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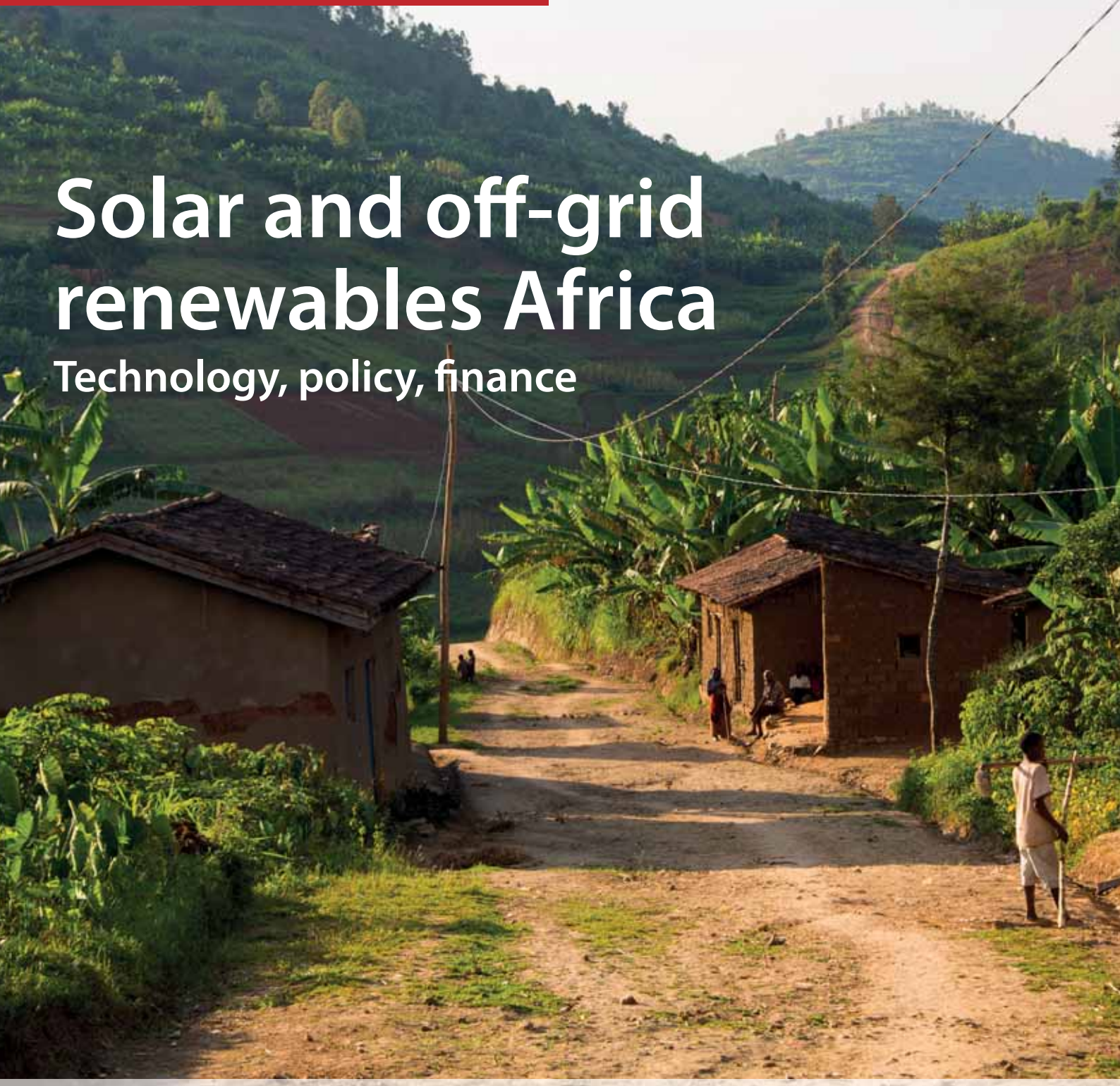
SPECIAL REPORT

# Solar and off-grid renewables Africa

## Technology, policy, finance



**Mini-grids**
Unlocking the opportunity for Africa

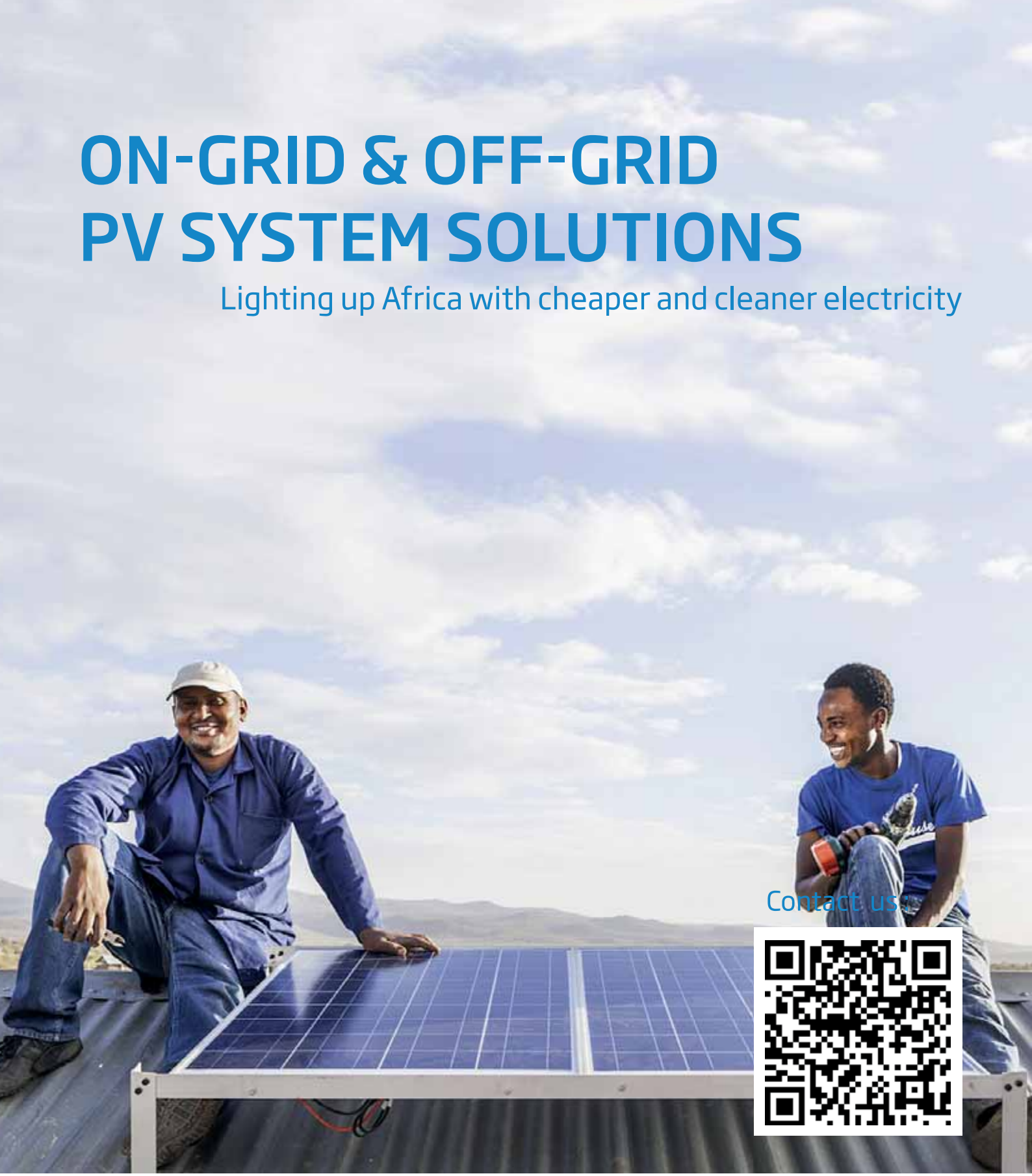
**Solar homes**
Heading towards the mainstream

**Storage**
What is the off-grid battery technology of choice?

**Finance**
The innovations bringing new capital into Africa's solar industry

# ON-GRID & OFF-GRID PV SYSTEM SOLUTIONS

Lighting up Africa with cheaper and cleaner electricity



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PV TECH POWER

**Published by**
**Solar Media Ltd.**
3rd Floor, America House,
2 America Square,
London, EC3N 2LU, UK
Tel: +44 (0) 207 871 0122
www.pv-tech.org

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**Printed by**
**Buxton Press Ltd.**, Derbyshire

PV Tech Power 2018
ISSN: 2057-438X



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*Cover image: Distribution lines run from a mini-grid in Ngororero, rural Rwanda. Photo courtesy of Energy 4 Impact*

# INTRODUCTION

*PV Tech Power's* annual Africa-focused special report is an opportunity to gauge the fortunes of solar and other renewables in a region where they arguably offer the most.

Last year we charted some of the sector's key milestones and argued that it looked as though the pace of progress was set to gather pace. A year on, that certainly seems to have been the case.

As we document on p.13, utility-scale PV has taken decisive steps forward, with a number of projects reaching completion, more going out to tender and the prospects of an African Development Bank-funded programme bringing 10GW of solar power to the Sahel region.

Meanwhile, the market for off-grid pay-as-you-go solar systems seems to be nudging into the mainstream, with a number of big international utility and energy companies starting to take a serious interest in the sector (p.16). Alongside that, as we explore on p.10, some new ideas are gaining traction about how to bring much-needed capital into the expansion of renewables in Africa.

Of particular interest this year are developments in the mini-grid space. This has always theoretically been one of the most promising concepts for Africa, filling the gap between costly, slow grid extensions and standalone solar systems that cover only the most basic electricity needs. So far that potential has not been realised, but as we report on p.6, there is currently a concerted push by a range of international actors to break down the many barriers that have held mini-grids back.

As always, the good news should be tempered by caveats. In the utility solar space, for example, a range of issues from grid capacity to questions marks over the viability of large projects outside multilateral programmes continue to loom large. And in the mini-grid space, there is a sense that if current efforts fail to bear fruit, policy makers and investors will lose interest and the sector will have missed its chance to make a decisive statement of intent.

For now though, the trajectory of solar and off-grid renewables in sub-Saharan Africa seems to be quite clearly forward and upwards. We look forward to continuing documenting the story as it unfolds.

**John Parnell**
Head of content

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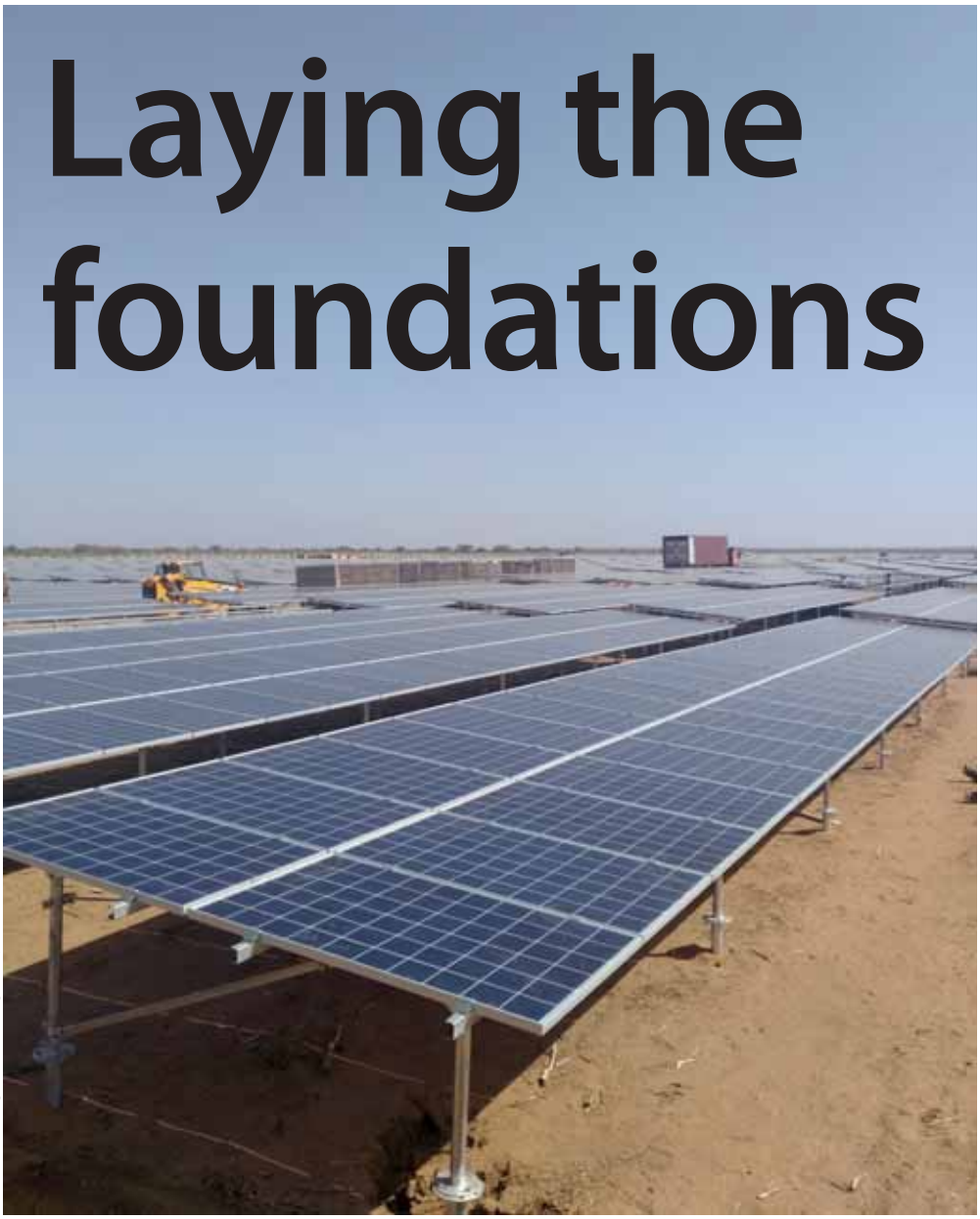
# Laying the foundations



*Credit for all images China Jiangxi Corporation for International Economic & Technical Cooperation*

China Jiangxi International Economic and Technical Cooperation Co., Ltd is currently building what will be the largest utility-scale PV power plant in East Africa. Located in Garissa County of north eastern Kenya, the 50MW project is set to be completed later this year.

The project manager, Dr. Ke Tabai, discussed how the project came to be, and how building partnerships with world-class technology suppliers, especially Huawei, had been instrumental in laying the foundations for this project.

Kenya has long been a pioneer in the green energy sector, with state-owned organisations such as the Rural Electrification Authority, Geothermal Development Company and Kenya Nuclear Electricity Board all seeking to maximise the utility of natural resources. It has long been a quintessential target for the Kenyan government to simultaneously address the issue of insufficient power supply and utilise abundant solar energy in the County of Garissa, though a lack of funding had always been in the way. But it wasn't long before two great purposes found their perfect blend with the launch of The Belt and Road Initiative envisioned by the President of China, Xi Jinping. Securing a concessional loan from the Exim-Bank of China, the construction of the 50MW solar power plant soon got underway.

**The 50MW Garissa project in Kenya will be the largest in East Africa**

**Kenya has yet to make it on to the map as a destination for large-scale PV projects. How did this project come to be?**

Since the election last year Kenya has been politically stable. Now the current president is looking to promote and improve the country's infrastructure, including energy. The Kenyan government is utilising a concessional loan from the Chinese government for this project through the Export-Import Bank of China.

And also the reason I think [the Kenyan government wanted solar] was because it can result in a reduction of thermal generation, because it is clean energy. It will offer voltage and grid support to areas in the north-eastern part of the country. Also it meets the demands of Kenya policy [in terms of renewable energy development]. So it is necessary for the regional sustainable development. It's going to improve the regional economy and promote the development of Garissa. So these are the major reasons behind the project.

**Who are your main technology partners for the project?**

For the equipment, we have chosen world-class suppliers. For example, for the main transformer we are using ABB. For the string inverters we chose Huawei and the modules are from JinkoSolar, which is now number one in the market.

**What influenced your choice of string inverters from Huawei for this project?**

The reason why we chose Huawei as one of our technology partners for this project, first of all Huawei supplies the smart PV solution. Two years ago, in 2016, I had a chance to visit the Huawei headquarters and factory and had a better understanding about this solution. It's a cutting-edge solution including smart PV string inverter, SmartLogger, PLC (Power Line Communication), Anti-PID Module and Smart Management System.



**Huawei's smart string inverter proved the ideal technology for the Garissa project**

Also, in the market nowadays there are two types of inverters – one is the central inverter, which is large and heavy duty with a big foundation and is not convenient or simple to install. This project is located in an area with a hot climate; it's close to the desert, so a central inverter would be difficult with installation and maintenance. But the Hauwei string inverter is light, it can be quickly installed and, by reducing the reliance on components such as DC combiner boxes and distribution cabinet, the string solution helps shorten the installation period and makes the whole process simpler and more efficient. It can also withstand the strongest sun and sand and ensure 25 years of service. So we chose them.

**How important are the smart capabilities of Huawei's technology to this project?**

String level monitoring allows us to rapidly locate any PV module with a low energy yield. It makes maintenance simpler and more efficient.

Meanwhile, the power line communication technology replaces the normal communication cables, cutting workload and the expense of cable routing as well as reducing loss on signal transmission and improving transmission efficiency. So I think the major factors are that it can reduce the cost during the O&M period and also the high efficiency.

**Sub-Saharan Africa is becoming a more attractive region for large-scale PV power plant projects such as this. Is your company planning any further projects?**

Yes, we are planning another project in Kenya right now. But first of all everyone is expecting this project to be done. They want to see how it is - because this is the first one in Kenya, the largest in East Africa and the first we're doing in Africa. But we have a long-term cooperation with world class equipment suppliers with a popular name. So we are planning many other projects, not only in African countries but also in Asia and other continents.

# Scaling green mini-grids

**Mini-grids |** Despite being hailed as a vital component in the electrification of rural Africa, mini-grids face numerous policy, financing and commercial barriers. But a concerted international effort is currently underway to unlock the sector. Ben Willis reports

Credit Powerhive

Mini-grids in sub-Saharan Africa have yet to live up to their potential

The magnitude of the electrification challenge in sub-Saharan Africa is such that a range of options will be required to connect currently unserved parts of the population. At one end of the scale is the 'traditional' infrastructural approach of extending the main grid to new areas. Somewhere towards the opposite end is the small standalone system, typically using solar energy in conjunction with a battery to provide basic power to individual off-grid households and small businesses.

Sitting between these two extremes is the mini-grid – or green mini-grid, as the concept is increasingly becoming known, given its compatibility with forms of renewable energy generation such as solar PV. Where standalone systems reach their limitations, mini-grids can step in, offering many of the benefits of the central grid in providing sufficient power to operate much larger applications but without the cost or slow lead times associated with main grid extensions.

"Mini-grids are really the cheapest, fastest way to deploy energy systems to rural populations," says Jessica Stephens, secretary of the newly launched Africa Mini-Grid Developers Association (AMDA). "Depending on what statistics you look at roughly three-quarters of all new connections in Africa are going to need to be through a decentralised approach either through solar home systems or through mini-grids. Solar home systems provide a really great entry point for users who've never had power access. But they're not a long-term infrastructure solution. And mini-grids sort of bridge the gap."

Given their many positive attributes, mini-grids have unsurprisingly garnered significant attention in recent years from governments, donors and developers for their potential in supporting Africa's energy access objectives. They now have their own trade body, AMDA, which launched officially earlier this year to represent the interests of private sector mini-grid developers. Mini-grids have been the focus of a major ongoing African Development Bank-led market development programme, which has launched a multitude of mini-grid policy and financing initiatives. And governments across the region are starting to look seriously at mini-grids as an answer to electrification pressures. Figures from the International Energy Agency have projected that by 2040 mini-grids could serve as many as 140 million people in sub-Saharan Africa.

## Challenges

Yet the reality is that getting to that point will require the mini-grid sector to overcome a number of significant barriers – and indeed much of the activity seen in this nascent sector lately has been focused on solving these many problems rather than actually building projects. One particularly pervasive obstacle is the persistent tendency among key policy- and decision-makers in the region to regard mini-grids as somehow inferior to full grid extensions, putting them at a disadvantage from the outset.

"One of biggest hurdles we're going to have is convincing governments that mini-grids are not the 'poor man's grid' but actually the grid of the future," says Stephens. "That is a core barrier that keeps coming up, so shifting the way we communicate and how governments talk about mini-grids as a solution to massive electrification problems is going to be really central."

Behind this general misperception of what mini-grids could offer sits a raft of more specific challenges, relating to the need to get the necessary policy,

regulatory, commercial and financing conditions in place to help the sector flourish.

On the policy and regulation side, the barriers for mini-grids can roughly be broken down into three areas, says Peter Weston, director of investment and advisory services at UK-based non-profit body Energy 4 Impact, which provides support to local businesses in Africa working to extend energy access.

"One is around tariffs. Many African countries do not allow cost-reflective tariffs for mini-grids; they require a uniform national tariff and mini-grids are more expensive than grid power. So there's a strong case for allowing cost-reflective tariffs. The second is the whole licensing regime in terms of the costs, timing and opaqueness of the process: it's not always clear which parts of government are responsible; sometimes they overlap and it can get very political," Weston says.

"The third area is around arrival of the main grid – what happens to a mini-grid when the main grid arrives in terms of technical integration and financial compensation for mini-grid developers. Because the mini-grid developer may have been charging tariffs that are higher; as soon as main grid arrives they will have to lower them, so there should be some kind of clear mechanism for buying out the mini-grid or, if it continues, ensuring the developer can continue to make a viable business."

On the commercial side, developing the right business models to make mini-grids profitable and self-sustaining will be of paramount importance to the future growth and longevity of the sector. Much of the anticipated development in the mini-grid space is likely to be driven by the private sector, which, according to Nico Peterschmidt, CEO of Germany-based mini-grid developer and consultancy INENSUS, is better placed than governments or national utilities to respond with the necessary agility and innovation to the opportunities presented by mini-grids. But, adds Peterschmidt, so far no one has truly cracked the nut of making the mini-grid business profitable.

"There are many private developers and operators out there, large and small, trying to develop models which can be profitable in the long run, but unfortunately nobody has succeeded so far. This is because they focus on electricity sales only … Their financial models usually calculate a certain growth of demand over time. It's a bet, and that bet is extremely high risk – and so far in most cases the growth rate is overestimated. People are not making money."

> "Mini-grids are the cheapest, fastest way to deploy energy systems to rural populations"

Sitting alongside shortcomings in the policy, regulatory and commercial aspects of the mini-grid business is of course the not insignificant matter of finance and how the sector will access the necessary capital to fund its growth. Broadly speaking the financing challenge for mini-grids can be broken down into two areas: access to subsidies; and access to long-term debt finance.

According to AMDA's Jessica Stephens there is broad recognition that some kind of subsidy or grant funding will be needed in the initial stages of developing the mini-grid sector, in much the same way as central grids all over the world have been subsidised in some way over the past 100 years. Some funding has indeed been available since 2014 via the UK's Department for International Development to support mini-grids in Tanzania and Kenya, the two countries widely regarded as being the best test beds for large-scale mini-grid deployment. But Stephens claims the money from these programmes has been slow to come forward, requiring onerous amounts of up-front due diligence work and, as yet, with no projects on the ground to show for these efforts.

## Developing the green mini-grids market

Through its Green Mini-Grids Market Development Programme launched in 2015, the African Development Bank and its associates have been seeking to break down some of the barriers to mini-grid deployment outlined in this article.

According to Daniel Schroth, coordinator of the Sustainable Energy for All Africa Hub at the bank, which oversees the programme, a key part of the initiative so far has been the rollout of a green mini-grids help desk.

"The helpdesk is an online platform with two purposes," he explains. "One is to bring together all the information around mini-grids in a practical way...to be a repository of knowledge and best practice.

"The second thing that was core was to be able to relatively quickly deploy technical assistance to developers on any specific issues they might be facing. So we have built in almost a kind of 'ask an expert' service, which is operated by Energy 4 Impact and INENSUS. To date we've roughly been providing support to some 60 developers across the continent, across different technologies and different states of development."

A second phase of the market development programme that is shortly due to get underway will see the scope of support offered by the helpdesk broadened to include public sector actors. "The new version of the helpdesk will also include, importantly, the public sector side, so we're equally able very quickly and unbureaucratically to respond to issues that ministries of energy, rural electrification agencies and regulators might have, as far as mini-grids are concerned," says Schroth.

Other key initiatives the bank is working on are seeking to ease some of the financing constraints the mini-grids sector faces. One of these is a pan-African results-based financing "instrument, which will provide an element of subsidy per connection made via a mini-grid.

"The idea is that the grid is subsidised and grid extensions are subsidised," says Joao Cunha, chief climate finance officer at the AfDB. "Governments are connecting people [via the main grid] using highly concessional funds, so there is an implicit element of subsidy; we would like to level the playing field and through this facility also provide a level of subsidy for mini-grid connections, at least for a period until you see more of a penetration of these technologies, more maturity in the business models and these projects become self-sustaining."

The bank is also working on a bigger debt platform for small-scale renewables including mini-grids. Financing for the fund, dubbed the Facility for Energy Inclusion, has not yet been closed, but Cunha expects that milestone to be reached later this year for the off-grid element of the initiative. When launched the idea is that the fund will provide debt finance for smaller projects under US$30 million that would normally fly under the radar of investors looking for larger opportunities.

Scroth also sees the next two to three years as being key for the mini-grid sector to prove itself: "We're seeing the sector becoming more mature, but hasn't yet reached the level it would like to see. It's similar in a way to what has happened with solar home systems, where now a lot of the financing is becoming increasingly commercial: we would like to see the same happening on the mini-grid side."

"That's super-problematic for an array of different reasons," Stephens adds. "And without access to the subsidy, really accessing debt financing is impossible."

## Solutions

Although the many challenges facing mini-grids in Africa may read like a litany of woes, the first positive for the sector is that with the nature of its problems so well understood, there would seem to be a greater chance of the right solutions emerging.

And, as briefly alluded to at the outset of this article, the second positive is that there is a huge amount of work going at the moment – by individual companies, national governments, regional bodies and international organisations – to find those solutions and give mini-grids the best possible chances of succeeding.

At a pan-regional level the African Development Bank has taken a leading role in delivering the UN's Sustainable Energy for All (SE4all) energy access programme and distributing money from the Sustainable Energy Fund for Africa, a US$95 million donor-funded pot of money also aimed at improving energy access. Green mini-grids feature prominently in the bank's work in this area, and it is currently delivering a number of initiatives designed to bolster the sector under the umbrella of its Green Mini-Grids Market Development Programme (see box ,previous page).

On the policy front, the main focus at the moment is on working with governments to produce legislative and regulatory frameworks that will provide some of the certainties private sector developers are looking for. According to Peterschmidt at INENSUS, which has been working with a number of governments on drafting mini-grid policies, two of the overriding concerns for developers from a regulatory perspective are: whether or not they will have the support of a national regulator if they charge cost-reflective tariffs to mini-grid customers that are higher than national grid tariffs; and what the agreed approach is in an area served by a mini-grid if or when the main grid arrives.

Some countries such as Tanzania and Nigeria have already taken a lead in addressing those issues, Tanzania through a now well-established 'small power producers framework' aimed at encouraging private sector green mini-grids, and Nigeria through a new set of regulations that Peterschmidt's company, INENSUS, helped draft.

In Nigeria's case, Peterschmidt says the cost-reflective tariff issue has been addressed through the development of a digital tool that calculates the tariff for which a mini-grid developer could receive regulatory approval in a particular area. And on the issue of what happens in the event of the main grid arriving in a mini-grid area, a similarly innovative approach has been taken.

"Normally the negotiating power is with the utility connecting to the mini-grid," he explains. "And even if you have some laws saying there is supposed to be some compensation for the mini-grid operator [if the grid arrives], as long as negotiating power is with the distribution company the mini-grid operator does not have any chance of getting anything out of it. And it usually ends up in a bankruptcy.

"Now in Nigeria we've put the negotiating power into the hands of the mini-grid operator, so the operator has the right to compensation. So if the main grid operator wants to avoid having to make that compensation he has to make a certain offer to the mini-grid operator in terms of staying an operator of a distribution network or feeding electricity into the main grid. [This] protects the mini-grid from becoming a stranded investment in case of the main grid arriving."

Where finance is concerned, Stephens says the newly formed AMDA is looking to take a particularly proactive role, initially in gathering data that will make the case for mini-grids and help de-risk future investments.

"Part of the initial question is to be very transparent about the structure of finance that developers have received so far – what percentage of that is grant, debt and equity so people start understanding the real picture of the financing that's actually available. Being able to provide some of that information is really going be key," she says.

AMDA and others are also pushing for a more effective results-based financing (RBF) mechanism for mini-grids Africa that goes beyond the ones already available in Kenya and Tanzania that

Credit IRENA

**What happens when the main grid arrives in a mini-grid area is just one of a number of issues for the sector to address**

Stephens claims have so far led to little by way of concrete projects: "We're really interested in focusing on a truly results-based financing facility as opposed to what exists now, which is incremental disbursements of funds throughout the project build that aren't actually leading to any connections until the last disbursements."

Stephens says another important development would be the creation of a centralised fund to provide debt financing to smaller mini-grids projects – "a facility that de-risks [mini-grid investments] by looking larger portfolios instead of as a single, one-off project for a quarter of a million dollars". Both this and a pan-African RBF facility are both areas that the African Development is looking it, suggesting AMDA's wishes may well be granted in the near future (see box, p.7).

One particularly interesting area of innovation is in the development of new business models to provide a sustainable commercial footing for mini-grid projects. There is an emerging consensus that because mini-grid operators will struggle to make money simply from selling power to households, they will also need to sell to larger users of electricity, such as small businesses – so-called productive users. "If you're just selling to households you're not generating income," says Weston. "There's a strong argument for selling to productive users who are generating income, which creates employment in the area and other benefits."

INENSUS has been trialling a version of this concept in Tanzania through JUMEME, a mini-grid company in which

it is one of a number of shareholders. INENSUS' has dubbed its take on the productive use concept as the 'Key Maker model'. It envisages mini-grid developers not just as localised providers of electricity but also as end users that, through entrepreneurial activities, create demand for that power as well as generating further revenue for the mini-grid company.

"The Key Maker model is a new perspective of looking at the opportunities that mini-grids provide to the mini-grid operator. We go to all the effort of bringing the equipment there [for the mini-grid], all the assets, acquiring finance, setting up the management structure, back office structures, controlling structure, accounting, logistics and so on just to supply a few kilowatt hour of electricity on site. So if we have all of that and have good relationships with the community, can't we do more than just supply electricity, and with the same resources create synergies to increase the revenue to make this whole business model financially viable?"

JUMEME is seeking to answer that question through a trial it is leading of the KeyMaker model on an island on Tanzania's section of Lake Victoria (see case study, previous page), and Peterschmidt is hopeful that it could provide a viable, scalable business model for mini-grids going forward. "We are not the only ones investigating this – a number of companies in Madagascar, Zambia and Uganda which have similar approaches, but a different name. But we believe we are most advanced. The mini-grid sector is suffering from not having a viable business model readily developed and implemented and scaled, and the conventional models are not showing the trajectory towards a successful, profitable business. We believe the Key Maker model can change that."

Though innovations such as this and the concerted efforts of the many other actors now getting behind the mini-grids cause, the prospects for the sector look promising. The many challenges mini-grids face in delivering on their huge potential are now firmly on the radar of the players who have the necessary influence and knowhow to address them once and for all and help the sector take a decisive step forward.

But by that same token, the current wave of interest in mini-grids also represents something of a make-or-break moment for the sector, one which it must grasp before the world moves on.

"I strongly believe we are moving in the right direction and there is a great potential to make this mini-grid dream work," says Peterschmidt. "I also believe we do not have more than two or three years to prove our concept. If we don't succeed in proving it in that time, the donors and governments will lose interest, I'm pretty sure about that. So now this is the time to come forward." ■

## Supply and demand

Tanzania-based JUMEME is seeking to build up evidence of a new business model that it hopes will provide mini-grids with a much-needed sustainable commercial footing.

The developer is putting into practice the concept that one of its main shareholders, INENSUS, calls the Key Maker model, under which mini-grid operators use their commercial capabilities and the presence of a reliable supply of electricity to open up new economic activities in an area.

Through a pilot project on an island on Lake Victoria, JUMEME is leveraging the opportunities arising from a small mini-grid it has built to create a new business that trades in tilapia fish. Although popular in Tanzania, tilapia has hitherto been caught only to a small extent in Lake Victoria, with imports from China meeting most of the local demand until now.

"We saw an opportunity for a new market for tilapia, which is a fish in Lake Victoria and which is caught to a very small extent so far," explains Peterschmidt. "But on the other hand we've got a growing middle class in Tanzania which wants to eat meat and fish, and a favourite fish is tilapia. There's a very large market and a very much undersupplied market. But somehow [local fishermen] cannot deliver the fish to the mainland because they're lacking the logistics capacities."

From its operation as a mini-grid business, JUMEME has all those capabilities the local fishermen lack. "We have sorted out the logistics, the cooling chain, the electricity supply on site," Peterschmidt says. "So what we do now is purchase fish from the local fishermen, freeze it on site in freezers we run off our own electricity and deliver the fish directly to the capital, Dar. And that is how we generate a pretty attractive margin. And on the other hand the fishermen earn more than they have before. And we create jobs for fishermen that were formally unemployed."

JUMEME has plans to expand the scope of the tilapia business on Lake Victoria and the number of islands it has electrified. And beyond this specific example, the Key Maker Model is theoretically adaptable to almost any other local economic activity – agriculture and artisanal mining are two areas Peterschmidt particularly highlights. Indeed, the company is already looking at a second Key Maker project involving the farming of sunflower seeds, where JUMEME will use another mini-grid to process sunflower seeds grown by local farmer on site before selling to wholesale markets. The attractiveness of the model is that offer mini-grid companies new routes to economic viability and, ultimately, long-term sustainability.

"Usually in you financial models, which are anyway very optimistic in the mini-grid sector, you have an amortisation period of let's say eight, 10 or 12 years depending on how optimistic you are – beyond 12 years you'll not find anybody investing there so you try to tweak somehow your assumptions to come up with different amortisation times. With the Key Maker model, with realistic values, you can cut your amortisation time to below five years. And that gets you into the main capital markets."


Credit: JUMEME

**JUMEME is trialling a new business model it hopes will bolster the commercial viability of mini-grids**

# How old and new money can finance Africa's solar future

**Finance |** Traditional and alternative sources of finance are backing the deployment of African solar right now. John Parnell explores some of the new models and programmes from players big and small that are making an impact

Credit Masdar

Finding finance for solar projects in sub-Saharan Africa ought to be getting easier. Globally, the established vendors and engineering practices are all too familiar to major investors. At least one layer of political risk is increasingly stripped away as project economics become unencumbered from government subsidy and grants. In short, it is benefitting from the global de-risking of solar that comes with more than 300GW of installed capacity.

Problems closer to home remain frustratingly familiar but in this new climate of (relatively) stable supply chains and reliably low PV power prices, even these challenges should be surmountable.

The scale of investment required across all infrastructure types means that private-public partnerships (PPP) are unavoidable. According to the World Bank, in the last five years a quarter of all PPP infrastructure investment projects in sub-Saharan Africa have been for solar. Energy as a whole represents 78% of such projects. With solar becoming the cornerstone of modern energy generation systems, it is easy to see its share of that 78% increasing further.

Scale is a crucial consideration: the scale of any individual investment programmes, the scale of the individual projects involved from the growing fleet of utility-scale arrays to the innovative solar-plus-storage mini grids that have caught the eye, and opened the wallets, of major utilities.

## Utility-scale

At the scale that these energy giants, from within and without Africa, are used to operating, solar has proven itself. The World Bank's IFC has built a framework an increasing number of governments are able to leverage to deploy solar. Its Scaling Solar Programme is already active in four countries (Zambia, Senegal, Ethiopia and Madagascar) and there is every indication that an equivalent programme for storage will follow suit.

In January 2018 the African Development Bank revealed plans to finance the deployment of 10GW of solar in the Sahel region by 2020.

South Africa's much-vaunted procurement programme (let's consider the recently resolved PPA issues a blip) also provided a replicable model that has been oft-imitated.

The development banks remain an important source of early-stage finance but as deployment continues and learnings from existing plants stack up, financing utility-scale assets can only become more straightforward. Solar manufacturers will continue to trim cost but matching the record breaking tariffs seen in other parts of the world will require further innovation in finance as well as the factory floor.

**With the technology proven and the demand clear, Africa now has to find the most efficient means of financing its solar future**

## C&I

The challenge in the commercial and industrial (C&I) sector, which again frustratingly, has such a strong business case for the correct end-users, is finding a bankable off-taker.

CrossBoundary began working in the Middle East and Africa as a financial advisory firm but has been enjoying recent success as a fund for C&I solar in Africa.

In the process of this advisory work it made the observation that businesses on the continent were enduring issues with power: it was too expensive and too unreliable. It sourced US$9 million of seed financing, mainly from impact investors, and set out to prove that its proposition could solve both problems.

Essentially, the fund builds, owns and operates C&I installations and negotiates power purchase agreements (PPAs) with the off-takers. CrossBoundary has focussed its seed investment on projects with major international corporates including Diageo, Heineken and Unilever.

Pieter Joubert, the company's lead in East Africa, is gearing up for a fresh financing round later this year that will see the fund scale up by one, if not two orders of magnitude. With 6.5MW in operation or development so far, CrossBoundary will now look to extend the scope of its work to include local firms as off-takers.

"We never wanted to be solely focused on the international companies. That defeats the purpose of wanting to be an African-centred company," says Joubert. "We have used those companies as the benchmark in order to show that this is a viable portion of the energy sector. Because when we grew as a fund, there certainly wasn't any proof to go off. So we had to prove to investors, companies and ourselves that this is real, and working with those multinationals has enabled us to do that."

The second finance round is targeting US$50 million but could raise US$75-100 million. Joubert says this is likely to see some of the impact investors from its seed funding return, but with the concept proven, he's confident that a more diverse group of backers will emerge. As the portfolio of assets owned by CrossBoundary increases, he sees its main function shifting.

"As opposed to being an infrastructure fund, we're moving towards being a distributed utility," he says.

Regulation can prove another challenge for a company looking to sell power with so many markets dominated by state-owned enterprises. It already has PPAs in Kenya, Rwanda and Ghana, with Nigeria next in line. But while regulators' willingness to handout feed-in tariffs makes or breaks subsidy-dependent markets, in a subsidy-free PPA model, all that is needed is access to that market. So far Joubert says it has been possible to work proactively with regulators on this.

At the C&I scale, most businesses already use a diesel generator to supplement their supply.

Storage can also play a part in securing supply. Joubert gives the example of a food producer in Nigeria. A break in power, even for a split second, triggers an automated cleaning procedure on the production line that lasts several hours. Staff and machinery are idle until the process of cleaning and restarting the line is complete. The result is a business case for uninterruptable energy storage back up supported entirely by operational rather than power savings.

> "The concept that the only way to own solar panels is to buy them and install on your own roof is about as sophisticated as making a telephone call with two cups and a piece of string."

According to a World Bank survey, Nigeria experiences 60 blackouts a week somewhere along the lines. The scale of the solar plus storage opportunity is obvious.

Just as Africa skipped from landlines to mobile phones, the stars are aligning for another leap to the same sort of distributed grid that European nations are attempting to reimagine from their legacy infrastructure.

Joubert demonstrates the suitability of this model versus the centralised 'spoke and wheel' approach with a neat example. A utility-scale renewable energy plant in Africa required so many hundreds of kilometres of new transmission lines for its grid connection that is colloquially, and sardonically, referred to as 'the world's largest off-grid plant'.

## Alternative routes offer innovation

Every now and again a handful of themes or topics build enough momentum and buzz that their mere inclusion in even the most tangential way can drive artificial interest. Graphene had this status for a while, block chain superseded it and machine learning appears to hold the mantle now.

The fog created by this buzz can mask the truly useful.

One more established example of an effective non-traditional route to investment is SunExchange.

The platform uses the low cost of cryptocurrency transactions to break C&I scale solar installs down to the individual cell level, dropping the lowest possible transaction size below US$10. It also transcends (traditional) currency risk and strips away the geographic barrier. The funded systems, in Africa, are then leased to the end users.

"Anyone can own solar panels located in the sunniest place on Earth, lease them to a commercial project and earn an income from it," says SunExchange's founder and CEO Abe Cambridge. "The concept that the only way to own solar panels is to buy them and install on your own roof is about as sophisticated as making a telephone call with two cups and a piece of string. We now have technology that makes that physical connection redundant."

In short, that means somebody living in a high-latitude apartment block, can invest their resources in a PV array soaking up the African sunshine. At the same time, that system is easily delivering a better return than the high-street bank's consumer savings offerings.

Cambridge argues that the SunExchange model can also fill in the final blank to mainstream solar in Africa.

"The population of Africa is 1.2 billion, it's going to be four billion by the end of this century. Everyone needs energy and out of that 1.2 billion, half the population has no energy whatsoever at great cost to health, social development, etc. Getting low cost clean energy to Africa is an imperative not just for Africa's development but the world's sustainability. So what's the barrier? Why is Africa not going solar? We have the technology, the skills and the desire. What's missing is the financial infrastructure," argues Cambridge.

"Africa is fairly unbanked in most of the continent. There's still scepticism and a level of difficulty transferring payments and value across borders, when using SWIFT and reserve banks all those things that come with a huge cost of effort and value when using US dollars or euros and rand. Cryptocurrencies overcome that barrier. We can now transact with the whole world using only one cryptocurrency," he says.

It is natural that these issues with established banking practices and currencies would also reduce some of the hesitancy to embrace cryptocurrencies.

## Don't underestimate climate finance

Another potential new driver of funding for solar in Africa is borne of the most top-down of organisations, the UN.

Climate finance is a catch-all term – in many instances is just re-branded development aid – but climate finance, specifically those commitments made as part of the UN's Paris Agreement, should not be ignored. The UN process spun out the Green Climate Fund (GCF). It acts as a development bank with a mission to deliver emissions-reducing and climate-adaptation projects in developing countries. In its first two years of operations it has invested US$1.3 billion in renewables, leveraging US$5.5 billion in investments. While it is encumbered with all the due process an organisation answerable to 195 governments ought to be, it has been quick to spot the potential of solar.

The organisation has aligned itself with Indian Prime Minister Narendra Modi's International Solar Alliance (ISA) and contributed US$100 million for a rooftop solar programme, and the potential for similar inputs in sub-Saharan Africa is undoubted.

The fund has eight impact factors that it looks for its projects to deliver and solar could realistically contribute to six of these, from the obvious "low-emission energy access" to the "increased health and wellbeing" that results from displacing kerosene and diesel. Funds will continue to pour into the GCF in the coming years. Programmes like IFC's Scaling Solar, South Africa's REIPPP and the growing body of evidence at the C&I scale that upfront investment has myriad benefits will only encourage money to trickle towards solar.

That trickle has already begun to gather momentum drawing on a wide variety of sources. For now this can only be healthy. The diversity increases the chances that each solar application will find the right financing mechanism. With plenty of demand and plenty of sunshine the pooling of financial resources is just in time. ■

## Embarrassment of riches: African solar's diverse financing sources

Solar is being installed in Africa in hugely diverse scales and applications from peco solar to micro-grids to the more familiar utility-scale plants. The range of funding mechanisms being explored is equally rich as institutions large and small look for ways to overcome the continent's investment challenges.

**Green bonds**

Green bonds and climate bonds are growing in scale hugely. In the first four months of 2018, US$35.9 billion of such bonds were issued. Individual companies are also finding success with smaller scale bonds to finance their own activities. In February this year, GreenTec Africa raised the first €1.7 million of its €10 million bond offering to fund containerised solar deployment. The 40ft containers will initially bring 45kW PV installs to around 50 villages in Mali. Just think what US$35.9 billion could do. The bond offers an annual return of 6.5%.

**Crowdfunding**

Crowdfunding in all walks of life certainly has more failures than roaring successes. The Pebble watch springs to mind as one success story, the Raspberry Pi computer is another. The infamous US$10 campaign launched so that one man could make himself a potato salad demonstrates the more frivolous element that can affect the seriousness awarded to more worthwhile projects. Off-grid energy firm BBOXX raised €1 million in just a few weeks solar in Kenya.

**Cryptocurrencies**

As explained by SunExchange's Abe Cambridge in the main article, currency risk and transaction costs can impact investment. Now for the first time since the bad old days of bartering, we now have a universal, accessible means to trade that is uncoupled from the state, and also from reams of paperwork. "We need to work from the ground up. There are lots of developers building and identifying these projects in communities," says Cambridge. "We will lease hardware to those businesses operating them and set up prepaid meters in the communities. Once they purchase electricity, it's is transferred to the owners of those panels. So there is no debt, you're not offering interest rate payments and there is no equity, shareholding, dividends, this is just a lease."


**BBOXX has used crowdfunding to finance its activities in Africa**

# Large-scale solar blossoms in Africa

**Utility PV |** A number of international initiatives have helped large-scale solar gain a foothold in Africa. The question now is how the market for this segment will develop beyond these programmes and how much capacity grids will be able to support, writes Tom Kenning

After years of unconverted pipelines, stale financing and cost barriers, utility-scale solar PV in Africa has started to spring up across the continent. The worldwide decline in equipment prices has of course been a pivotal influence, but Sub-Saharan Africa also now hosts a number of support schemes backed by development banks that are driving significant project sizes in a number of countries. Some have suggested that initiatives such as the World Bank's Scaling Solar programme favour big international players and can only achieve low prices through a generous debt scheme. Thus, one question is what kind of long-term solar industry will be left in the wake of such programmes and for whom? It's also clear that Africa will have to move even faster than other markets in terms of matching the upgrade of transmission networks to the addition of renewables, since most countries have very small total power capacities and weak grids.

Two years ago, *PV Tech Power* wrote about 'flickers of progress' in West Africa specifically, but project sizes were limited to 20MW at most and despite the momentum, the pace was still regarded as slower than expected. Fast-forward to Q4 2017 and the market kicked off in a convincing way across many parts of Africa, with project completions, major tenders and long-term support polices being regularly announced all the way up to the time of writing. This period saw a deluge of headlines from the African continent.

## Milestones and opportunities

"Large-scale solar build-out in sub-Saharan Africa will continue to be driven by multilateral programmes in the short to medium term," says Silvia Macri, senior research analyst at IHS Markit. "Therefore I would keep an eye on those countries where tenders have already been announced under any of those schemes. On the list we can certainly mention Zambia, Senegal and Ethiopia and likely other countries will soon follow.

"This year projects were announced in Burkina Faso, Mozambique, Namibia, Cameroon, to name a few, which could hint to a domino effect of positive tender results elsewhere in the region. Outside of these programmes, it will be interesting to see what happens in Kenya. The former signed a number of solar PPAs at a relatively high feed-in tariff level, before an announced shift to a tender mechanism. Nigeria has a huge potential but no progress has been made with large-scale PPAs; definitely another market to follow closely," adds Macri.

Credit Total Eren/Access Power

**Falling costs have helped large-scale solar projects spring up with greater frequency across sub-Saharan Africa**

"It's mostly the price which is driving this development, together with a better trust in the technology and the possibility to have available capacities very fast in a context of impending need for power," says Karim Megherbi, director of origination, West Africa and Central Asia, at developer Access Power. "The renewable energy policies in most of the countries have existed for maybe 10 years including commitments to green energy for quite some time. But they were just waiting somehow for the right moment to develop on the larger scale with these technologies and it's the price and the quick implementation that enables them to do that. There is also a huge potential to target remote areas, where a large demand subsists, and developers are more and more prepared to address this market."

However, Megherbi notes that most African power markets on a national basis are very small, with the likes of Burkina Faso and Benin having roughly just 250-350MW each, for example. There are very few gigawatt markets, although Nigeria with 5-7GW of available capacity is a standout. This is why governments and institutions need to not just think about solar but also about the transmission infrastructure at as early a stage as possible.

Solar prices reached new lows for the region this year with Engie and Meridiam winning 60MW(AC) of projects in Senegal with sub-€4 cent (~US$0.048) per unit tariffs. However, it should be noted that this was part of the World Bank's Scaling Solar programme, which has a highly favourable debt financing mechanism. West Africa's largest project standing at 33MW also came online in Burkina Faso, while financing was also secured for a 50MW project in Mali. Similar announcements have been plentiful, alongside regular Scaling Solar tender results in select countries.

## Regional prospects

Many African governments are now willing to organise tenders and to add solar to the energy matrix, but in deciding which regions hold the most promise, Megherbi says there are two questions: which countries have grid potential and which countries are actually going to take action?

For example, big markets in Nigeria and Kenya have huge potential but the fastest moving markets are in smaller countries right now such as in Senegal.

Megherbi picks out West Africa as having a regional trend in favour of solar, since Ghana, Mali, Burkina Faso and Senegal are all discussing the possibility of interconnection.

"You have a kind of homogenous trend here," adds Megherbi, "that you may not have actually in the other regions of sub-Saharan Africa."

He also cites attractive individual countries including Ethiopia, Zambia and Malawi, where tenders have been organised. However he is quick to play down any hope of massive scale development in the region.

"There are a lot of markets now which are clearly trying to attract international investors and to develop megawatts of projects," he says. "At the same time, if you put together all the markets of sub-Saharan Africa, it still remains not a huge market and mostly because you still will have the constraint on the grid and the fact that all markets on an individual basis would represent a few hundred megawatts maximum. Only in Nigeria and South Africa can you have a market on a gigawatt basis. The rest is a few hundred megawatts and sometimes it's a few tenths of a megawatt. So unless there is a regional approach there will be a very fragmented market."

## Support programmes

The Sahel region, stretching across the south of the Sahara Desert, had a dramatic boost with this year's announcement that the African Development Bank (AfDB) was targeting 10GW of solar installations by 2020 in that region (see box). However, there are a number of other ventures driving solar across sub-Saharan Africa.

German development bank KfW has been supporting government tendering through its 'GET FiT' programme. For example, the government of Zambia has issued a request for qualification for up to 100MW of solar under the first round of the scheme. The capacity will become available via a reverse bid, competitive auction process. 'GET FiT' offers a standardised set of bankable legal documents, risk mitigation, procurement and financing support as well as technical assistance for solar PV grid integration.

The Zambian programme followed the successful implementation of the GET FiT Uganda programme, which spurred investment in over 170MW of renewable energy projects.

The West Africa Clean Energy Corridor (WACEC), aimed at accelerating the deployment of utility-scale renewable energy into the region, was also launched last year. The plans, led by Ecowas Centre for Renewable Energy and Energy Efficiency (ECREEE), seek to harness the

## Solar's role in halting the Sahara

The African Development Bank (AfDB) is planning huge developments in grid-connected and off-grid solar to support countries in electrification and mitigating climate change across the Sahel region by 2020. Following on from the concept of the 'Great Green Wall' – a section of forest to slow down the spread of the Sahara Desert, AfDB plans to provide solar power to energy-poor households which might otherwise cut down trees for fuel.

As well as offering to support African countries insuring themselves against weather disasters, the bank will use its 'Desert to Power' initiative to help develop 10GW of solar power projects across the Sahel region. This is expected to supply power to 250 million people, with 90 million of these provided through off-grid systems.

The bank has already financed the development of a 50MW solar power system in Burkina Faso. As part of that financing, the AfDB is also supporting the North Dorsal electrification project, which will connect Burkina Faso with Nigeria, Nigeria and Benin.

Ousseynou Nakoulima, AfDB director for renewable energy and energy efficiency, says the bank is in process of sending teams into each country and it's all about achieving speed and scale in a sector that has previously seen actions carried out in a very isolated and protracted way.

The countries being examined, from west to east include: Mauritania, Senegal, Mali, Burkina Faso, Niger, Chad, Ethiopia, Eritrea, Somalia and Sudan.

Nakoulima says: "We will go into each country with a catalogue of what we could do and adapt our programme to the circumstances of the country.

"So we started in Burkina Faso and we partnered with Agence Francaise, the French development agency. About a year ago we did our first mission to understand what are the ambitions of the country, how can we scale up these ambitions, what does it take, what are the barriers and how we can fast-track reaching these ambitions in terms of solar.

"It happened that in Burkina Faso there was already this very strong political will to harness solar power for the development of the country so we did in Burkina what we are going to do in each of these countries, which means making an assessment of the current context, making an assessment of the ambition in the short-term and in the long-term and just to start very concretely driving investment.

"We wanted at the same time to reinforce the grid so that we can very quickly pave the way for deployment of additional capacity. So the 50MW will be developed in partnership with a local utility, but at the same time the country is engaged with some private players to develop IPPs and the investment that we will be doing in the grid will be quite important in order to be able to incorporate these IPPs. We would have a combination of public sector type projects and private sector," says Nakoulima.

benefits of hydro, solar, wind and biomass resources across the region whilst also easing the strain on the grid through trading of power between countries.

## Scaling Solar

Perhaps the most widely publicised support scheme has been the World Bank's 'Scaling Solar' programme, led by the International Finance Corporation (IFC). It has drawn record low prices and driven the largest scale projects in sub-Saharan Africa.

Ethiopia's utility Ethiopian Electric Power (EEP) recently announced the list of pre-qualified bidders for a 250MW(AC) Scaling Solar tender. Meanwhile, Madagascar's energy ministry has also released a list of pre-qualified bidders for a 25MW(AC) Scaling Solar tender, which is the first to include energy storage in its remit. The Ethiopian tender represented the fifth Scaling Solar tender in Africa to date, with two rounds initiated in Zambia, one in Senegal and the one in Madagascar.

The aim of the programme is to make privately funded grid-connected solar projects operational within two years at competitive tariffs. Low tariffs are also helped by the tenders having pre-arranged financing attached to them. IFC provides 30% of the debt financing on a concessional basis, which explains the level of prices reached with this programme, together with the fact that the development risks are largely reduced.

Some have complained that the programme is conducive only to big international companies with large-scale portfolios given the focus on low costs and tariffs. Nevertheless the same commentators also believe that it is still a major positive for so many megawatts to be developed while attracting investors, helping governments to learn, focusing competition and lowering prices. The concern is whether an industry can be built off the back of this programme, but all agree that Scaling Solar has sent a signal to the market and kicked off large-scale development where there was little before.

## Challenges

"The main concern is financing, which could affect any large infrastructural project in sub-Saharan Africa, not just solar," says Macri. "For the industry, the question is whether projects will continue to need external financial support at low interest rates or private investments could take off with the backing of local commercial funds. Grid integration could also raise some concern in the future but more in the longer term and governments will have time to consider grid expansion projects to allocate more renewables into the mix."

However, while financing has been cited as a key barrier countless times in recent years, Megherbi claims it was never really an issue. Fare more hindering was the lack of appropriate legislation and contract structures. Nowadays both governments and developers can offer the appropriate structures to attract the financing of the banks. The main issue now is whether governments will hit their limit in terms of the number of PPAs that they are willing to back with sovereign guarantees

"The grid is going to be the main challenge," adds Megherbi. "And this is going to come sooner than we expect."

Some countries are already struggling to absorb project capacities of 20-30MW. Upgrading grid infrastructure also take some years, so if not acted upon soon, the whole solar development will be slowed down, says Megherbi. The AfDB is showing good intent on this area by making grid infrastructure upgrades a fundamental part of its 10GW solar deployment mission in the Sahel.

## Conclusion

For the region to continue its large-scale PV progress, it's clear that support programmes will continue to be critical in the near future.

"The large multilateral programmes are key drivers but in the short term, progress will likely be made in small steps," says Macri. "Sub-Saharan African countries still lack the necessary infrastructure to allocate large capacities and the pace at which solar grows will also depend on the implementation of programmes to facilitate grid integration."

Looking further ahead, there may be opportunities for hybrid technologies. The World Bank plans to make energy storage an integral part of its Scaling Solar programme, which until now has been focused purely on facilitating large-scale solar tendering, although this may not be entirely focused on Africa. ■

**Sponsor case study** | Senegal's first grid-connected PV power plant

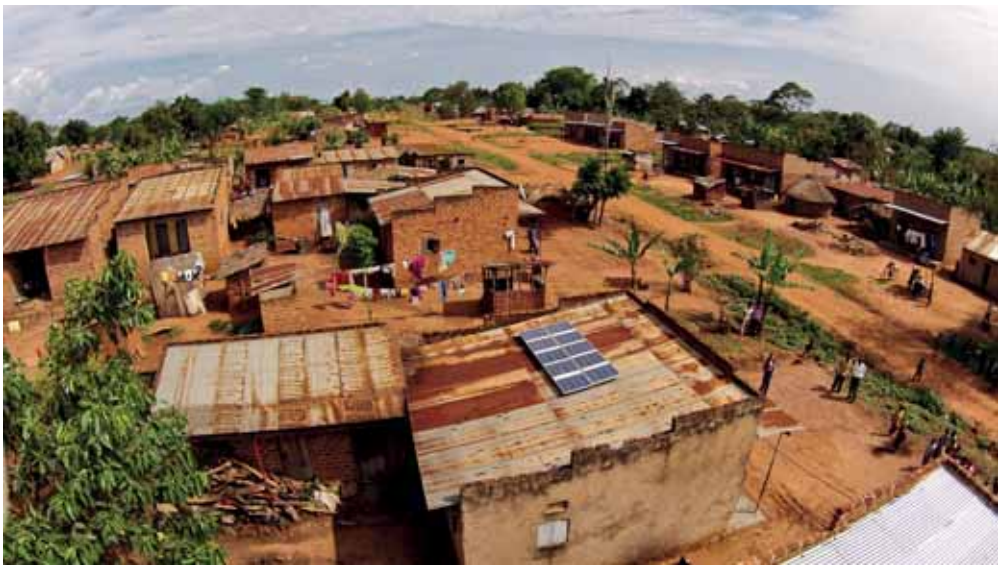
Huawei supplied inverters to Senegal's first grid-connected 20MW PV power plant. A total of 600 SUN2000-33KTL inverters were used.

Huawei inverters are stable after more than one year exposed to the hot climate with no malfunctions observed, zero failure rate and offer a high power yield. They are well received by customers.

The power plant employs three engineers, 20 local villagers, and several security guards, creating jobs and training professional skill workers for the local community. This project supplies the affordable and eco-friendly electricity to the nearby villages, solves lack-of-electricity-connection issues, improves the quality of life for the villagers and is conducive to the promotion of local economic development.

# Marching into the mainstream

**Solar homes |** Sub-Saharan Africa's pay-as-you-go solar systems market has been bubbling under the surface for some time, but are recent moves from some of energy's biggest names evidence of the sector becoming mainstream? Liam Stoker investigates



Credit SunFunder/SolarNow

In case you've missed developments from the likes of BP, Shell, Vattenfall and DONG Energy (now Orsted) of late, utilities are flocking to solar in a big way. And it's this hunt for sun-soaked opportunities that has led many to the off-grid solar market in sub-Saharan Africa.

The 2018 edition of the 'Global Off-Grid Solar Market Trends Report', released by development consultac Dalberg in January, revealed that nearly US$1 billion had been raised since 2012, with investments in the sector doubling annually each year between 2012 and 2016. Those investments have largely come from major energy players and utilities, and it appears there's an acceleration at hand.

E.On's off-grid solar arm, Rafiki Power, has been operational since 2013, and in 2016 EDF teamed up with Off Grid Electric to target West Africa. Italy's Enel has ploughed investment into Powerhive for a mini-grids project in Kenya, Powerhive also being the subject of an investment from Total.

In October 2017 France's Engie showed its hand, announcing a move to acquire 100% of Fenix International, a specialist in pay-as-you-go solar systems. Having launched in 2009, Fenix had grown steadily to become one of the more dominant players in sub-Saharan Africa. Bruno Bensasson, chief executive at Engie Africa, described Fenix as the company's "agile growth engine" for Engie's own solar home system business on the continent.

Engie's interest in Fenix started when the off-grid developer was kicking off its Series C funding round. The French energy major already had an interest in Fenix through the corporate social responsibility side of its business and originally sought to get more involved as a part-funder. But having gone through the due diligence process to sound out that investment, Engie liked what it saw and talks advanced to such an extent that soon an acquisition offer was on the table.

Chris Bagnall, sales and marketing director at Fenix, says that after analysing the offer in detail, the promise of regular, significant capital being injected into the business was something too attractive to turn down. But more so than that was the "general alignment" between Engie and Fenix's values of empowering Africa's rural communities. "What it fundamentally meant for them is they were looking to divest out from traditional centralised power and move into decentralised power within Africa, and that really spoke to us," he says.

**Growing corporate interest in off-grid solar in Africa is helping the sector build momentum**

Engie was able to bring not just the necessary capital, but people and experience within Africa that represented a significant value-add to the offer on the table. But, above all, Engie insisted that Fenix remain Fenix. "The ability to… retain our culture, retain the management team was also a key influencer in making that decision," Bagnall says, adding that Fenix is predominantly left to its own devices day to day.

The Engie deal is a game changer for Fenix, all but breaking some of the shackles caused by the inherent problems it has faced in sourcing vital capital. But what does it say for the sector in general?

## Into the mainstream

Koen Peters, executive director at off-grid solar trade association GOGLA, says that continued investments in off-grid renewables in Africa have been "very significant" for the sector, and a huge factor in how seriously it is now being taken. "The fact that some of the larger corporates are now starting to move and make investments into this is, I think, a clear indication of how the solar home systems industry is to be taken seriously. People are assuming it's here to stay and the start of a development that's getting bigger," he says.

But have we not been here before? Peters speaks of times in the past when the industry has appeared on the cusp of a major breakthrough, only for a quiet period to loom around the corner. At one stage it was suggested that off-grid renewables could follow a growth trajectory similar to that of

mobile telecommunications, perhaps contributing to concerns that off-grid solar could be overhyping itself. Now there appears to be tangible movement behind the sub-Saharan Africa market, and that's giving Peters reason to be buoyant.

"We're clearly out of the starting blocks, and we're clearly on the radar of companies interested in renewable energy, investors and governments. And increasingly we're being seen as a developed solution," he says.

Bagnall is perhaps a little more cautious, stressing his belief that while the industry is becoming more and more mainstream, it's still "very early days". A glance at the market's current state might add weight to Bagnall's reservations. While Kenya and Rwanda – two of the earliest adopters of PAYG solar services – boast established players and a mature marketplace, a large number of countries on the continent lack a stable base of operators despite significant off-grid populations.

Fenix still doesn't see its competition as rival solar companies, but instead the traditional energy sources such as kerosene lights and candles, or poor quality diesel torches. "I don't think there's a level of competition that's seeing us cannibalising sales from each other," Bagnall says.

Peters categorises the companies operating in PAYG solar into three tiers, largely separated by the capital they have at their disposal. There's a top tier of companies capable of attracting tens of millions worth of capital, all the while possessing highly capable management teams to direct that finance, followed by a second tier that are hot on their heels. There's then a third tier of companies looking to "get out of the starting blocks", as Peters puts it.

Peters adds that it's now vitally important for a number of the players in the second and third tiers to push on and provide choice to the off-grid market. But these are still only scratching the surface of what's possible in sub-Saharan Africa. It's evident that a number of hurdles remain.

## People and capital

Unsurprisingly, sub-Saharan Africa is not an easy environment in which to do business, and PAYG solar is by no means an easy prospect. Peters says that not only does it take time and effort to get things moving, but there are a significant number of capabilities required from the outset. Raising capital might take up the top team's time, but then there's the logistical challenge of shipping and installing solar equipment to rural communities. The right suppliers need to be sourced and contracts negotiated. End customers need to be credit-checked and verified. It's a heady mix requiring people power and solid expertise.

Bagnall agrees, stating that one of the main challenges Fenix faced in its early days was finding the right talent. "It's a big driver for the business and its success. We are working in a fledgling industry and it can be difficult to find people with experience, and with strong commercial business experience as well, that can go into a new country, set up an operation and get it working well," he says. Throw in the need for a good understanding of how to work with a very rural customer base, and it's quite the challenge.

But, challenges and hurdles aside, it is inescapable that there is a new momentum behind PAYG solar, brought about largely by the activity and interest of major energy players. In bringing capital investment and strong expertise, the march of the utilities is maturing the market more rapidly than before. Bagnall foresees more interest from utilities in the near future, which may change the market once again: "I do believe over the next five to 10 years we'll see the industry rapidly grow and expand into new markets, but even then I believe the opportunity remains active." ■

### Fenix's ReadyPay Power success

Fenix claims its solution, ReadyPay Power, to be one of the most affordable PAYG solar home systems available on the off-grid market, offering customers access to power for lighting and phone charging for as little as US$0.19c per day. The solution is also fully scalable, allowing customers to add more capacity to power other electrical appliances should they wish to. Batteries start at 22Wh but can be upgraded to 44Wh, with an 80Wh battery also added to power larger appliances.

Systems are paid for over 24-36 months using MTN Mobile Money. Each payment unlocks a unique code which is entered into the system to charge the customer's credit. All systems come with a three-year warranty and service.

Bringing solar to sub-Saharan Africa is a global operation for Fenix. Its products are designed in Silicon Valley before being manufactured in China, and then shipped to Uganda for distribution throughout Africa.

To date more than 180,000 ReadyPay Power systems have been sold to rural customers, with Engie's recent acquisition of the company set to accelerate this further. By 2016 it was estimated that Fenix's work had replaced 120,000 kerosene lamps, saved 720,000 tons of $CO_2$ emissions and delivered more than US$19.5 million in customer savings.


**Fenix is gradually rolling out its ReadyPay Power system across Africa**

# Li-Ions of Africa: The new battery of off-grid choice


Credit Powerhive

**Storage |** Standalone and mini-grid systems in sub-Saharan Africa are increasingly combining storage with solar and other renewables. Andy Colthorpe gauges how attitudes are changing towards the best battery technologies for off-grid applications

While it would be a mistake to generalise such a vast continent, it might surprise some to hear that lithium-ion is considered affordable even for smaller projects in Africa. Focusing on communities with little to no access to electricity besides perhaps from expensive diesel generators, and replacing kerosene used for lighting, we spoke with two US-headquartered providers of energy access. Off Grid Electric offers home solar-plus-storage on an individual basis for residential customers, who lease the products on a pay-as-you-go basis, in Tanzania, Rwanda, Ghana and the Ivory Coast. Powerhive conversely installs larger, community-scale solar-plus-storage mini-grids, selling the power on a kilowatt-hour basis in Kenya, where it has operated for six years, with Rwanda and Nigeria on the horizon for this year and next.

### What sort of technologies are you using in Africa?

**Joshua Pierce, co-founder and CTO, Off Grid Electric:** Anything from individual light sources like solar lanterns, all the way up through low voltage solar home systems. We provide what I would characterise as aspirational modern energy systems for off-grid and weak-grid consumers; low voltage DC-only solar home kits that include the appliances, energy storage and the solar. All

**Lithium-ion is becoming the favoured battery technology in off-grid projects in sub-Saharan Africa**

of our systems include energy storage and we use lithium iron phosphate batteries for that application. Exclusively.

**Rik Wuts, co-founder and vice president for business development, Powerhive:** We are basically a full-on utility. We build an actual power plant, we build the distribution network, we do metering and we sell power on the kWh in the end. We can power productive loads. It's exactly the same electricity you have in your house, 240V AC electricity.

We use predominantly solar power, we have AC-coupled systems and we currently are using flooded lead acid batteries, which is the cheapest technology available, from a relatively good brand – we use Trojan Batteries. We are

in the process of migrating to lithium-ion. We'll be working with a big Chinese vendor.

**You have both selected lithium batteries, albeit in the future in Powerhive's case. Some people might be surprised to see them considered affordable in a developing market. What's behind their selection?**

**JP:** When we started Off Grid [in 2012] we selected lithium from day one – even though the price was between US$400 and US$500 per kWh. Today we're seeing prices approaching US$200 per kWh with projections for it to go below that. When you look at the use profile of the lithium chemistry versus the lead acid and customer lifetime value, for a company like ours that is a lease-to-own essentially, the economics begin to very quickly swing in favour of lithium over cheaper chemistries that have shorter lifecycles or other potential issues.

We chose lithium iron phosphate for some very specific reasons. Firstly, this is one of if not the most common small-scale modular lithium chemistries available today. The 18650 lithium phosphate cell, thanks primarily to the Chinese EV industry and similar industries, is an extremely common platform. It's highly flexible and it balances energy density with cost and high cycle life. The safety of lithium iron phosphate was also a critical factor for us.

Another benefit is that we talk about providing what's called an 'Energy Ladder', where consumers can start with a relatively small system and upgrade over time. This is not necessarily easy to do with other types of energy storage.

**RW:** Lead acid batteries are cheap to buy but expensive to maintain. They're very finicky. You have to refill them all the time with water, you have to always be checking the voltages and if you run them on too high temperature for a day the capacity goes back dramatically. They don't last very long and they are really hard to manage. Lithium-ion is more of a closed system with inbuilt power management and air conditioning, all that kind of stuff. It's a little bit more heavy on the wallet initially but it lasts much longer and you have basically no maintenance. If it's twice as expensive upfront and it's going to last three times as long and has no maintenance, there's a clear case there.


**Lithium-ion batteries are also becoming more cost-effective for small standalone solar off-grid systems**

**What were the alternative options you considered?**

**JP:** We could use a lead acid battery, which has some benefits and some drawbacks, we could use a different type of lithium chemistry, an LMC (Lithium Nickel Manganese Cobalt Oxide) or nickel or cobalt that has a higher energy density and potentially lower costs per watt-hour.

We could use some other kind of innovative [technology], maybe something that's not as commercially available but might have beneficial properties, like high temperature or extreme temperature or high energy density, something like a solid-state battery or some other form of rechargeable battery.

**RW:** For our type of application, which is really an off-grid power plant, any battery can do it in principle. The biggest considerations are cost and lifecycles. We looked at new technologies such as flow batteries and also Aquion ('saltwater electrolyte' battery). The problem with the Aquion solution, which is grave for us from almost any perspective is that the discharge curves are not suitable for a typical mini-grid application. It has a very slow discharge curve and we need a very fast discharging and charging curve so that technology did not work for us from that perspective.

Flow batteries are too expensive and too big. I think ultimately, we'll see those are very safe, they'll come down in cost and they have very long longevity. But the footprint is humungous, and yet the cost per unit right now is very high. We wouldn't be able to use those without a subsidy from a vendor. So that's a real challenge in that sense. Surely we'll come to that point – at some point. So if you look at the mass market stuff, what's best for us are lead acid AGM and lithium-ion and we're finding it starts to be cost-effective to do lithium-ion. For now I think lithium-ion looks like the way to go for us in terms of footprint, cost and longevity.

**There's an argument that while lead acid is more toxic than lithium, it is still more widely recycled in the supply chain. How does lithium do from a sustainability perspective?**

**JP:** The common argument is that lead acid is a highly recyclable product for which it can be economically viable to recycle and repurpose raw materials. That's true. However there has to be an effective recycling supply chain. I would argue, having operated in multiple African environments and lived in Africa myself, that that supply chain is not nearly as robust as it is in other places in the world. Where the impact is the worst is on the most vulnerable populations.

The other thing I would say is, go to a rural village and yes, lead acid batteries will eventually make it out of the ecosystem, but not before they've done their damage. I've seen countless piles of dead lead acid batteries. That is a resource people will use until there's nothing left in it. They'll use it in their car until it won't start their car. Then they'll use it in their business, then they'll use it in their house for lights. It's amazing how resourceful people are but then that battery may sit and corrode and pollute the local groundwater, which is what children drink. I've seen it time and time again.

**RW:** There is already a supply chain for doing that for lithium actually because of the computer industry. Every laptop, every cell phone has a lithium-ion battery obviously. So there is already, even in Kenya there's that supply chain. It's actually harder for us with lead acid because we have to ship it back to the vendor, who's on another continent. So it's actually going to be easier doing it with lithium-ion where there are much more savvy systems around that than there is with lead acid technology. ■

# The heat and the dust

**O&M |** The operational and logistical difficulties associated with solar plant management in sub-Saharan Africa are numerous. Sara Verbruggen reports on how O&M firms are gearing up for the challenge

Credit Juwi

Plant size and geographical remoteness are just two of the challenges for solar O&M teams in Africa

You have to be a good driver, and not mind sitting for hours in a car, to be a solar plant O&M engineer in Africa. It is a job that is largely spent on the road. Often a road that's long – several hundreds of kilometres long – bumpy and potholed in parts, through seemingly endless dry and dusty desert. Flash flooding, wildlife crossing, possibly bandits would certainly add a frisson to a routine trip to visit a solar plant.

Christos Charalampidis, Europe Middle East and Africa (EMEA) head of O&M at Juwi oversees the solar assets the company operates and manages in South Africa. After some consideration, he says:

"The biggest O&M challenge that springs to mind is the geographical challenge. There are huge driving distances between plants themselves, often driving through deserts. You can be spending around 16-17 hours to get to plants. So yes, it can be tiring."

Weather and climate can also provide challenging conditions and environments to work in. In certain months, temperatures can climb so high that O&M activity is out of the question in the middle of the day and preventative maintenance has to be scheduled outside of sunshine hours, according to Charalampidis. Conversely night time temperatures can plummet, so appropriate clothing and gear need to be worn.

Since South Africa's Department of Energy signed outstanding power purchase agreements for many large-scale renewable energy projects, Juwi is expecting to increase its share of solar plants under O&M, possibly doubling or even tripling the amount of capacity it currently manages. The experience Juwi has gained from its O&M work to date in South Africa will stand it in good stead to take on further projects, but also holds valuable lessons for O&M practices elsewhere in the region. As solar projects become more common in sub-Saharan Africa, O&M will become increasingly important, but as Charalampidis has learned the hard way, the region presents a number of distinct operational challenges.

## Recruitment and training

One key consideration is workforce management. Many of Juwi's O&M teams are based on site and are recruited from local communities or the wider area. South Africa's renewable energy auctions stipulate measures that aim to ensure that previously marginalised communities and social demographic groups are involved in development, ownership and also management of renewable energy projects.

The training programme arranged by Juwi for local recruits covers competencies such as being authorised to work with high voltage equipment. Inverter-specific training is also given. "We always try to recruit people who do have some basic electrical experience," says Charalampidis.

To train and skill up someone to work on Juwi's solar plants in Africa can take up to one year. Afterwards staff can go on to improve their skills further.

"We organise seminars, or work with our inverter suppliers to provide training seminars. Sometimes these take place abroad. We try to motivate our staff to stay with us, so if they want they can undertake further training to take on more responsibility," he says.

Usually for an 8-10MW plant there are two people on site. For a plant of up to 75MW, there could be a team of four full-time Juwi staff and then subcontractors, where required. "We have trained our teams to work in a way so that the plants are managed with a high degree of autonomy, hence

furnishing them with high voltage switch and inverter knowledge," says Charalampidis.

## Maintenance

From its Cape Town office Juwi can provide administrative support and also specialist support in SCADA-related operations. There is also engineering support available in Germany, when required.

Because of the long shipping times between Europe and Africa, it is important to keep spare parts and stock on the ground. At the plants, some smaller parts are stored, and these are in special secure containers, rain proof and well ventilated. There are regular inventory checks and tests to ensure the spare parts do work.

Over time, Juwi has been able to gauge quantities to keep in stock based on the projected need of each plant to carry what it needs. The bigger parts, like transformers, are kept in warehouses, further from plants but on routes. Depending on the part, replacement times can vary. A fuse can take several minutes to replace but a transformer can take two to three days.

This same approach will be rolled out to the new plants that Juwi will manage. In terms of scheduled basic maintenance activities, like cleaning panels careful planning is needed to use limited amounts of water wisely. Timings and frequencies can be subject to change, for example if heavy rains are forecast so there is no cleaning during these periods. The company also measures panel soiling levels with a dust detection system.

Preventative maintenance depends on a field operating plan, which considers past experience and needs of equipment but also factors in heat and dust and impact on equipment.

"Inverter filters, for instance, need replacing more often than they would in Europe. The internal inverter temperature is also monitored," says Charalampidis. For modules, EL or IV curve measurements are carried out.

In Europe Juwi has been carrying out aerial inspections using drones. This has also been piloted in South Africa on the biggest plant Juwi manages.

"Trying to visually inspect an 86MW plant is practically impossible. The drone imaging picks up hotspots on modules, malfunctioning diodes and disconnected strings. When you add these various things up, it justifies the financial cost of using drones. Usually these aerial inspections happen annually. Results have satisfied us that it could also be used on other large plants in the market," he says.

## East Africa

UK company Solarcentury is starting to make bigger inroads into East Africa, where it has built both standalone solar PV plants and, more recently, plants incorporating batteries.

As the territory over which the plants are spread is so extensive, when any unscheduled maintenance issues do occur, the first step is to always try to rectify these remotely, explains Guy Lawrence, director of Solarcentury, East Africa.

"If that doesn't work then the local teams that are part of the facilities are contacted and if they have not been able to sort the issue within 12 hours, then Solarcentury's own technicians are dispatched with the replacement, such as an inverter," he says.

In terms of maintenance issues, there have been rare problems with panels themselves, says Lawrence, counting just one breakage. However, the plants are all relatively young in their operational lifetimes, with the first coming online in 2014.

In East Africa Solarcentury has five plants under management in the region, totalling 5MW, all about 1MW apiece.

They are in and around Nairobi, in Kenya, and include a shopping mall, distillery, tea factory and research institute, as well as a research institution on the Ugandan border, which includes the lead acid battery and solar PV system.

Over the rest of 2018, Solarcentury will be commissioning a number of new plants that it has built in sub-Saharan Africa, including Eritrea, Rwanda and Uganda.

To prepare for employing and training more technicians, the company has contacted the various universities with engineering departments to recruit students in the countries it will have plants in.

"This is part of Solarcentury's commitment to employing local staff in the countries it operates. European staff initially set up the O&M hub in the region (see box) but Solarcentury's operations in Africa are now 100% locally recruited which will continue as it expands in the region," says Lawrence. ■

### How Solarcentury resources O&M

In preparation for an increase in plants under management, about a year ago Solarcentury set up an O&M hub in Nairobi, Kenya, as a centre of excellence in Africa.

There, a full time operator, sitting in front of a bank of screens, keeps an eye on all the assets, applying the first line of defence, of detecting and rectify issues remotely, wherever possible.

The company has also employed and trained two full-time roving technicians. At each site, a facilities team is also trained to do some basic O&M. The technicians are employed to participate in the build of the solar plants, so that they understand how the systems connect up.

"This structure works in order to try to minimise unscheduled maintenance for a replacement, as due to long distances, and sometimes hazardous roads, can make it challenging to replace parts immediately," says Guy Lawrence, Solarcentury's East Africa director.

For inverters, filters can need replacing more often than in Europe. Spare parts – mainly panels and inverters – are stored in Nairobi, which the technicians are trained to change out if required.

Because there are no major inverter companies with bases in the region, if they do have to be contacted then invariably the offices in Europe of these companies deal with the issue. Sometimes this can pose a challenges as they sometimes do not understand or see what the operating environment is like in East Africa, according to Lawrence.

"If you stick to the manufacturer's maintenance guidance, the warranty is not invalidated. This means annual checks for inverters, for instance. In the case of lead-acid batteries, that means changing, or topping up, the water every six months. The batteries have also got to be housed in an air-conditioning unit to reduce temperature and humidity levels," Lawrence says.

Scheduled O&M activities, such as panel cleaning, are affected by weather, location and accessibility, water adequacy, dust and pollution. In some areas the panels are dry cleaned with a wet clean on an annual basis. Because labour costs are lower, it is affordable to employ people to undertake dry cleaning, which takes longer.

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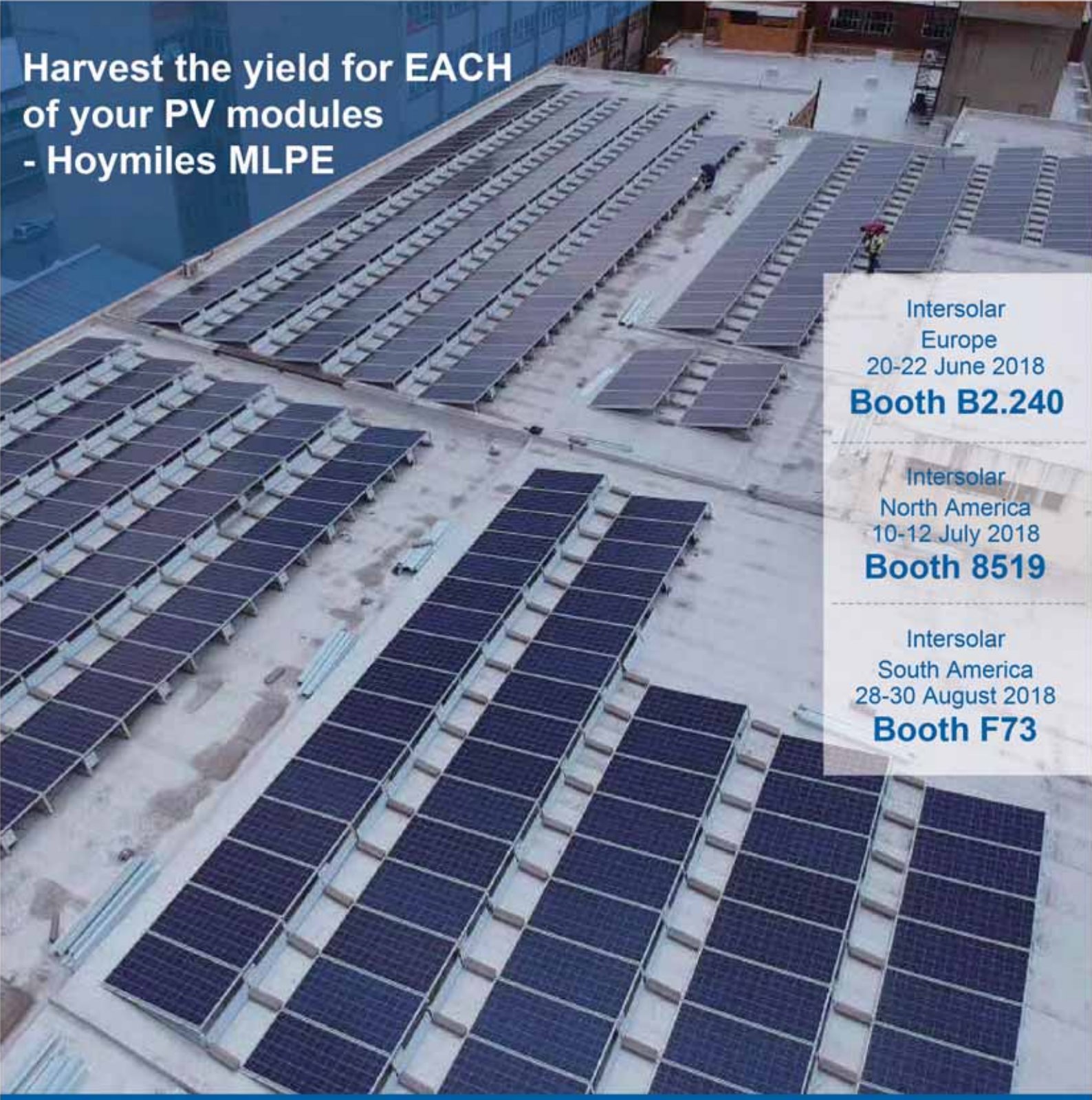

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# Digitisation — the inevitable path for Africa to solar grid parity

Going forward, digitised and intelligent products and technologies are expected to lead a new round of development in the PV industry. Take the Top Runner programme in China as an example – here digitisation plays an important role in achieving solar grid parity, offering important lessons for other regions such as sub-Saharan Africa, which stand to benefit from similar technological advances.

## Digitisation simplifies PV systems and improves O&M efficiency

"Many Top Runner Projects need to deal with great challenges from natural conditions, including undulating terrain, scattered landmass and ongoing mine subsidence that widely occurs," said Jian Zhaohui, deputy general manager of Power China Guizhou Engineering Corporation. Overcoming such challenges requires the solutions and product models that meet higher standards. "For example, we prefer the inverter that features a long life cycle, high conversion efficiency and easy and quick maintenance. As for the monitoring system, it should provide proactive alarm reporting, smart analysis, remote monitoring, central management, open interface, and continuous capacity expansion."

Smart inspection, for instance, has huge advantages over traditional manual troubleshooting. According to Pei Yongfeng, chief electrical engineer at Zhongtai Power Plant of Huaneng Shandong Power Generation Limited, the annual energy yield of Xintai 100MW solar-agricultural project could rise by 2.433 million kilowatt-hours thanks to the Smart I-V Curve Diagnosis function provided by Huawei FusionSolar Smart PV Solution.

The reporter on the spot found that the simplified and optimised inspection is merely a microcosm of the smart PV plant. The layout of PV modules, control of trackers and communication within the plant are all characterised by digitised and intelligent design. A technician of the plant said: "The smart I-V curve inspection itself can help raise the revenue of a 100MW PV plant by nearly US$1.58 million dollars in 25 years. By calculating from multiple dimensions, such as the energy yield, operation and maintenance (O&M) and fault rate, we found that the on-grid electricity price per kWh for a smart PV solution is US$0.013 dollars lower than that of a traditional solution."

**PV power plants incorporating digitised and intelligent technologies represent the next phase in the industry's evolution**

## Smart inverter + smart tracker + bifacial module: raising energy yield by digitised integration

Tony Xu, president of Huawei Smart PV Business, said: "With the technology advancement and rapid expansion of installation scale, the upgrade of PV power generation has transformed from component-led to system-led." He

agreed with Wan Hong, chief engineer at the Design General Institute of Golden Concord Group Limited, when he said that digitised and smart PV plants should opt for full system-level upgrades for future development. For example, a simple circuit system with digitised lights would not make much difference from the traditional system if the switch is not digitised. Digitisation requires full integration.

Xu explained: "Likewise, the previously interdependent PV module, inverter and mount cannot sense or integrate with one another. In this way, the angle of the mount can hardly be adjusted to the geographical location and astronomical algorithm. When bifacial modules are put into use, a fixed algorithm does not work anymore because the reflection condition varies with the grassland, sand and water surface, and the intensity of sunlight also varies with the height of PV module. The traditional inverter cannot collaborate with the tracker either. To increase energy yield, we should combine the inverter and bifacial module with the tracker by digitised integration."

According to Xu, the combination of the three devices will be a major achievement of digitisation in the next phase of the Top Runner Programme.

"The first step is to replace the power supply and communication devices with the string inverter, which will improve the PV system reliability, optimise general investment and, most of all, maximise energy yield."

The intelligent integration of the tracker and inverter has taken effect in Huaneng Xintai 100MW solar-agricultural project. According to Pei, it reduces the workloads of building communication and power supply circuits as well as the communication failure rate.

The capacity of a single PV array is 1,750kW. Using the Huawei smart string inverter can reduce construction costs by about US$0.003 dollar per watt by sparing the dedicated power and communications cables for trackers.

**The Huaneng Xintai 100MW solar-agricultural project intelligently integrates the tracker and inverter**

According to Wang Mengsong, product director of LONGi Solar, joint verification projects have been launched in Xinjiang, Heilongjiang, Guangdong and Shaanxi to test the performance of bifacial module and string inverter integration at different latitudes, ground surfaces and sunlight conditions.

On most occasions, the ground surface for a bifacial module cannot be chosen. "The ground reflection index varies with the season since grass grows in summer and withers in winter. There is no way to adjust the angle of the tracker by any algorithm. The digitised string inverter, however, can detect the optimal power given a reflection index. The module can also send the real-time power back to the inverter. Then the angle of the tracker can be adjusted by an adapting algorithm."

Digitised integration enables interworking between systems. As for the seamless integration of the inverter, tracker and bifacial module, Huawei has been a top runner in the industry. Based on the abundant application data and big data platform analysis, it has developed a leading smart design toolkit for the bifacial module. The toolkit combines an all-scenario, adapting and auto-learning "bifacial module + tracker" smart algorithm with the most efficient PV module MPP intelligent tracking algorithm. Compared with the normal solution design, the toolkit helps reduce the electricity cost per kWh of a PV plant by US$0.013 dollars and raises the energy yield by more than 3.9%.

## Reliable digitisation: raising the PV system energy yield

The deepening of product and device digitisation further complicates the PV system, increasing the need for system reliability.

Xu used a metaphor to illustrate the importance of reliability to digitisation: "For example, we use a kettle basically to boil water. To make it smart, we install a sensor in it and turn it into a digitised kettle. If the sensor often breaks down and we can't even boil water, no one would appreciate this type of digitistion. The tracker is not widely used mainly because the motor has a high fault rate. It is our ultimate goal that the machine serves human, not the other way around."

Wan shared his deep understanding on the energy yield brought by reliable devices: "A Top Runner project in Wuhai, Inner Mongolia, is located in a mining subsidence area with unstable terrain and large dust emission. It adopted the Huawei string inverter with a high protection level and a wireless transmission system to adapt to the terrain. Since the operation, the project has been maintaining a device fault rate lower than 0.5% and an energy yield rise by more than 2%, reducing the device maintenance workload."

"To be a top runner, a PV plant should focus on efficiency. To run for a long distance, however, it should put priority on reliability, which is determined by the device fault rate." According to Ji Zhenshuang, deputy director of China General Certification Centre, the centre collected the data of 150 PV plants for reliability analysis in the first half year of 2017. "Taking the inverter for example, the energy yield loss rate incurred by faults is around 1.5% on average and 0.5% for some quality products. The industry benchmark level, represented by Huawei, is below 0.3%. So there is still large room to improve the reliability of PV projects or reduce the loss rate incurred by faults."

With regard to the reliability of the PV plant monitoring system, Ji said: "We usually evaluate the system function by the completeness rate of the monitored items and data collection. The figure is 85% for the industry's average level, but more competitive companies like Huawei can reach above 95%."

Recently, authoritative international market consulting institution GTM Research released the global PV inverter report listing the world's leading PV inverter suppliers in 2017. In terms of shipment and revenue, Huawei came out on top in the list. Moreover, Huawei has been ranked No. 1 globally in inverter shipment for three consecutive years, 2015-2017.

Huawei's vision and mission is to bring digital technology to every person, home and organisation for a fully connected, intelligent world. Digitisation and 'intelligentisation' are also driving the optimisation and development of the PV ecosystem in Africa. ■

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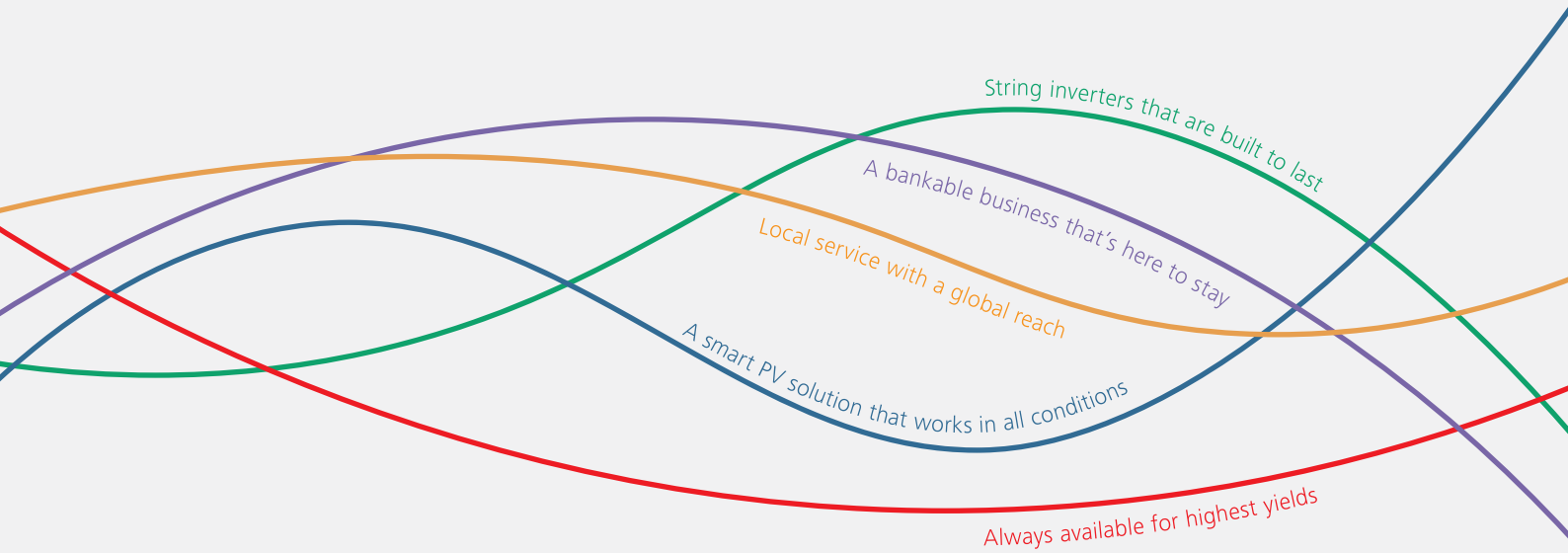


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