Digitalisation & solar in emerging markets

Task Force Report

SolarPower Europe

DIGITALISATION & SOLAR IN EMERGING MARKETS

Digitalisation & solar in emerging markets

2019 Case Studies

SolarPower Europe

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Supporters: The Alliance for Rural Electrification (ARE) is an international business association that promotes a sustainable decentralised renewable energy industry for the 21st century, activating markets for affordable energy services, and creating local jobs and inclusive economies. ARE enables improved energy access through business development support for its membership along the whole value chain for off-grid technologies.

GOGLA, the global association for the off-grid solar energy industry. Established in 2012, GOGLA now represents over 150 members as a neutral, independent, not-for-profit industry association. Its mission is to help its members build sustainable markets, delivering quality, affordable products and services to as many households, businesses and communities as possible across the developing world. To find out more, visit www.gogla.org.

Energy Web Foundation (EWF) is a global, member-driven nonprofit accelerating a low-carbon, customer-centric electricity system by unleashing the potential of blockchain and decentralized technologies. EWF focuses on technology integration and development, co-creating standards and architectures, speeding adoption, and building community. In mid-2019, EWF launched the Energy Web Chain (EWC), the world's first enterprise-grade, open-source blockchain platform for the energy sector.

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Project information: This report is a joint deliverable between SolarPower Europe's Emerging Markets Task Force and Digitalisation & Solar Task Force. The Emerging Markets Task Force, chaired by Eni SpA, was launched in March 2018 and since then has become an active working group of more than 120 experts from over 60 companies. The objective of the Task Force is to identify business and cooperation opportunities and thereby contribute to the energy transition in emerging markets outside Europe. The Digitalisation & Solar Task Force, chaired by SMA Solar Technology AG, started its work in December 2016 and has developed several reports around digitalisation & solar, and is providing input to the European Commission's stakeholder consultation on behalf of the solar industry.

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TABLE OF CONTENTS

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FOREWORD

BY STEFANO MANTELLASSI, ENI SpA– EMERGING MARKETS TASK FORCE CHAIR,

& PROFESSOR BERND ENGEL, SMA – DIGITALISATION TASK FORCE CHAIR.

Our first report on Digitalisation & Solar was published in 2017. It explored the intersection of solar PV and digitalisation and, in particular, how digital technology can be applied to solar. It looked at new and improved business models, the digitalisation of the entire solar value chain from manufacturing to Operation & Maintenance services, and digital grid integration. Yet, Europe and mature markets in general remained the focus of our 2017 report. It only included a teaser on the relevance of digital technology for emerging markets and off-grid contexts.

As a spin-off to our 2017 Digitalisation & Solar report, this report explores the importance of digital solar in new and emerging markets outside of Europe. It shows that digital solar is indeed a key pillar of the global energy transition in all segments of economy and society. On the one hand, this report includes off-grid digital solar technologies and business models such as solar-based microgrids and pay-as-you-go for solar, which enable access to energy in off-grid contexts or regions with unreliable power supply. On the other hand, we have also included on-grid technologies and business models that are interesting for new and emerging solar markets with stable power grids, such as smart data analytics or digital asset management for utility-scale solar power plants.

This report has been produced jointly by SolarPower Europe's Emerging Markets Task Force and Digitalisation & Solar Task Force, with valuable support from the Alliance of Rural Electrification (ARE), GOGLA and the Energy Web Foundation. With this report, we aim to show to policy makers, international institutions, public and private companies and end consumers how agile and versatile digital solar is. It provides answers to the world's most pressing challenges, including ensuring access to affordable, reliable, sustainable and modern energy for all – Sustainable Development Goal 7 of the United Nations.

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INTRODUCTION

The transposition of traditionally centralised energy systems to developing countries has not succeeded in providing access to clean and reliable electricity for all. In many developing countries, governments and utilities are still advocating for the expansion of existing grid infrastructure. However, many grids in emerging markets are not delivering reliable electricity to their urban customers, let alone to customers in rural areas.

Access to reliable electricity, however, is crucial for the economic and social development of a community and for reducing the social divide between citizens. In Africa, for example, there is a vast urban-rural divide with about 60% of the urban population able to access electricity, compared to only 15% of the rural population,[1] leaving many social and business opportunities untapped.

The need to expand electrification for all is accompanied by advancements in digital technologies and a quick penetration of digital technologies globally. In just five years, the number of internet users around the world has grown more than 75% since 2014; and there are no signs that growth is slowing down.[2] Particularly, investment in digital technologies by energy companies has risen sharply over the last few years. For instance, global investment in digital electricity infrastructure and software has increased by over 20% per year since 2014, and by the end of 2016, global digital investment was almost equal to total investment in India's electricity sector (USD 55 billion).[3] Even more impressive are the benefits that digitalising the energy sector can bring in the future:

- Digital grids could lead to EUR 810 billion in extra revenues for renewables between now and 2030.[4]
- Digitalisation could represent up to USD 1.3 trillion of value to the electricity sector from 2016 to 2025.[5]
- Some projections show that we could see 200 billion Internet of Things (IoT) devices by 2020.[6]
- The volume of controllable smart appliances in the EU by 2025 is expected to be at least 60 GW, which could reduce peak demand by 10%.[7]
- Consumer expectations are changing in all sectors including electricity: they want to have more choices and more comprehensive, seamless, intuitive, personalised, ethical and engaging services.

1 https://microgridnews.com/improving-energy-access-in-rural-africa-depends-on-renewable-energy-microgrids/#easy-footnote-bottom-4-7513

2 https://datareportal.com/reports/digital-2019-global-digital-overview

3 https://www.iea.org/digital/

4 Global e-Sustainability Initiative, available here: http://smarter2030.gesi.org/downloads/Full_report2.pdf

5 World Economic Forum/Accenture (2016) "Digital transformation of industries: Electricity industry". Available here: https://www.accenture.com/t20170116T084450__w__/us-en/_acnmedia/Accenture/Conversion-Assets/WEF/PDF/Accenture-Electricity-Industry.pdf

6 Estimation from the United Nations, IDC and Intel, available here: https://www.intel.com/content/www/us/en/internet-of-things/infographics/guide-to-iot.html

7 European Commission (2015) "Best practices on renewable energy self-consumption", p. 5. Available here: http://ec.europa.eu/energy/sites/ener/files/documents/1_En_autre_document_travail_service_part1_v6.pdf

The diagram below shows how digital technologies are being applied to smarten the wider energy system, and solar PV systems in particular.

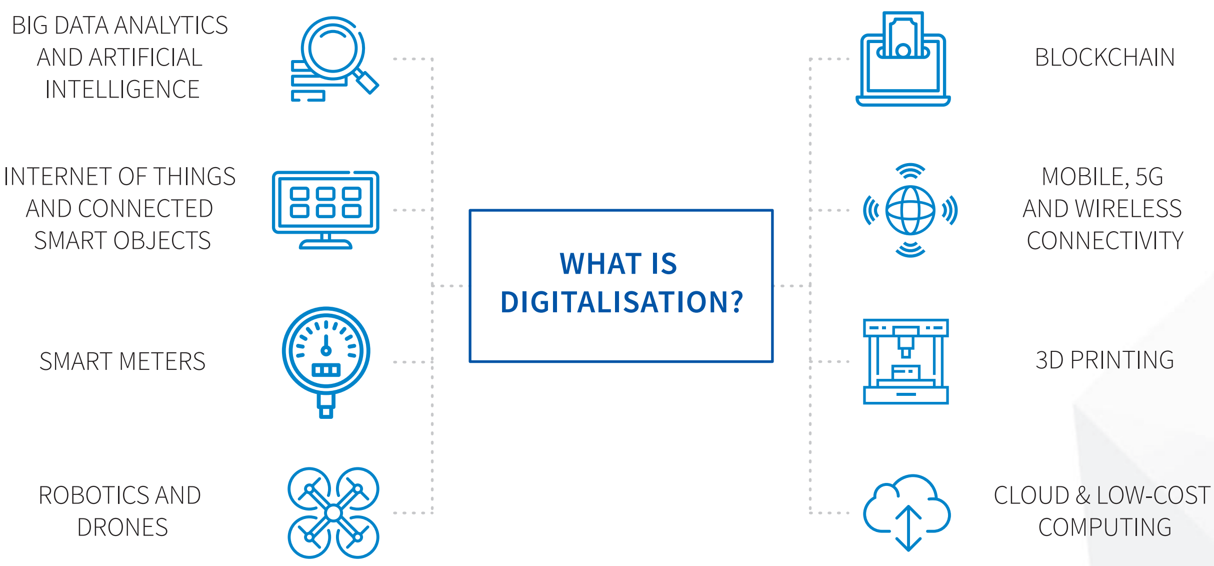
Digital technologies and business models are transforming the energy landscape worldwide, with the potential to enable an unprecedented uptake of solar installations in emerging markets. The digitalisation of the solar sector is extremely relevant for emerging and developing countries since it can enable these countries to leapfrog elements of traditional power systems in terms of both technology and regulation, and the benefits are myriad: acceleration of electrification timeframes, improvement of service delivery, reduction of electricity costs and better redistribution of social benefits.

Digitalisation in emerging markets is also a vast opportunity for solar developers to harness innovative digital technologies and business models, scaling-up sustainable and impactful solutions. In the first chapter of this report, we introduce examples and case studies demonstrating how digital solar solutions enable access to energy in off-grid contexts and areas with unreliable power supply. The rapidly falling prices of solar equipment coupled with the development of new technology-enabled business models such as pay-as-you-go, which leverages mobile money systems present in many African countries, have created a bright market for off-grid solar and a brighter future for citizens confronted for the first time with the opportunity of universal energy access.

In the second chapter, the report showcases how digitalisation helps to boost grid-connected solar in emerging markets. We look at how solar players in these markets are leapfrogging to the most advanced smart data analytics and machine learning technologies, digital asset management platforms and grid intelligent solar applications.

While digital technologies and business models are presented in two distinct chapters based on whether they tend to be used in off-grid or on-grid contexts, it is important to note that there is no hard line between off-grid and on-grid technologies. Digital solar is highly agile and versatile and many innovations can be adapted to off-grid or on-grid contexts.

FIGURE 1 WHAT IS DIGITALISATION?



1 DIGITAL SOLAR ENABLING ACCESS TO ENERGY IN OFF-GRID AND UNRELIABLE GRID CONTEXTS

Aerial View of Robben Island microgrid, South Africa. © ABB.

Around one billion people – mostly concentrated in South Asia and Sub-Saharan Africa – still live without access to electricity, and for hundreds of millions more, the electricity is simply unreliable or too expensive.[8] The systemic lack of access to sustainable, secure and affordable electricity is deterring social and economic development in emerging economies,[9] and leaving economic opportunities untapped.

The number of people gaining access to electricity has been steadily increasing over the last years, but efforts need to greatly accelerate if the world is to meet the Sustainable Development Goal 7 and ensure access to affordable, reliable, sustainable and modern energy for all by 2030.

One way to ensure access to electricity for all is by extending the grid in places where the grid does not exist or where the grid is simply too weak and unreliable. However, extending grid-based electricity has important hurdles including connecting to an already weak transmission and distribution grid, insufficient power generation capacity to meet the electricity demand, high costs of extending the electricity network to remote areas, or simply a lack of affordability to pay for the electricity.

Off-grid electrification has proved to be an interesting alternative to electrify remote areas or regions where the grid is too weak and unreliable. Developing countries and emerging markets are making impressive progress in increasing access to electricity thanks to the increased recognition that the fastest and least expensive path to electrification may be via off-grid, distributed, renewable energy. In fact, off-grid solar products have seen considerable growth over the past decade. Since 2010, at least 245 million people[10] have opted for off-grid solar to gain access to clean and reliable electricity. In addition, the IEA estimates that off-grid systems and mini-grids will be the most cost-effective solution for over 70 per cent of those who will gain energy access in rural areas by 2030.[11] Off-grid solar is a decentralised technology that is spreading through commercial markets; moving at speed and costing less than the incumbent.

8 www.iea.org/newsroom/news/2018/october/population-without-access-to-electricity-falls-below-1-billion.html

9 www.worldbank.org/en/news/feature/2018/04/18/access-energy-sustainable-development-goal-7

10 Global Off-Grid Solar Market Report. H2 2018. GOGLA/Lighting Global/Efficiency for Access Coalition 2019. https://www.gogla.org/global-off-grid-solar-market-report

11 https://sustainabledevelopment.un.org/content/documents/17589PB24.pdf

Digital innovation will continue to be a major driver of off-grid solar market growth. With around 1 billion people without electricity access, there is space and a need for more companies, innovation and investment to bring the benefits of off-grid solar to those who need them the most, and reach universal energy access by 2030 (SDG7).

This chapter presents digital solar technologies and business models that enable access to energy in off-grid contexts and can help consumers to cope with unreliable power supply.

1.1. Solar-based mini-grids

Off-grid electrification includes the deployment of mini-grids. A mini-grid (a very small version of which is called microgrid) is a network of small-scale electricity generators, and possibly energy storage systems, that supplies electricity to a localised group of customers. Mini-grids are small networks that can be independent (autonomous) of a nearby grid or can be connected to the main grid.

Mini-grids are being rapidly deployed to customers where the utility grid is absent or has failed. Globally, at least 19,000 mini-grids installed in 134 countries provide electricity to about 47 million people, most of them in rural areas. Emerging markets in Asia have the most mini-grids installed today, while Africa has the largest share of planned mini-grids.[12]

The reasons for installing mini-grids can be manifold. It could be that the utility cannot afford to upgrade infrastructure that is already aging and inadequate, or that it is economically or technically not feasible to extend the central grid to certain remote areas or islands. Even if an urban or rural community has access to the central grid, it may be forced to complement unreliable electricity supply with expensive and highly polluting backup diesel generators to compensate for frequent power failures. Given the savings over kerosene, avoided infrastructure costs, and cascading benefits, there is an investment opportunity for mini-grids in emerging markets, and an increasing policy push to fairly value and promote off-grid mini-grids.

There is also an increasing tendency to reduce the use of diesel generators in mini-grids by hybridising diesel with solar. In hybrid mini-grids diesel generators are only turned on when there is not enough solar generation, which can significantly reduce fuel costs. Diesel is not only more expensive than solar,[13] but the burning of the fuel contributes to greenhouse gas emissions and negatively impacts health.[14] Solar-based micro-grids are increasingly being equipped with battery storage, which allows the consumer to use solar electricity when the sun is not shining or over cloudy periods and thus further reduce diesel generation.

Significant progress in extending solar-based mini-grids can be achieved thanks to the technological innovations shown in the following case studies.

12 https://esmap.org/mini_grids_for_half_a_billion_people

13 https://www.nature.com/articles/s41893-018-0151-8

14 https://www.atsjournals.org/doi/full/10.1164/ajrccm.183.10.1437

1 DIGITAL SOLAR ENABLING ACCESS TO ENERGY IN OFF-GRID AND UNRELIABLE GRID CONTEXTS / CONTINUED

SMA'S SOLAR-POWERED MICROGRID IN NEPAL BRINGING POWER TO 1,000 PEOPLE

In March 2019, public life was completely transformed for the 1,000 inhabitants of Gutu, Nepal.

Since then, 275 households, a post office, businesses, schools, the hospital and administrative offices have been connected to a solar-powered microgrid. Before that, most residents had no electricity access at all. System operator Peak Power has set up a 100-kilowatt PV power plant which reliably supplies clean electricity to the location via more than 7 kilometers of overhead power lines. Every building is connected to smart counters which ensure sustainability and fair use in the community. People are in control of purchasing their own power. They buy energy in a pre-paid system and reinvest the money from the energy back into the co-operative that operates the plant. In this way, it remains a sustainable business.

The system can be controlled and monitored via the online portal SMA Sunny Portal using 3G internet. Any excess solar energy is stored by battery storage which can provide the energy as required even after sundown. Within a particularly short time, the solar microgrid has substantially improved the quality of life in Gutu.

The hospital, government office and bank are now in a position to reliably operate their IT and communication devices as well as vital AC devices in part. Finally, the school is now able to utilise the computer room again, which was put out of operation for years due to the unreliable electricity supply. Lights and heating can now be switched on wherever required. Farmers are profiting from electric grinding and husking machines and are able to process their harvest faster and more efficiently. The hotels are becoming more attractive for tourists due to their reliable lighting, hot water or cable TV.

Several full-time jobs have been created in the power plant itself. The employees, who received appropriate training, are responsible for plant maintenance and administration of the settlement system, amongst other things.

People are now able to cook using AC solar power instead of open fires – they use AC-coupled rice cookers without any soot and air pollution. The candles and diesel generators have mainly become redundant. The location is much quieter and the air substantially clearer.

DIGITAL TECHNOLOGIES USED:

- INTERNET OF THINGS AND CONNECTED SMART OBJECTS
- MOBILE, 5G AND WIRELESS CONNECTIVITY
- SMART METERS

Message on climate protection from Mount Everest.

Seven kilometres of overhead lines supply solar power to the households.

Excess solar energy is stored by a battery storage which can provide the energy as required.

System operator Peak Power has set up a 100-kilowatt PV power plant in Gutu.

EATON'S WADEVILLE MICROGRID IN SOUTH AFRICA ANSWERS TO CHALLENGES DUE TO UNRELIABLE POWER SUPPLY

At Eaton's Wadeville facility in South Africa we faced some key challenges due to unreliable energy supplies and high electricity costs.

We experienced more load shedding due to cable faults and scheduled maintenance of the grid. Within the manufacturing facility, we faced increased energy charges impacted by seasonality, peak time and high network demand charges.

To solve these issues, we decided to build a microgrid as a stand-alone power generation, distribution and storage system that would work with, or independently from, the main utility grid.

The Wadeville Microgrid is a stand-alone power generation, distribution and storage system that can be operated independently of, or in parallel with, the primary utility grid. The Wadeville Microgrid leverages Eaton´s proprietary Power Xpert Energy Optimizer™ microgrid controller, solar PV and the xStorage energy storage system to create a range of financial and environmental benefits for the Wadeville manufacturing campus. It helps to:

- Save **money** on energy costs by offsetting utility and diesel
- Being **confident** in continuous energy supply
- Meet **renewable energy** and CO_2 reduction goals
- Reduce **risk** as the utility landscape continues to evolve

With the integration of the microgrid controller, the project is offsetting the cost of diesel generators and it is catching the grid energy when available. It can seamlessly island from utility to microgrid in the event of an outage without interruption and can activate the synchronisation between storage, utility / storage and genset.

We reduce the electricity bill for energy and peak charges of more than 30%, diesel costs of the genset are reduced by 26% and we are preventing production losses due to an average of 33 outages per year. Overall, it does improve resiliency, cost and efficiency.

The project is stacking multiple value streams to reach a high return on investment (ROI), and the break-even is expected in less than 5 years, generating operational savings of 56%.

DIGITAL TECHNOLOGIES USED:

BIG DATA ANALYTICS AND ARTIFICIAL INTELLIGENCE

SMART METERS

Eaton's Wadeville facility in South Africa.

1 DIGITAL SOLAR ENABLING ACCESS TO ENERGY IN OFF-GRID AND UNRELIABLE GRID CONTEXTS / CONTINUED

SMA'S BLACKSTART FUNCTION CREATING A STABLE UTILITY GRID IN JUST A FEW SECONDS ON MARLON BRANDO'S DREAM ISLAND

"No more fossil fuels on this island." These were the words of Hollywood legend Marlon Brando.

Now, the luxury private resort on the island of Tetiaroa in the South Pacific has been receiving a near around-the-clock supply of solar power. In order to operate a complete power grid in this isolated region, special solutions were required.

Blackstart challenge: a stable electricity supply in just seconds

The greatest challenge, however, was to simultaneously magnetise the large transformers on the utility grid and to start the utility grid from the battery system. We therefore developed the Blackstart function: Working in conjunction with the hybrid controller, the battery inverter creates a stable utility grid in just a few seconds. The Blackstart function is now a valuable, additional standard feature in the SMA products Sunny Central Storage 2200 and SMA Hybrid Controller, making a major contribution to grid stabilisation even in large battery systems on the utility grid.

Remote maintenance: professional support

We of course also support our customer during the operational phase with our remote maintenance service. The monitoring system runs fully automatically and reports any irregularities. This support is vital for the customer because maintenance work and failures occur much less frequently in PV systems than in more maintenance-intensive thermal generation systems, which in turn means that maintenance and repairs do not become routine jobs for the local operator. This is why our experts are on hand to provide fast and highly professional support as required—including software updates.

The goal: 100% solar power

Now, 60% of the electricity supply for The Brando comes from solar energy. Everything is running as it should be—and we even improved the quality of the utility grid on the island. The team once again did a stunning job, and our partnership with the customer is every bit as smooth as the system itself. Richard Bailey is so impressed with the new energy supply that he is investigating possibilities to make the energy supply for the island 100%-solar-energy-based. This would represent the perfect realisation of Marlon Brando's vision: "My mind is always soothed when I imagine myself sitting on my South Sea island at night. If I have my way, Tetiaroa will remain forever a place that reminds Tahitians of what they are and what they were centuries ago."

Special features of the energy system:

- Largest BEES in French Polynesia.
- Stable utility grid in just seconds thanks to the Blackstart function.
- Annual solar fraction of over 60%.

Special features of the energy system:

- System size: 1.4 MWp solar power, 2.6 MWh battery-storage system
- SMA components: Sunny Central Storage 2200, SMA Hybrid Controller, 32 SMA Sunny Tripower, Remote Service.
- Fuel saving: 500,000 liters.
- Commissioning: December 2018.

DIGITAL TECHNOLOGIES USED:

- INTERNET OF THINGS AND CONNECTED SMART OBJECTS
- BIG DATA ANALYTICS AND ARTIFICIAL INTELLIGENCE
- CLOUD & LOW-COST COMPUTING

With the new black start function and grid-forming properties, the Sunny Central Storage battery inverter ensures that a stable grid is established in seconds.

ABB: TURNING ROBBEN ISLAND, MANDELA'S PRISON, INTO A SOLAR-POWERED MICROGRID, SOUTH AFRICA

Bringing a modern, sustainable technology solution to a historically significant site, ABB has provided a microgrid system to integrate solar energy and supply power to Robben Island, the place where Nelson Mandela spent 18 years in prison during the apartheid era.

Now a living museum and World Heritage Site that receives up to 2,000 ferry-riding visitors a day, Robben Island previously relied on diesel generators burning around 600,000 liters of fuel annually as the only source of electric power.

The new Robben Island microgrid captures solar power from an array of photovoltaic panels on the southeast side of the island that cover an area the size of a football field and have a peak capacity of 667 kilowatts. 12 solar inverters convert the variable direct current (DC) output from the solar panels into the alternating current (AC) needed to provide electrical power to the island. By enabling the island to run on solar power for at least nine months of the year, and using diesel only as a backup, the microgrid significantly lowers fuel costs and carbon emissions are reduced by around 820 tons per year.

To run on 100% renewables during a period of time, achieve optimal efficiency, the microgrid depends on extensive digital capabilities. The e-mesh control system enables management of the power supply, including energy storage and balancing of the use of renewable energy and diesel back-up in accordance with changing demand.

ABB's containerized, modular plug-and-play microgrid solution includes an e-mesh™ PowerStore™ battery energy storage system with a capacity of 500 kW/837kWh forms the grid and balances energy supply. The dedicated internet cloud-based capabilities make remote operation possible from Cape Town, 9 kilometers away across waters with treacherous currents. The remote set-up also eliminates the need to maintain a workforce on the island, and the use of a wireless network removes the need for cable trenches, helping protect the local habitat.

As of 2019, ABB has an installed base of microgrids and BESS that aggregates more than 450 MW worldwide and over 170 installations serving remote communities, islands, utilities and industrial campuses.

DIGITAL TECHNOLOGIES USED:

- INTERNET OF THINGS AND CONNECTED SMART OBJECTS
- CLOUD & LOW-COST COMPUTING

e-mesh PowerStore battery energy storage system, Robben Island, South Africa.

1.2. Demand forecasting and Demand Side Management in off-grid contexts

Forecasting of power demand plays an essential role in the electric industry, as it provides the basis for making decisions in power system planning and operation, both for utility-scale and off-grid solutions. In rural and remote areas in Africa, Asia-Pacific, Latin America and the Caribbean, forecasting demand is especially challenging because new customers often lack historical data about their electricity consumption.

In the context of mini-grids - where integrating renewable energies from variable and distributed resources is a complex piece of work - digitalisation helps developers to reduce operational costs and thereby optimise their projects to be much more effective for the consumers.[15] For both new (greenfield) and hybridized existing projects (brownfield), digital technologies can be adopted throughout different phases of decentralised rural electrification projects. For example, mini-grid sizing can be optimised by relying on more accurate load profiles: that can be achieved using remote monitoring and modern control system equipment like smart meters. Already existing systems can be optimised through Demand Side Management (DSM).

The different types of DSM include peak clipping, valley filling, load shifting, demand reduction and demand stimulation.[16] These interventions take many forms, both push (e.g. new technology and hardware) and pull (e.g. customer incentives). Examples for push incentives include selling electric appliances to different customer groups and providing associated financing; replacing inefficient appliances; whereas examples for pull incentives are targeted at scheduling commercial loads for certain times of day; limiting power consumption; mini-grid operators setting up ancillary businesses that consume electricity; customer education; and tariff incentives.

The benefits of DSM are two-fold: first, consumers can reduce their electricity bills by deciding and adjusting themselves the timing and amount of their electricity use. Second, the energy system can benefit from the shifting of energy consumption from peak to non-peak hours which will contribute to increasing revenues, relieving the stress on the system and improve (mini-) grid reliability. The behaviour of electricity consumers, especially of anchor clients has a strong impact on the stability of a mini-grid system because of their higher power demand. Therefore, a thorough evaluation of such consumers facilitates proper demand forecasting and management.

In cases of greenfield projects, traditional electricity demand forecasting approaches, like village surveys and predictions of population density to estimate the electricity demand, are time-consuming, expensive, and most importantly at times not precise enough as they rely on estimates. However, the use of modern technologies such as Geographical Information System (GIS) for mini-grid site selection, and Artificial Intelligence (AI), like machine learning algorithms, can already help to assess and predict the socio-economic conditions and thereby assist in the electricity demand forecasting of the potential project site.[17]

15 https://setis.ec.europa.eu/system/files/setis_magazine_17_digitalisation.pdf

16 https://www.energy4impact.org/file/2100/download?token=9k2uhkpD

17 https://minigrids.org/wp-content/uploads/2019/07/VIDA_TFE_short.pdf

BLUE SOLAR'S 'KOH JIK RECHARGE' OPTIMISING AN EXISTING MICROGRID THROUGH ENHANCED DEMAND FORECASTING IN THAILAND

Koh Jik Island, Thailand, is showcasing a community owned and operated renewable energy micro-grid.

A micro-grid was established and has been operating since 2004 which was upgraded in 2012. However, in 2018, critical system components reached their end-of-life. The community of 400 inhabitants was losing reliable 24/7 access to clean electricity. Therefore, the Koh Jik ReCharge project was commenced by Blue Solar and other project partners to restore and improve the micro-grid system implemented in Koh Jik, Thailand. It was done by replacing failing assets, implementing an automatic control system, flexible hybrid AC-DC configuration as well as network connected digital meters for easier management and monitoring.

Facing an already existing microgrid, emphasis has been placed on the optimisation of the electricity generation capacity sizing in terms of generation costs and renewable energy fraction. Accurate load profile and forecasting of future demand has been crucial in the optimisation process. For this reason, high resolution load profile data (1-minute resolution) on the network level was collected for a period of more than six months. Data sent from the island through 2G/3G cellular communications was remotely accessed through an online cloud server. The project has also received funding from Australian Aid to install smart meters which have enabled detailed monitoring of demand at household level, improving demand forecast. The use of digital technologies for system monitoring, metering, and connectivity has allowed for an overall improvement in the data collection process.

The Koh Jik project is jointly developed by Blue Solar and Symbior, who are renewable energy project developers based in Thailand.

DIGITAL TECHNOLOGIES USED:

CLOUD & LOW-COST COMPUTING

MOBILE, 5G AND WIRELESS CONNECTIVITY

SMART METERS

The Koh Jik Micro-grid.

1 DIGITAL SOLAR ENABLING ACCESS TO ENERGY IN OFF-GRID AND UNRELIABLE GRID CONTEXTS / CONTINUED

1.3. Operation & Maintenance in remote areas

Operation and maintenance (O&M) of solar PV systems in remote areas – often off-grid systems and mini-grids – come with various challenges due to several factors. First, off-grid projects are sometimes funded through various grants, only covering the installation costs but not long-term O&M. Second, rural populations who are beneficiaries of off-grid installations can in many situations not afford O&M costs, especially when it comes to replacing spare parts and components. Third, the necessary technical skills to execute quality O&M services are not always available in rural areas where off-grid PV systems and microgrids are located.[18]

These issues can impact the long-term health of off-grid solar systems and mini-grids negatively, which is a problem on multiple levels. On the one hand, the lack of (quality) O&M services leads to higher operational costs, lower energy output and a lower return on investment due to increased failure rates of systems and components. On the other hand, regular failures of solar systems create distrust in local communities and decreases public acceptance of the energy transition.

To tackle these challenges, O&M service providers are using digital technology to **reduce operational costs and increase asset performance**. The following digital technologies are increasingly being used by O&M service providers of off-grid and remote PV installations and mini-grids:

- **Predictive maintenance** can use patterns in temperature and output to predict module degradation, soiling, component (e.g. module, inverter or combiner boxes) failures or system failures. This could eliminate some maintenance visits, anticipate others and reduce expensive unplanned emergency visits.
- **Remote sensoring and control**, 5G and wireless communications, embedded test electronics and data analysis can help diagnose faults remotely, enhance preventative maintenance and increase plant yield. At present, most solar data is communicated using a normal interconnection DSL and LAN with GPRS as backup. Low-power wide-area networks (LPWAN) may be used in future, which are also enabling a lot of IoT communications.
- **Cloud computing** is used to store data from data loggers on site in data centres accessed over the internet.
- **Digital field workers** who use mobile technology can make field operations more efficient, and central control centres can track the locations of teams to assign them to jobs in an optimised manner. The more data field workers input into systems in real-time, the better the reporting on response times can be and the better the analysis of improvements in performance. Smart glasses technology could even be used in the future to assist in maintenance.
- **Satellite forecasting** for irradiance measurements and remote sensing is now considered best practice. Forecasting also allows for better-timed maintenance visits and can be compared with real measurement data to further improve accuracy. Satellite-based data services are accurate across the year and are less prone to systemic errors. Looking ahead, we are likely to see more and more granularity in satellite data e.g. 15--minute intervals. Similar technology can also be used to track dust, pollution and particulate matter that impacts yield.
- **3D printing** could, in the future, reduce spare parts management costs by reducing the number of spare parts in storage, decrease lead times and manufacture spare parts closer to site.

18 Feron, Sarah. 2016. "Sustainability of Off-Grid Photovoltaic Systems for Rural Electrification in Developing Countries: A Review", in: Sustainability. https://www.researchgate.net/publication/311883258_Sustainability_of_Off-Grid_Photovoltaic_Systems_for_Rural_Electrification_in_Developing_Countries_A_Review

FERNTECH'S UNIVERSAL MONITORING AND CONTROL TECHNOLOGIES FOR OFF-GRID INDUSTRIAL APPLICATIONS (WATER) IN COLOMBIA

Even though La Guajira is on the coast in the northeast of Colombia, it is a very dry area.

The local residents, many of whom are indigenous, are poor and suffer from a lack of clean drinking water. There is little chance in the region accessing drinking water suitable for human consumption.

The potential for renewables in this area is huge. La Guajira area is basically a wild desert where the sun, wind and saltwater are abundant, but clean drinking water is scarce.

With the co-financing of DEG, and together with our partners MFT (https://www.mft-koeln.de/) and Colenergy (https://colenergy.co/), Ferntech has participated in the deployment of an off-grid Reverse Osmosis (RO) water desalination plant that is in operation since more than 1 year in La Guajira.

The plant is powered with wind and solar energy, which is stored in lithium-ion batteries.

Main specifications:

- Capacity Up to 120L/h drinking water output
- Energy Sources: 7,5 KWp PV, 350 W Wind turbine
- Storage: 11,2 kWh Lithium Ion

All data of the plant, including the separate weather station, is monitored and recorded using Ferntech's Controller. The data is sent via GSM to Ferntech's portal so that actionable decisions can be taken in real time by MFT back in Cologne.

The remote-control system makes it possible to see in Cologne how the system is performing real time. The system records the weather condition, how much electricity is being provided by wind and solar sources, how much water is being produced and at which quality. If the drinking water quality falls below a certain limit, the system switches off automatically to prevent unfit water from being supplied to consumers.

FERN TECH

A business model is also being tested based on gallons sales of clean water in the community where this system was donated.

This project was selected as one of the best water-projects in Latin-America.

More info here:

https://ferntech.io/industrial-applications

https://www.dw.com/en/clean-water-for-the-wayuu-in-colombia/av-44038759

DIGITAL TECHNOLOGIES USED:

- INTERNET OF THINGS AND CONNECTED SMART OBJECTS
- MOBILE, 5G AND WIRELESS CONNECTIVITY
- CLOUD & LOW-COST COMPUTING

Remotely controlled off-grid water desalination plant in northern Colombia.

1 DIGITAL SOLAR ENABLING ACCESS TO ENERGY IN OFF-GRID AND UNRELIABLE GRID CONTEXTS / CONTINUED

AMMP'S UNIFIED OPERATION CENTRE IN NIGERIA TO ENABLE REMOTE MONITORING AND MANAGEMENT OF HUNDREDS OF SOLAR-POWERED MINI-GRIDS

AMMP

The Sabon Gari Market is the second largest industrial centre in Nigeria.

It is home to around 12,000 small enterprises and shops. Like many similar commercial areas in Nigeria, it is completely off-grid with no access to the national electricity grid. This means that shop owners as well as the one million monthly visitors are constantly exposed to the noise and the pollution of thousands of small-scale diesel generators.

In 2018, the energy service company Rensource[19] installed 100 decentralised solar mini-grids to replace these diesel generators.

Rensource is responsible for the operation and maintenance of these systems. Operating such a large portfolio of mini-grids efficiently means being able to quickly respond to issues in order to keep customer satisfaction high and operational costs in check.

To facilitate this, AMMP provides a unified network operation centre for Rensource, which processes generation data and smart meter data, as well as allows the management of multiple associations such as between smart meters and generation systems. The solution also gives the data more meaning by including "physical ground truths" of installed equipment – such as relationships between smart meters, systems and physical equipment locations.

AMMP was designed to serve Rensource's field service engineers and operations engineers during their daily operation. The software provides real-time system monitoring and control functionalities as well as instantaneous and selective alerts to email and Slack channels in order to reduce downtimes and increase customer satisfaction. Furthermore, project managers, engineers, and stakeholders now have a detailed overview of the long-term performance of each mini-grid.

By using these smart solar mini-grids, the Sabon Gari Market was able to prove the advantages of solar over diesel generators to the public, as with this step, high customer satisfaction and a reliable energy supply was achieved. As a result, by now, the Rural Electrification Agency (REA) expanded this concept together with Rensource to seven additional industrial clusters in Nigeria – with AMMP being at the core of Rensource's operations – proving, once again, how digital solutions can really have an impact on scaling decentralised renewable energy systems.

DIGITAL TECHNOLOGIES USED:

- INTERNET OF THINGS AND CONNECTED SMART OBJECTS
- MOBILE, 5G AND WIRELESS CONNECTIVITY
- SMART METERS
- CLOUD & LOW-COST COMPUTING
- BIG DATA ANALYTICS AND ARTIFICIAL INTELLIGENCE

AMMP provides a unified network operation centre for Rensource. © Rensource, www.rensource.energy

19 With the support of the Federal Ministry of Power and the Rural Electrification Agency (https://rea.gov.ng/energizing-economies/)

1.4. Pay-as-you-go for solar

The off-grid solar sector has been at the forefront of leveraging technological innovation and digital solutions to reach as many customers as possible. A new and increasingly common digital solar business model in frontier markets is pay-as-you-go (PAYGo) solar. Digital innovation has created a sweet spot – delivering excellent products and services for customers, enabling low-cost operations for companies, and protecting assets and revenue streams for investors.

The business model allows customers to pay for their off-grid solar product in small installments. Particularly in East Africa, companies utilise the ubiquity of mobile phones to allow customers to pay their regular instalments with mobile money, e.g. M-Pesa in Kenya. In the second half of 2018, GOGLA members and affiliates reported sales of almost one million PAYGo-enabled products.[20]

There's evidence PAYGo solar unlocks benefits for its users beyond access to clean and affordable electricity. People who have never had access to financial services and banks can build a credit history with PAYGo providers and gain eligibility with formal financial service providers.[21] In addition, solar home systems enable many customers to work and earn more, leading to reported improvements in quality of life, health and safety.[22]

Woman recharging her Simpa PAYGo meter. © Simpa Networks

20 Ibid.

21 https://www.cgap.org/blog/four-ways-energy-access-can-propel-financial-inclusion

22 https://www.gogla.org/poweringopportunity

1 DIGITAL SOLAR ENABLING ACCESS TO ENERGY IN OFF-GRID AND UNRELIABLE GRID CONTEXTS / CONTINUE

BBOXX'S PAY-AS-YOU-GO FOR SOLAR MODEL BOOSTING ELECTRIFICATION IN SUB-SAHARAN AFRICA

BBOXX's pay-as-you-go (PAYGo) model has been transformative for the many countries where it operates, including Rwanda, Kenya, Togo and DRC.

The ability to pay for Solar Home Systems (SHSs) in small installments and with the use of mobile money has enabled access to electricity for those who would otherwise not be able to pay for a SHS up front as the total cost is still prohibitive to the majority of those currently without access, and/or are too remote to be able to pay at a designated point. Through BBOXX's SMART Solar remote monitoring technology, which brings together SHSs, Internet of Things (IoT) and Machine to Machine (M2M) technologies and allows automatic enabling and disabling of a SHS based on payments made, a quicker response to payment delinquencies and therefore a reduction in payment defaults has been achieved. SMART Solar also helps BBOXX improve the understanding about how customers use their SHSs. By monitoring the battery voltage and current, the portion of total available energy that a customer uses each day can be calculated. Load disaggregation provides further insight into each device that is being used. By analysing both how much energy a customer uses, and which devices they use, it is possible to learn about each customer's energy priorities and energy profiles, and through remote control capability, adjust the systems' parameters and charging profiles to best suit the customers' needs.

Understanding customers' energy use behaviour and improved repayment rates through remote monitoring and PAYGo has also enabled BBOXX to boost customer financing – a common challenge in the off-grid solar sector. By utilising IoT, M2M and PAYG technologies, greater control over SHSs, and therefore a lower risk on the assets, has attracted investors who have gradually demonstrated an increased interest in the sector, with recent fundraising rounds of PAYGo solar companies reaching more than USD 1 billion over 2018-2019, including BBOXX's USD 50 million Series D financing lead by Mitsubishi Corporation. For Sub-Saharan African countries, which make up a considerable fraction of those investments, this positive trend improves the prospect of boosting electrification efforts. For example, in Rwanda, off-grid electrification stood at 2% in 2016, grew rapidly to over 11% in 2019 due to a spike in activity of PAYGo off-grid solar companies, and is expected to reach over 40% by 2024.

DIGITAL TECHNOLOGIES USED:

- INTERNET OF THINGS AND CONNECTED SMART OBJECTS
- MOBILE, 5G AND WIRELESS CONNECTIVITY
- BIG DATA ANALYTICS AND ARTIFICIAL INTELLIGENCE

BBOXX Home solar system is sold on a PAYG basis across 11 Sub-Saharan African markets and provides customers with a range of appliances, including lights, phone chargers, radios, TVs, shavers and more.

2

DIGITALISATION & GRID-CONNECTED SOLAR IN EMERGING MARKETS

Roof system for a brewery with 1.15 MW solar plans, Nicaragua, SMA.

Grid-connected solar PV is now being deployed in many regions of the world, in some more competitively than other. Companies active in these regions include a mix of new local entrants, global players from European or other mature market developers, or semi-autonomous subsidiaries of global players.

In any case, best practices tested in more mature solar markets such as Europe are being imported, adapted, or even replaced by more suitable techniques, depending on past experiences in comparable climates, grids, and design requirements.

Not all solutions readily exist though. Some emerging solar markets face challenges that previously only existed in very selected regions, and not at the same scale. To cite a few, advanced grid support functionalities by solar plants have been championed, challenged and greatly improved following deployments in weak grids such as islands or countries with a less stable or saturated grid infrastructure. PV module soiling faces new extremes in India and the Middle East and requires digitally-optimised detection and wash schedule optimisation techniques, and new cleaning solutions requiring less water.

State of the art technologies with low entry barriers, such as data analytics or drone surveys, are being adopted. At the same time, lower cost labor available for routine maintenance makes washing, I-V curve tracing and visual inspections more accessible, changing assumptions made in other markets for which techniques are cost-effective.

Best practices developed in emerging markets are also being adopted in mature markets. In the area of grid support, emerging markets with less stable utility-scale grids or mini-grids have challenged existing technologies. For example, Puerto Rico brought utility-scale frequency regulation and solar firming to a new level in 2012, and more recently, some Asian markets pushed adoption of zero-export controls. As for mini-grids, digital solar & storage innovations are already providing grid support services, such as frequency and voltage control and blackstart capability. Such innovations will increasingly be applied to utility-scale grids in Europe and North America, where ancillary services will no longer be exclusively based on conventional power plants.

As opposed to the previous chapter, the technologies and business models presented in this chapter are designed for on-grid contexts. They are aimed at increasing the performance of grid-connected solar or to support existing utility grids.

2 DIGITALISATION & GRID-CONNECTED SOLAR IN EMERGING MARKETS / CONTINUED

2.1. Smart data analytics and machine learning to improve asset performance

Asset operators and owners need to manage more sites demonstrating diverse characteristics and needs, with limited personnel and budget. Managing portfolios reaching 1 GW or more in size is a challenge in any circumstance – even more so when the portfolio is fast increasing and the team is relatively new.

Emerging markets may not yet have all the skilled workforce they need on hand to make thorough assessments of their assets. Thus, they benefit significantly from readily available data analytics tools to identify PV module or inverter failures, prescribe performance-based corrective actions, and identify low performers.

Granular and quality monitoring data has been routinely collected since the early European designs in the 2000s. What is new is the availability of advanced analytics and machine learning tools to transform large amounts of raw data into automated intelligence, guiding asset owners, operators and performance analysts in their decisions and prioritization.

Modern analytic algorithms now recognise numbers of performance issues, from degrading solar panels, soiling, to inverter system faults, misaligned trackers, and bring to the user's attention the most relevant findings.

Accurate and same-day performance impact quantification allows for revenue-based scheduling of typical maintenance tasks: module washing, down strings, inverter issues. Factoring the cost to take action and recoverable energy establishes which actions are worth taking, at which time of year.

When the same analytics tools are deployed at the fleet level, they allow for portfolio-wide or regional prioritisation of maintenance crew dispatching, focusing on the most cost-effective actions for a given team.

Thermography has made a lot of inroads in recent years, with the more sophisticated providers using machine learning recognition to suggest different PV module failure modes.

Machine learning has been a game changer for weather and production models, improving production forecast and serving grid stability requirements.

ENVISION DIGITAL'S PORTFOLIO-WIDE PRESCRIPTIVE ANALYTICS TO COPE WITH FAST-GROWING SOLAR FLEETS IN MALAYSIA AND VIETNAM

New entrants in Southeast Asian markets, such as Malaysia or Vietnam, are managing fast-growing portfolios and are required to handle numerous solar farms with limited resources, while at the same time lacking expert performance analysis and asset management personnel.

In addition, region-specific factors affect the performance in unexpected ways. Amongst them:

An increasing presence of grid curtailment of solar generation in these two countries, an expectation to produce flatter production profiles and predefined power production times.

Heavy and frequent rain, coupled with a lack of high irradiance intervals, enhances the risk of PV module degradation modes such as potential-induced degradation (PID).

A lack of knowledge of industry best practices during construction may lead to damaged wire insulation, resulting in frequent inverter outages, again exacerbated by frequent rain.

All these conditions affecting performance make traditional analysis based on performance ratio and availability KPI at best incomplete, if not outright irrelevant.

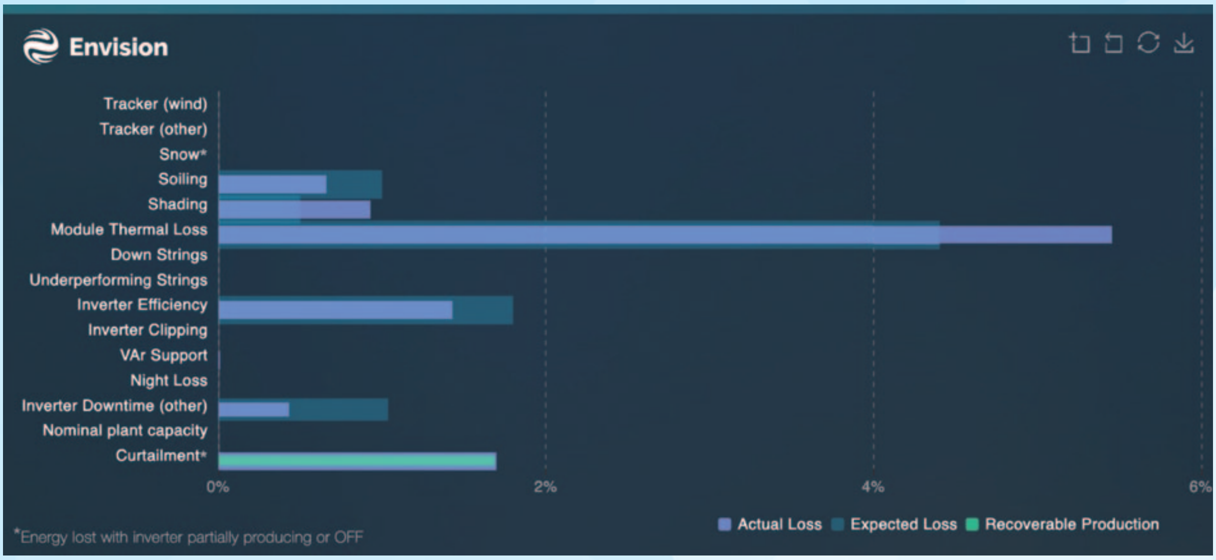
Envision Digital created Ensight™ Solar, an advanced analytics tool designed to facilitate the automation of solar plant performance analysis. It provides a detailed description of energy lost to various conditions such as module soiling, grid curtailment, electrical design limits, and recognizes the cause of diverse outages. Using pattern recognition, it separates what can and cannot be influenced, identifies PV module and inverter reliability concerns, and provides accurate metrics and cost/revenue analyses-based prescriptions to improve performance where possible.

Now equipped with precise information on the impact of grid support and curtailment, developers are better able to find a solution that optimises the design of future plants, which may or may not involve energy storage. They also use this information to work with grid operators, deploy better suited grid support control functionalities, and make use of production forecasting tools, to reduce the ultimate need for solar power curtailment.

DIGITAL TECHNOLOGIES USED:

BIG DATA ANALYTICS AND ARTIFICIAL INTELLIGENCE

CLOUD & LOW-COST COMPUTING



Envision Ensight™ loss breakdown performance summary for a plant in Asia, exhibiting curtailment loss. Curtailment reflects the challenge of utilities adapting to new solar capacity.

3E'S SYNAPTIQ: SOLAR PORTFOLIO MANAGEMENT WITH SATELLITE-BASED IRRADIATION DATA FOR INDIA

Over 1 GW of solar parks & solar rooftop systems spread over different states in India are monitored with our SynaptiQ solar software solution.

The advanced analytics that are an integral part of this solution make use of the new satellite-based irradiation data. Together with KNMI the R&D department of 3E accessed the Meteosat IODC satellite to cover the Indian Ocean region and applied the Cloud Physical Properties models to further increase the accuracy of the solar resource quantification for solar energy applications. All plants in India part of the software portfolio management tool SynaptiQ make use of this irradiation data for e.g. forecasting and benchmarking.

The use of underlying cloud models considering the physical properties of the clouds has improved significantly the accuracy of the satellite-based irradiation data over this region. Moreover, models compensating for satellite sun path and cloud geometry provide the highest accuracy, even at high temporal resolutions (hourly or sub-hourly data).

The resulting data is comparable and sometimes even better than the one of the on-site measurements, particularly in remote regions like, where local sensors are prone to more issues and failures due to severe environment conditions.

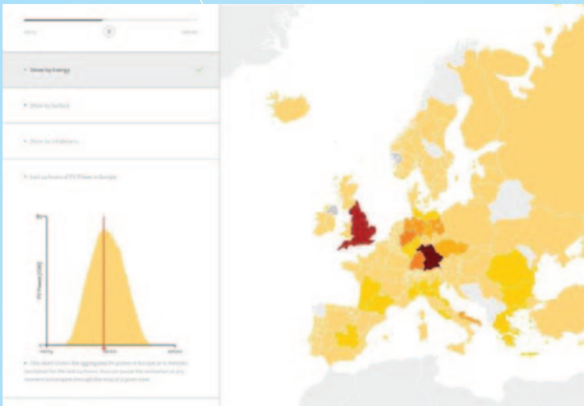
The improved high temporal resolution accuracy and the availability of real-time 15-minute data is enabling the digitalisation of solar energy in emerging markets. Solar energy forecasting services, for example, are benefiting from this new technology resulting in improved forecast accuracy, thanks to the use of real-time 15 minutes satellite data through implementation of new continuous training algorithms for intra-day corrections.

Smart data analytics also benefits from this higher quality satellite-based irradiation data due to its temporal and spatial availability. Services like, 3E's Solar Sensor Check and the PV Health Scan rely on this satellite-based irradiation data for quality checks and digital twin models enabling increased accuracy of failure detection routines and root cause identification.

Finally, 3E's Dynamic Solar & Wind Energy Maps are another good example of applications. Building upon this high-resolution satellite data and detailed information on the operating renewable assets, 3E has developed the technology to generate high accuracy dynamic maps and applications to display the real-time, historical evolution, and forecasted energy production of renewable energy assets across cities, regions or even continents. 3E's Dynamic Solar & Wind Energy Maps are accelerating the digitalization of the renewable energy sector and creating new service opportunities for solar and wind energy, increasing awareness of public communities, and shaping the regulatory environment in emerging markets. The first version of this tool, The European Solar Power Live Map,[23] was made in collaboration with leading solar experts of 3E and SolarPower Europe. The Flemish Solar & Wind power map (Stroomvoorspeller)[24] was recently developed by 3E providing high resolution information and including also on-shore and off-shore wind energy in addition to solar energy. This can be easy applied to India as well.

DIGITAL TECHNOLOGIES USED:

- BIG DATA ANALYTICS AND ARTIFICIAL INTELLIGENCE
- CLOUD & LOW-COST COMPUTING



The SolarPower Live Map developed by 3E together with SolarPower Europe as proof of concept for EU as methodology applicable for India

23 http://www.solarpowereurope.org/solar-live-map/

24 https://apps.energiesparen.be/stroomvoorspeller

2.2. Digital asset management

With the professionalization and globalisation of solar investors and investment portfolios, service quality expectations are changing and rising rapidly, which puts increasing requirements on asset managers – both in mature and emerging markets. As opposed to operation and maintenance (O&M) service providers, who take care of the solar power plant on a technical level, asset managers deal with the commercial and financial management of a solar investment. They manage a company – or a portfolio of Special Purpose Vehicles (SPVs) – rather than a power plant, often across different geographies, with different regulatory and environmental challenges and with a variety of different business models. Asset managers cover topics such as accounting and financial reporting, cash-flow management, debt management, insurance management, Power Purchase Agreement (PPA) management, SPV representation, O&M contractor supervision, land leasing and any other statutory or regulatory obligations arising from the operation of solar power plants.

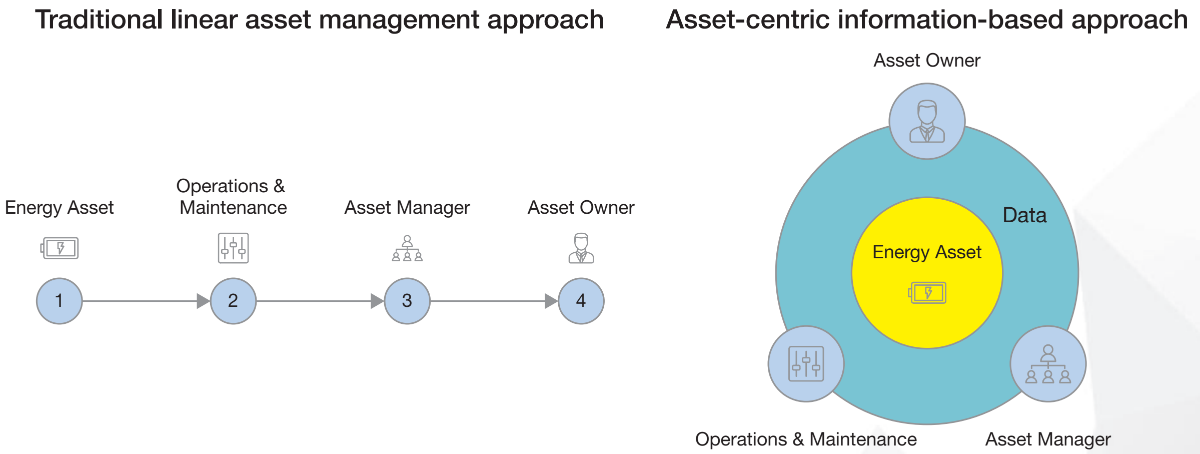
Traditional asset management models employ a linear management approach, where information flows from the asset manager and ultimately to the asset owner. This linear approach means that the asset owner does not have direct access to data and information from the solar power plant. Rather, data and information from the asset are filtered before reaching the asset owner, creating mistrust and a lack of transparency between the main stakeholders. To address these inefficiencies, the asset management industry is transitioning to an asset-centric information-based management approach to address three key problems: (1) loss of generation and income, (2) loss of time, and (3) lack of transparency.

At the same time, asset managers are increasingly expected to continuously improve the return on investment by reducing costs. It is especially the case in emerging markets, many of which are particularly price sensitive. Revenue and cost optimisation rely on six key processes:

1. Plant performance optimisation
2. Operation cost reduction
3. Financial restructuring / re-engineering
4. Legal and contractual renegotiation
5. Technology adaptation and upgrades
6. People management

Asset management is still done through self-made spreadsheets in many cases, especially in emerging markets. At the same time, it can be observed in an increasing number of cases that asset managers are leapfrogging from spreadsheets to the most advanced digital platforms integrated with other systems such as the monitoring platform in order to effectively and transparently manage assets. To manage effectively and efficiently a wide portfolio of power plants with different specifications in different geographies and legislations and with a number of different O&M service providers or subcontractors using a variety of monitoring platforms, asset managers need a centralized software platform that can handle all of the above, remotely and centrally.

FIGURE 2 TRADITIONAL LINEAR ASSET MANAGEMENT APPROACH AND ASSET-CENTRIC INFORMATION-BASED APPROACH WITH THE THREE MAIN STAKEHOLDERS OF ASSET MANAGEMENT



Source: Greensolver.

ALECTRIS' ACTIS SYSTEMS TO DIGITALISE AND OPERATE AND MANAGE EXPANDING O&M PORTFOLIOS IN JORDAN REMOTELY

ALECTRIS SOLAR ASSET CARE INNOVATION.℠

As renewable energy is expanding in emerging markets even more, it is essential for these countries to adopt and adapt tools and practices from mature markets.

Digitalisation and more specifically digitalisation of asset management and operations is vital in successfully managing this expansion.

Alectris is remotely supervising, monitoring, managing and reporting all O&M activities that the field technicians of a local subcontractor (MASE) are performing in Jordan, through its centralised control room located in Europe by utilising the infrastructure and functionalities of its Enterprise Resource Planning (ERP) software platform ACTIS. Once the centralised control room receives an alert the experienced control room engineers follow the procedure explained below, tracked in ACTIS:

1. Create a ticket that is sent to the field technicians with a complete description of the alert and instructions on what to do (work order)
2. Warranty validation – if a faulty spare part is under warranty, an insurance claim is initiated
3. Field technicians resolve the issue – they fill in the required fields in the work order, such as the spare parts used, time spent, etc. Once the work order is saved and closed, it is automatically sent to the ACTIS platform with all activities and related costs tracked and recorded.
4. Root cause analysis, impact analysis, contract compliance and incident resolution are then all calculated and verified automatically.

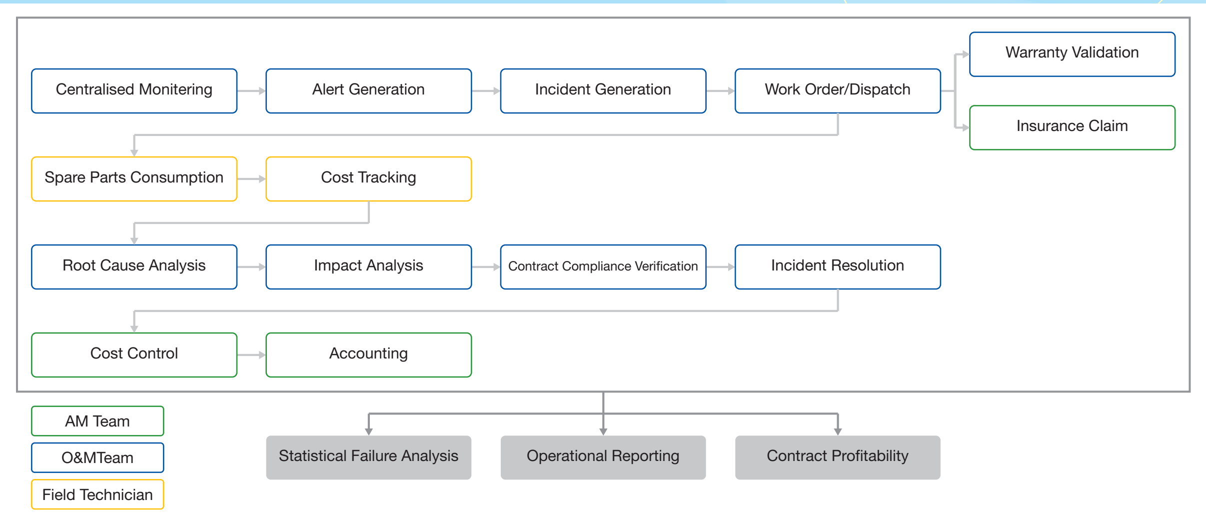
All the above lead to a tight cost control and at the same time ensuring accountability.

Statistical failure, operational and technical reporting are automatically generated as well as contract profitability.

DIGITAL TECHNOLOGIES USED:

- INTERNET OF THINGS AND CONNECTED SMART OBJECTS
- BIG DATA ANALYTICS AND ARTIFICIAL INTELLIGENCE

10 MW plant in Jordan, remotely managed and operated by Alectris.



Division of responsibilities in solar asset management (AM) and operation & maintenance (O&M).

2.3. Grid intelligent solar

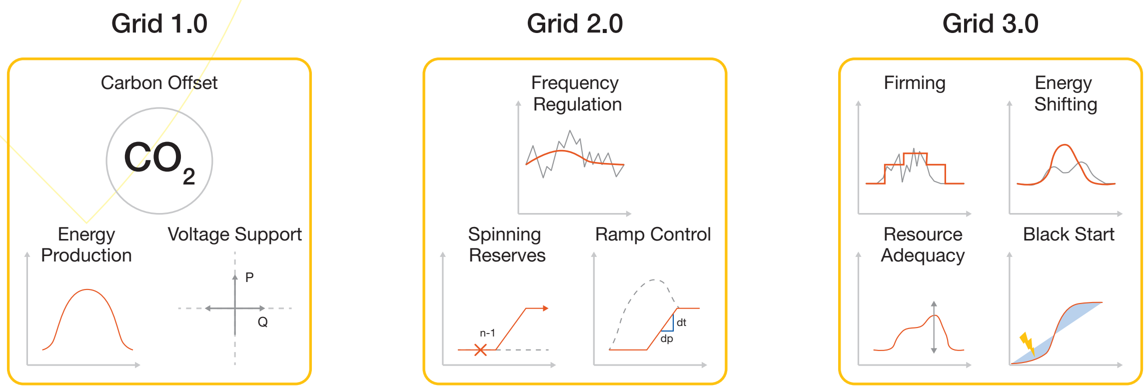
Through intelligent plant controls paired with solution-oriented plant sizing/layout, solar can be used to create cost-effective flexible capacity that supports supply and demand balancing. This is increasingly interesting in markets with less stable or saturated grid infrastructure.

Utility-scale solar power plants support grid reliability by providing features such as ramping capability, voltage support, fault ride-through and other services, and in some cases, more effectively than conventional power plants.

Utility-scale solar plants are controllable and can provide flexible grid services, like frequency regulation, that allow system operators to respond quickly and strategically to changing conditions. Even without energy storage, solar can already achieve significant penetration on the grid economically. With decreasing energy storage costs, solar energy can be cost-effectively dispatched like conventional plants, even when the sun is not shining, enabling the addition of even more clean energy on the grid.

The following figure shows the three phases of solar power plant evolution.

FIGURE 3 THREE GRID PHASES OF SOLAR POWER PLANT EVOLUTION – BASIC SOLAR, GRID FLEXIBLE SOLAR, FIRM DISPATCHABLE SOLAR



Basic Solar
Lower solar penetration markets; maximises energy production

Grid Flexible Solar
Moderate solar penetration markets; solar controlled to provide flexibility and grid reliability services

Firm Dispatchable Solar
Higher solar penetration markets; addition of storage provides firm dispatchable capacity

Source: First Solar / SolarPower Europe Global Market Outlook For Solar Power 2019-2023.

FIRST SOLAR'S SOLAR PV PLANT PROVIDING ANCILLARY SERVICES TO REDUCE DEPENDENCE ON CONVENTIONAL SOURCES IN CHILE

First Solar, Laborelec Latam and Coordinador Eléctrico Nacional collaborated to explore provision of ancillary services from photovoltaic (PV) power plants.

In late 2017, Luz del Norte, a First Solar PV power plant with 141.04 MW installed capacity, was used to demonstrate the technical feasibility of providing essential services needed for the reliable operation of the electrical grid. The test results show that a PV plant equipped with a sophisticated plant control system can change its active and reactive power production in such a way that enables the plant to provide ancillary services.

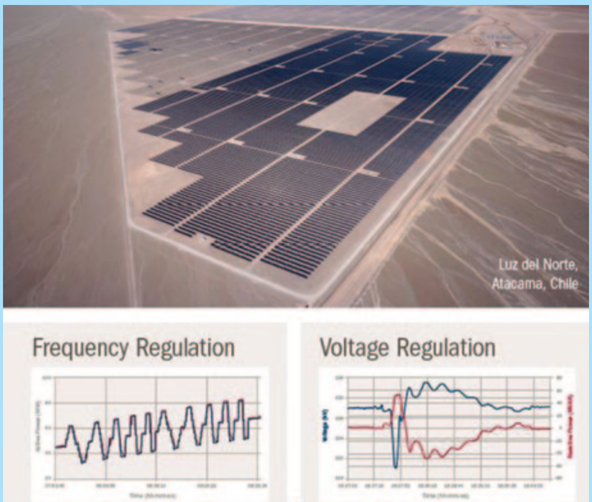
The test was the first of its kind performed in South America. This capability provides the opportunity to utilize solar for providing ancillary services when needed. It reduces the dependence on other conventional sources that normally provide these services, and thereby, enables higher penetration of solar.

This demonstration project was selected as one of the 100 innovative solutions capable of preventing a global warming beyond 1.5°C by the Mission Innovation program of the COP21. Mission Innovation has estimated that this project could save 29 million tonnes of CO_2 per year by 2030.

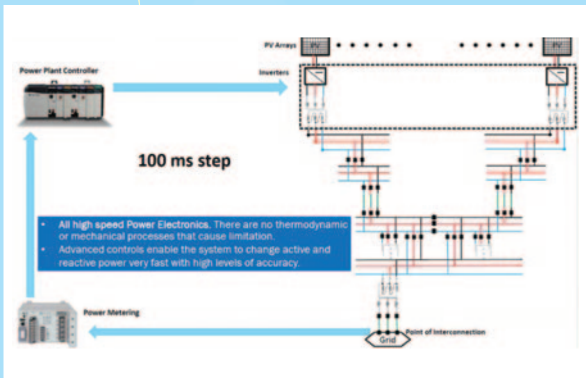
Currently, First Solar is working with the grid operator (Coordinador) to implement Luz del Norte as one of the ancillary service providers to the electrical grid in real operation. We expect to have the system functioning before the end of October 2019.

DIGITAL TECHNOLOGIES USED:

SMART METERS



Ancillary Services from a PV Plant in Chile.



PV Plant: all electric, all static, all digital.

SMA'S ENNEXOS ENERGY MANAGEMENT PLATFORM'S ZERO FEED-IN AND PEAK SHAVING FUNCTIONS WHEN GRID FEED-IN IS PROHIBITED IN NICARAGUA

Energy management systems in companies in Nicaragua prevent solar power from finding its way into the utility grid.

In this Central American country, no specifications have been defined for the grid feed-in of self-generated electricity. Grid operators fear that the electricity grids could collapse under the strain. For ECAMI S.A., a company that plans and builds renewable energy systems, SMA Data Manager M powered by EnnexOS was just what it needed.

Nicaragua's largest – and only – brewery, Compañía Cervercera de Nicaragua (CCN) in the country's capital, Managua, has been using solar power since 2017. ECAMI S.A. installed solar modules on its premises and covered parking lots. Coupled with 36 Sunny Tripower 30000TL string inverters, they produce roughly 1,152.00 kWp of clean solar power for brewing beer. CCN obtains the rest of its electricity from the medium-voltage grid. Over the course of a week, this amounts to an extra 2.5 MW or so each day. At weekends, consumption is just below the maximum generation output of 700 to 900 kW.

Free, self-generated electricity is a great way for companies to avoid paying the country's relatively high electricity prices and to achieve significant reductions in their energy costs.

It is not only the current functions of SMA Data Manager that are of interest to project engineers at ECAMI as well as the operators of the brewery, but also those that will be available in the future. That is because the new EnnexOS energy management platform from SMA, which also provides the basis on which Data Manager works, is a modular system, enabling it to be expanded alongside the functions of the devices based on it. In addition to zero export, the ECAMI project engineers are thinking about peak load shaving at manufacturing companies because electricity prices in Nicaragua are very high and billed monthly.

DIGITAL TECHNOLOGIES USED:

- INTERNET OF THINGS AND CONNECTED SMART OBJECTS
- MOBILE, 5G AND WIRELESS CONNECTIVITY
- SMART METERS

Installations of Sunny Tripower and the SMA Data Manger which features medium-voltage meter and lower-voltage energy meter.

2 DIGITALISATION & GRID-CONNECTED SOLAR IN EMERGING MARKETS / CONTINUED

QOS ENERGY'S CLOUD PLATFORM INCREASING ENERGY FORECAST ACCURACY USING FEEDBACK LOOP TECHNOLOGY IN INDIA

India is aiming to install 100 GW of solar power systems by 2022, out of which 40 GW is to come from rooftop solar systems.

Integrating intermittent renewable energies into the grid requires accurate forecasting and scheduling to ensure grid stability.

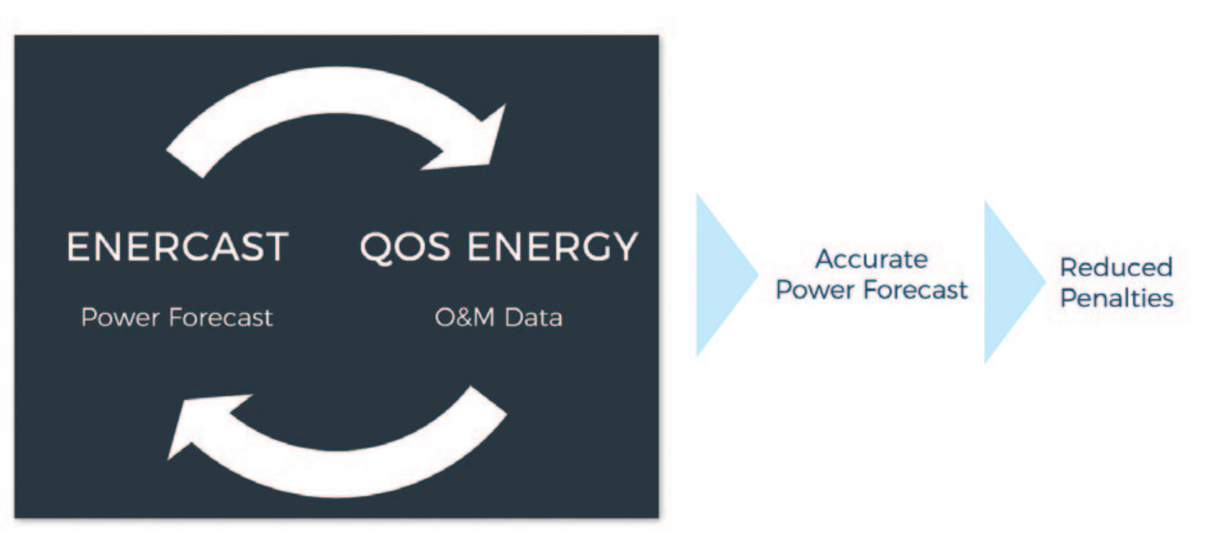
Today, 70% of the Indian states require plants (and clusters) above 10 MVA to provide day-ahead and intraday forecasts. Indian states apply financial penalties in case actual energy generation deviates from the forecasts by more than 15%. Penalties may vary from state to state but can be as high as INR 1.50/kWh. Therefore, it is crucial for developers and independent power producers to get the most accurate forecast levels.

enercast is a provider of highly accurate power forecasts for renewable energy producers worldwide. In order to further reduce forecast-related penalties, the partnership between QOS Energy and enercast facilitates an immediate feedback loop which helps enercast increase the accuracy of their intraday and day-ahead forecasts.

Using QOS Energy's cloud platform for unified access to operations and maintenance KPIs, enercast is able to continuously optimise the forecast models. By comparing forecasts with the actual energy production from the cloud platform, IPPs can then ensure no undue penalty has been applied and feed this data into their automated reporting & analytics dashboards.

DIGITAL TECHNOLOGIES USED:

- INTERNET OF THINGS AND CONNECTED SMART OBJECTS
- BIG DATA ANALYTICS AND ARTIFICIAL INTELLIGENCE
- CLOUD & LOW-COST COMPUTING
- SMART METERS



The use of QOS Energy's cloud platform makes it easier for enercast to access operational data from multiple different sources.

2.4. Blockchain-based solutions to digitalise, decentralise and decarbonise electric grids worldwide

Multinational corporations provide a growing source of demand for new renewable energy projects across the globe. Corporate buyers, however, face significant challenges finding and procuring renewable energy from (preferably new) projects. These challenges are amplified in emerging markets, where buyers also lack trust in the credibility of available options.

Corporate buyers want to modernise renewable energy procurement such that finding, buying and proving purchases of electricity generated from renewables in any market where they and their suppliers have operations provides the comparable user experience of booking a flight or hotel. In other words, buyers want something better compared to how renewable energy markets today depend on third-party brokers who match buyers with procurement options meeting their diverse requirements and manual updating of spreadsheets and market-specific tracking systems based on any transactions.

Electric utilities and energy companies in emerging markets have a unique opportunity to leverage leapfrog technologies, such as blockchain, to attract these corporate buyers and reach their respective ambitious renewable energy targets. Blockchain technology, combined with smart Internet of Things (IoT) connected devices, plays a key role in the technology stack for digital solutions that utilities and energy companies should deploy to modernise renewables procurement and, ultimately, deploy more advanced solutions like grid flexibility. Blockchain technology helps to (1) establish a shared agreement over the true state of the world by providing a single and transparent view on who owns what energy assets, the events and payments associated with each asset, the timestamp associated with each event, and other critical information and (2) automate the execution of actions, such as renewable energy purchases or grid flexibility services, based on pre-specified criteria for how to respond to a given scenario. The resulting solutions enable direct (even automated) renewable energy procurement and obviate the need for current cross-referencing processes across dispersed market participants to prove the true state of renewable energy supplies, demands, and completed transactions.

Utilities and energy companies in emerging markets that develop digital renewable energy procurement marketplaces and deliver a modern user experience for buyers can, in addition to supporting the clean energy transition, capture new business value by better meeting buyers' needs. These value streams include increasing revenues from existing renewable energy assets through direct sales of energy attribute certificates (EACs) to buyers, attracting more demand for new renewables projects, securing better financing for new projects based on greater expected revenues from EAC sales to buyers, and supporting innovative new services, such as automated 100% green electric vehicle guarantees and battery storage certificate trading.

2 DIGITALISATION & GRID-CONNECTED SOLAR IN EMERGING MARKETS / CONTINUED

ENERGY WEB FOUNDATION: MODERNISING CORPORATE RENEWABLE ENERGY PROCUREMENT IN THAILAND WITH A NEW, DIGITAL, BLOCKCHAIN-BASED PLATFORM

Corporations across the globe are setting ambitious renewable energy procurement targets and looking for new enhanced solutions to find, procure, and report credible renewable energy purchases.

They are also looking for solutions to track renewables procurement among their suppliers. While these corporate buyers are looking for improvements across markets where they operate to simply fulfill their targets, facilitate new renewable energy projects, and increase clean energy access, they face especially great challenges in meeting their goals in markets outside the US and EU.

With the aim of solving various market pain points and to enabling buyers to more easily and directly find, buy, and report credible renewably-generated electricity purchases, EWF developed Energy Web Origin—a family of open-source software development toolkits designed to support utilities and energy companies with building their own digital renewable energy marketplaces to attract buyers and promote investments in new renewable energy projects. Utilities and energy companies can deploy such marketplaces with decentralized applications (dApps) built using EW Origin and running on the Energy Web Chain.

For example, EWF and Thailand-based multinational energy conglomerate PTT are developing a new, state-of-the-art, blockchain-based renewables platform for ASEAN markets – starting in Thailand. The PTT application will be built on the Energy Web Chain and leverage EW Origin to create a regional solution compliant with the I-REC Standard. PTT's platform will benefit corporate renewable energy buyers and renewable energy developers by streamlining the matchmaking between these two groups in a transparent, credible manner based on established global industry practices.

PTT and EWF are jointly developing several modules for the application based on needs assessments of diverse market participants, including:

- A user and asset connection solution aligned with the I-REC Standard and I-REC issuing body requirements.
- An I-REC marketplace for posting supplies and demands, trading I-RECs, claiming I-RECs, and generating needed reports.
- A solution for small solar PV generators to access corporate buyers through streamlined aggregation of renewables production and associated I-REC issuance.
- Additional solutions being considered around clean charging for electric vehicles and a digital platform for power purchase agreements (PPAs).

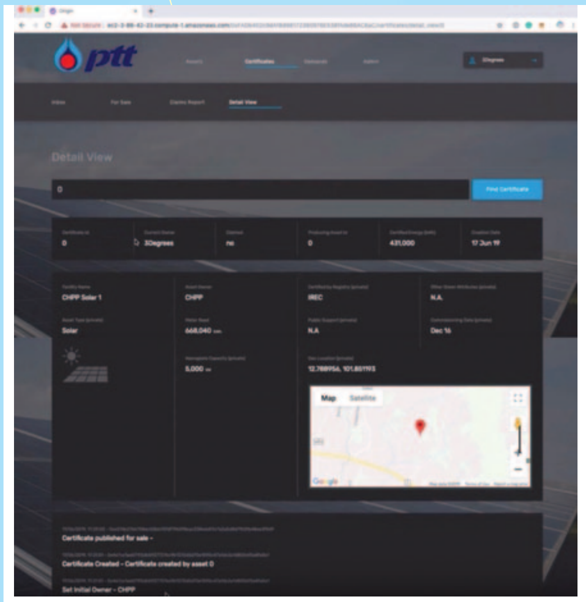
PTT and EWF completed the first proof point of this platform in June 2019, which demonstrated a transaction of 431 I-RECs between the seller, PTT, and the buyer, 3Degrees, based on needs specified by 3Degrees. This demonstration shows early progress in the development of the PTT platform. More proof points will take place over the coming months to test and collect feedback on various features as PTT and EWF target a launch date of May/June 2020 for the complete PTT Renewables Marketplace Platform.

DIGITAL TECHNOLOGIES USED:

INTERNET OF THINGS AND CONNECTED SMART OBJECTS

BLOCKCHAIN

SMART METERS



The image summarises the product details and transaction history from a trade in June 2019 of 431 I-RECs between the seller, PTT, and the buyer, 3Degrees, based on electricity production from a solar asset in Thailand.

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SolarPower Europe is an association that aims to ensure that more energy is generated by solar than any other energy source by 2030 and lead our members to make solar the core of a smart, sustainable and inclusive energy system.

Find more information: **www.solarpowereurope.org**

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