs to be systematically expanded, with increases in available capital matching growth in the industry.

Improve public understanding of renewable energy

Renewable-industry actors and government need to make a significant investment in public education that will improve consumer and policy choices and overcome existing prejudices against the industry.

Cultivate collaboration between renewable energy developers and policymakers

Policymakers and renewable-energy developers need to work closely together to develop best practice options for services in rural areas—particularly for education, health centres and water provision.

Educate on energy use and efficiency

Energy use, particularly energy efficiency and renewable energy, needs to be a core part of the education system as swiftly as feasible, with a view to changing public behaviour and expanding participation in a growing renewable-energy sector.

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