



The Solar Revolution



In 2018 the global tipping point for solar power will be reached. Tumbling prices and dramatic improvements in technology mean that, for the first time, this under-exploited source of renewable energy will be viable, profitable and sustainable. This presents a huge opportunity to bring electricity to over a billion people for the first time.

The world has been aware of the global potential of solar as an energy source for over 25 years, but we have failed to realise this potential to the full. High cost coupled with complex technological challenges have stymied attempts to scale solar power to the point where it can have a global impact on the world's energy architecture, opening access to electricity for everyone.

That situation has changed. Advances in infrastructure and, crucially, in battery storage mean that it is now possible for large solar power to electrify the world without further use of fossil fuels, expanding the electricity grid or relying on centralised power generation.

The only remaining barrier to solar power is investment. Investors and donors must be brave enough to reframe the way they look

at solar energy. For those that show such foresight, the opportunity to deliver life-changing, sustainable energy to more than a billion people while achieving significant returns on investment is within grasp.

The renewable landscape

Ensuring reliable, affordable access to electricity remains one of the greatest challenges of our time. There are as many people living without electricity today as there were in the time of Thomas Edison's first light bulb- approximately 1.1 billion.

The International Energy Agency estimated in 2016 that there are over 600 million people in sub-Saharan Africa (66% of the region's population) with no access to reliable electricity.

The entire world could be powered by harnessing solar energy from just **1%** of the Sahara

In 2015 **\$348.5 billion** was invested in renewables

In 2016, growth in solar-power capacity overtook new coal-fired generation for the first time, with capacity rising **50%** faster than any other source of electricity

The real cost of off-grid solar power (including battery storage) is now below **20 cents per kWh** compared to a minimum of **60 cents per kWh** for energy from small diesel and petrol generators

Just **\$2 million** would provide the basic power needs of every primary healthcare clinic in Sierra Leone

Households in developing countries would immediately save up to **80%** by switching to solar and energy storage technology from diesel and petrol

In Zambia 85% of the population are not electrified. Millions remain reliant on diesel-fuelled generators, which are both costly to run and hugely damaging to the environment. Rising fuel costs and the inefficiency of small-scale diesel generators have made electrifying the world's poorest areas sustainably more urgent and challenging than ever.

For the continent to deliver sustainable and inclusive growth, this gulf in connectivity must be breached.

This gulf presents an opportunity. The supply-side issues related to fossil fuels are driving the largest sustained

push so far towards the commercialisation and large-scale adoption of renewables, not least in solar power. In 2016, renewables accounted for 11.3% of the world's energy consumption, up 1% from the previous year (these figures exclude large hydro, which, while renewable, is excluded from much of the sustainable-energy discourse due to argument that it is not environmentally sustainable).

This increase in market share took place in spite of a fall in investment in renewables in 2015. It was made possible by the dramatic fall in cost and a significant rise in efficiency of solar power. Solar photo voltaic (PV) in particular has fallen in cost per watt, from US\$76 per watt in 1977 to US\$0.3 per watt in 2015, more than halving in the past three years alone. Panel efficiency has simultaneously improved by more than 20%.

It is this change in the cost benefit of solar PV that is bringing the commercial tipping point within reach. As of 2015, renewables accounted for 55% of the global generating capacity, the highest proportion in any year to date.

Kenya case study

This year Crown Agents was selected to provide low-cost clean energy for poor and vulnerable communities in Kakuma refugee camp in Kenya. Capitalising on smart-inverter technology, the pilot project seeks to demonstrate the financial viability of solar in off-grid settings.

In partnership with Moving Energy Initiative and Africa Power Storage, Crown Agents designed a solar information and technology (ICT) hub for communities in the camp, providing affordable clean energy for charging mobile phones, lanterns and computers. The ICT hub will use a smart-card system to monitor usage, ensuring equal access to hub use and training for men and women.

The solar hub has been designed to become a community asset by the end of the pilot project: ensuring sustainability – financially and in terms of maintenance – will be crucial to its success. Training in cleaning PV panels and in monitoring PV and battery performance will ensure skills transfer to the local community and increase understanding of solar energy.

The emergence of renewables in the developing world

Emerging market economies have now overtaken their richer counterparts in total investment in renewable energy (excluding large hydro). This is a result of drastic growth in the market over the past decade, driven by demographic change and rising consumer demand, which is set to continue in the long term.

The developing world is far more motivated to expand energy capacity than the developed world; while the developed world is universally powered and equipped with the necessary installations, much of the developing world is off-grid (or grid-challenged) in areas of low population density, lacking the infrastructure to install traditional methods of electricity. Renewables and cutting-edge energy storage can fill this void.

New investors and new initiatives

In 2015, US\$348.5 billion was invested globally in renewables. Investment in renewables has been attracting some major new players: technology titans Bill Gates, Mark Zuckerberg, Jeff Bezos and Jack Ma recently committed US\$1 billion to launch a new, low-carbon energy fund.

Power Africa

Power Africa is a USAID-funded movement that aims to add more than 30,000 megawatts [MW] of cleaner, more efficient electricity-generation capacity and 60 million new home and business connections. Power Africa uses a transaction-centred approach to address directly the constraints to project development and investment in sub-Saharan Africa's energy sector. The model works with the private sector to build local capacity by supporting innovative ways to make traditional assistance programmes more effective and sustainable.

SE4ALL

Sustainable Energy for All (SE4ALL) operates across Asia, Africa and Latin America and empowers leaders to broker partnerships and unlock finance to achieve universal access to sustainable energy as a contribution to a cleaner, just and prosperous world for all. Its programmes marshal evidence, benchmark progress and connect stakeholders. Currently the initiative is developing a series of 'heat-maps' to help show leaders where they can make the biggest and fastest inroads towards the goal of universal sustainable electrification. These 'heat maps' also show where progress is happening – so that it can replicate the success of others and help leaders in government, business and civil society to make the right choices. Both SE4ALL and the Power Africa movement are stellar examples of the momentum of sustainable energy that is gaining traction in the Global South.



Furthermore, many developing countries have made admirable commitments to clean energy. India, for example, has aggressively promoted renewables on both utility scale and for rural electrification, leading a global consortium of like-minded states aiming to raise billions in finance for future renewables projects. Many sub-Saharan African countries have also set themselves ambitious targets for renewables, including Sierra Leone, which announced sales targets for 50,000 'solar units' in 2016 and 200,000 in 2017. Around 42% of Sierra Leone's electricity is currently powered by low-carbon sources.

Why solar?

Of all the sources of renewable energy, one has the greatest potential of all to electrify the world: solar power. The entire world could be powered by harnessing solar energy from just 1% of the sunshine that falls on the Sahara desert.

Utility-scale projects in Europe, Australia and the US have demonstrated that solar can be harnessed to provide energy to millions. And global solar capacity is growing rapidly – it is now 305GW, up from approximately 50GW in 2010 and virtually zero at the turn of the millennium.

The Africa Progress Panel

The Africa Progress Panel estimates that 620 million Africans live with no power at all. A recent study conducted by the group found that in nine African countries, more than 80% of primary schools had no lighting. The World Health Organization reported that in 11 African countries, one in four clinics and hospitals had no power, and that many powered clinics frequently suffered from power outages caused by faulty or unreliable generators.

In 2016 growth in solar-power capacity overtook new coal-fired generation for the first time, with capacity rising 50%, faster than any other source of electricity. In fact, solar power accounted for nearly half of all new capacity in renewables that year.

What's more, the realisation of a calculation called levelised cost of electricity (LCOE) has revealed how solar projects have historically been priced too high, making solar power appear more expensive to run and install (compared with diesel) than it should. LCOE measures the long-term cost of solar appropriately and showcases the cost-effectiveness of solar energy over the life of the project.

Yet globally there remains vast room for expansion in the sector. Falling prices and increasing technological capability have put the sector on the cusp of a global solar revolution.

The barriers to bringing the solar revolution to developing countries

Investors, engineers and implementers have struggled to break through four barriers to revolution in the solar energy market:

- the perception of high capital cost and maintenance
- an inability to monitor solar-energy consumption and manage consumer usage in a cost-efficient manner
- inadequate energy-storage technology
- an inability to access sufficient finance.

This has changed.

Falling costs

Unlike the cost of other forms of energy, the cost of solar power has fallen dramatically in the past five years, due to the shrinking costs of components. The running costs of solar energy are also now exceptionally low.

Until now, the CapEx (capital expenditure) costs of solar panels and, crucially, of lithium energy storage have been high when compared to other energy sources, particularly in small-scale off-grid projects where electricity is needed most (i.e. rural health centres). This was because the solar market lacked the economies of scale that currently benefit other energy markets, as well as the relatively high price of solar panels, lithium storage and the installation process.

Falling PV-panel prices have enabled enormous utility-scale solar projects to bring energy costs down to well below US\$0.05 per kWh.

However, these low costs have not been reflected in small-scale off-grid solar systems such as those that could power health services and schools.

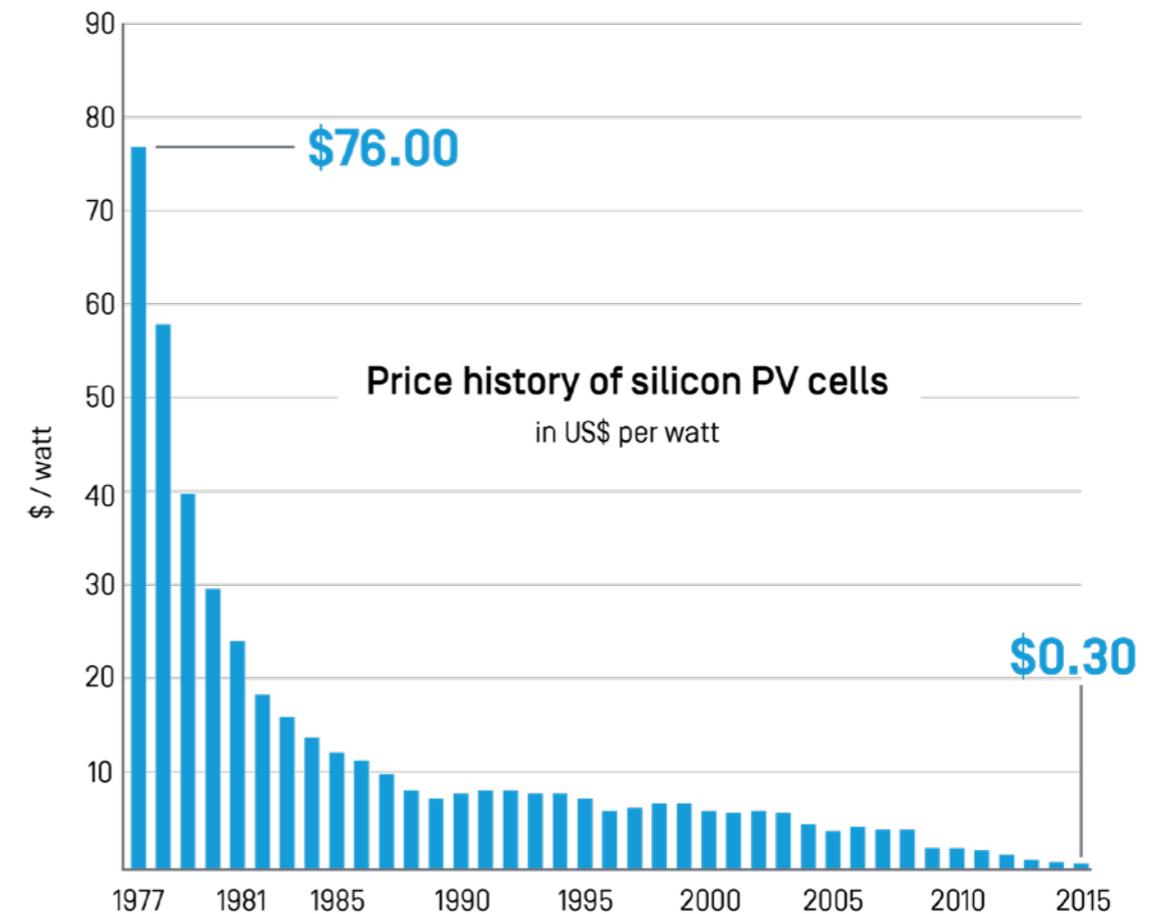
When you scale down by a factor of 100,000 to a 3,000-watt off-grid solar system for a clinic or classroom, an off-grid solar project cannot compete with a diesel generator (which has a running cost of US\$0.60 per kWh) because of the complexity of installation and the high battery and running costs of solar.

Until now, that is. Improvements in lithium storage and new off-grid inverter technology have enabled a new generation of small-scale off-grid power systems with running costs of just US\$0.10 per kWh – less than the grid in many countries.

Accurate monitoring and management

Off-grid solar power has typically suffered from an inability to monitor energy consumption accurately, particularly at circuit or appliance level, leading to a misallocation of resources that results in power shortages and waste.

This problem has been particularly acute in developing countries; here solar power has been costly and wasteful because systems are vastly over-specified to ensure there is no shortage of power, especially in remote areas where wireless internet and mobile coverage is limited or non-existent.



Source: Bloomberg New Energy Finance & pv.energytrend.com

The potential for development investment

Development projects that aim to fund energy infrastructure also stand to benefit from innovations in off-grid solar energy. In 2015 the Department for International Development funded 5 megawatts of off-grid solar and storage projects in Nigeria, at £3 per installed watt and a total cost of £15 million. Although the project successfully provided electricity to large parts of Nigeria, the per-watt cost was very high. With APS's new technology, **the £15 million spent could have provided at least 10 times as much energy.** An APS 5000 SolarEnabler including 5kWh of back-up power is sufficient to supply a rural school or clinic with continuous power at an installed cost of less than US\$10,000 including the APS unit, lithium-ion batteries and all solar PV panels. This technology provides funders with the means to deliver far greater results for the same cost

Crown Agents and Africa Power Storage Ltd

Crown Agents have teamed up with Africa Power Storage Products Ltd (APS), an innovative tech company making clean energy available in off-grid contexts. Focusing on expanding the use of solar, APS has devised smart technology that overcomes the problems that solar power typically faces through their flagship technology, the SolarEnabler.

The APS SolarEnabler presents solutions to the two main problems that have limited the scale and efficiency of solar installations in the developing world: power storage, and the accurate monitoring of power consumption. It works by combining a smart lithium battery with built-in charge controller, hybrid inverter and GPRS-connected computer to monitor energy consumption.

Designed to replace diesel generators, the SolarEnabler makes solar power affordable and easy to install for the first time, and is currently the only technology of its kind with the power to disrupt the market. It is the only energy-storage system that can be self-installed, and contains all the necessary components for solar power to be effective, in just one box. This makes the SolarEnabler highly compatible with low-resource settings, particularly in rural areas or crisis zones that lack the necessary equipment for installation of traditional energy sources.

APS uses the latest lithium-ion batteries, allowing power storage of up to 10 years, and a monitoring system that tracks power consumption, giving users the ability to choose how best to spend their power. The most sophisticated units incorporate a novel load-control system that allows circuits to be switched off in order

to preserve power for vital appliances such as vaccine fridges. This is crucial when powering clinics in low-resource settings, and is a critical feature distinguishing APS technology from others – access to 24-hour electricity is essential for effective primary healthcare and particularly for immunisation schemes. The APS units can also be connected to traditional lead acid batteries when lithium-ion batteries are not readily available.

a. Storage capacity

The SolarEnabler includes a state-of-the-art lithium-ion battery that revolutionises energy storage for remote and off-grid applications. Although lithium technology is not new in itself, recent breakthroughs in lithium batteries have propelled the potential storage capacity of energy from four years up to 10 years. Lithium-battery prices have also halved since 2014, and many analysts predict that prices will fall further as a new generation of large battery factories are built. New lithium batteries provide a solution to solar energy's most persistent problem, and the huge improvement made to their longevity in recent years marks a milestone in solar energy.

b. Monitoring consumption

The second key feature of APS's SolarEnabler is the ability to monitor energy consumption. SolarEnablers gather new datasets on actual consumption of electricity by device. APS has effectively replaced the distribution board so that every power plug can be monitored remotely, allowing the exact quantity of power used to be measured.



Now, smart technology that monitors consumption accurately has opened the doors to affordable solar power for remote areas by enabling the installation of cost-efficient solar-power systems. This technology has overcome one of the major global obstacles to solar power.

Better energy storage

The other key challenge facing all renewable energies has been the efficient storage of power. How do you ensure that energy produced sporadically by wind or sun is always available when needed? Major advances in lithium-battery technology are solving this problem.

Driven by the demand for electric vehicles, lithium-ion batteries are now being produced affordably at residential and utility scale, capturing and storing renewable energy and vastly improving the energy productivity of wind and solar sites. By the start of 2018, South Australia will have opened the world's largest lithium-ion battery plant, capturing wind power and storing enough energy to power 30,000 homes; smaller residential and community-scale battery storage units are also now available.

The key to scaling solar power

Combining smart-inverter technology with a revised approach to energy costing has the potential to revolutionise the market and bring power to millions.

Crown Agents are at the forefront of this drive. We connect innovative technology providers such as APS with local installation and maintenance service-providers, and we oversee financial and project management to deliver high-quality, sustainable solar capacity at the lowest life-cycle cost possible. We are helping to turn the lights on in more places, for more people, more quickly, at less cost.

We have delivered 11 mWp (megawatt peak) of decentralised generating capacity to support public-service delivery in emerging economies. We focus on supporting projects in developing countries where the expansion of grid-electricity provision is either unviable in the near- to medium-term or where current grid capacity is unreliable. It is in this context – often rural and remote regions – where improvements in the cost and efficiency of off-grid solar power will be most beneficial.

We recognise the barriers to electrification: overloaded and underfunded grid systems that fail to reach large portions of the population in many countries. Off-grid solar technology could meet the needs of the 630 million people living without electricity in Africa alone.

Right now we, and others like us, are developing and delivering groundbreaking solar projects to empower those without access to reliable electricity. Yet more needs to be done – we must create systemic change in how power is supplied across the developing world.

Starting the revolution

Crown Agents is already pioneering this approach to solar-power provision, but a change is urgently needed across both the public and private sectors.

We have a real opportunity to revolutionise how energy is generated and distributed, finally closing the energy gap within some of the world's poorest countries once and for all. But there must be genuine collaboration and action from policymakers, international donors and the private sector.

- Governments: the state plays a critical role in facilitating solar-power projects by creating the right environment for the right investment. Governments need to look at the regulatory, technological and trade environments required to attract the right kind of solar investment especially where power provision is currently low. This could include installation of new generating capacity, sale of electricity generated by decentralised supply companies, and regulation of the grid.
- Donors: investors such as donors have been deterred from solar-energy investment by the apparently high costs. But donors rarely get to see an accurate interpretation of the true cost of solar. We urge funders to use LCOE when calculating the costs of solar-power systems. Through further funding donors can prove the value of solar, thereby creating greater impetus for private capital to meet the funding needs. Investors in turn need to look beyond traditional approaches to risk, taking advantage of new funding bodies to de-risk renewables projects.
- Private sector: the private sector has made great progress in research and development around PV solar and battery technology, driving down prices while scaling up efficiency and reliability. It is essential that it continues to do so. The under-utilised solar potential in developing countries presents a vast opportunity for the private sector to deliver a sustainable energy revolution. If private investment in solar power were to grow by just 50% over the next two years, this would provide the financing needed to turn on the lights at last for the billion people on earth with no power.





About Crown Agents

We help countries grow their economies, strengthen their welfare and energy systems and improve financial management. We do this by providing consultancy, fund management and training in health systems strengthening, supply chain solutions, public procurement, governance and growth.

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