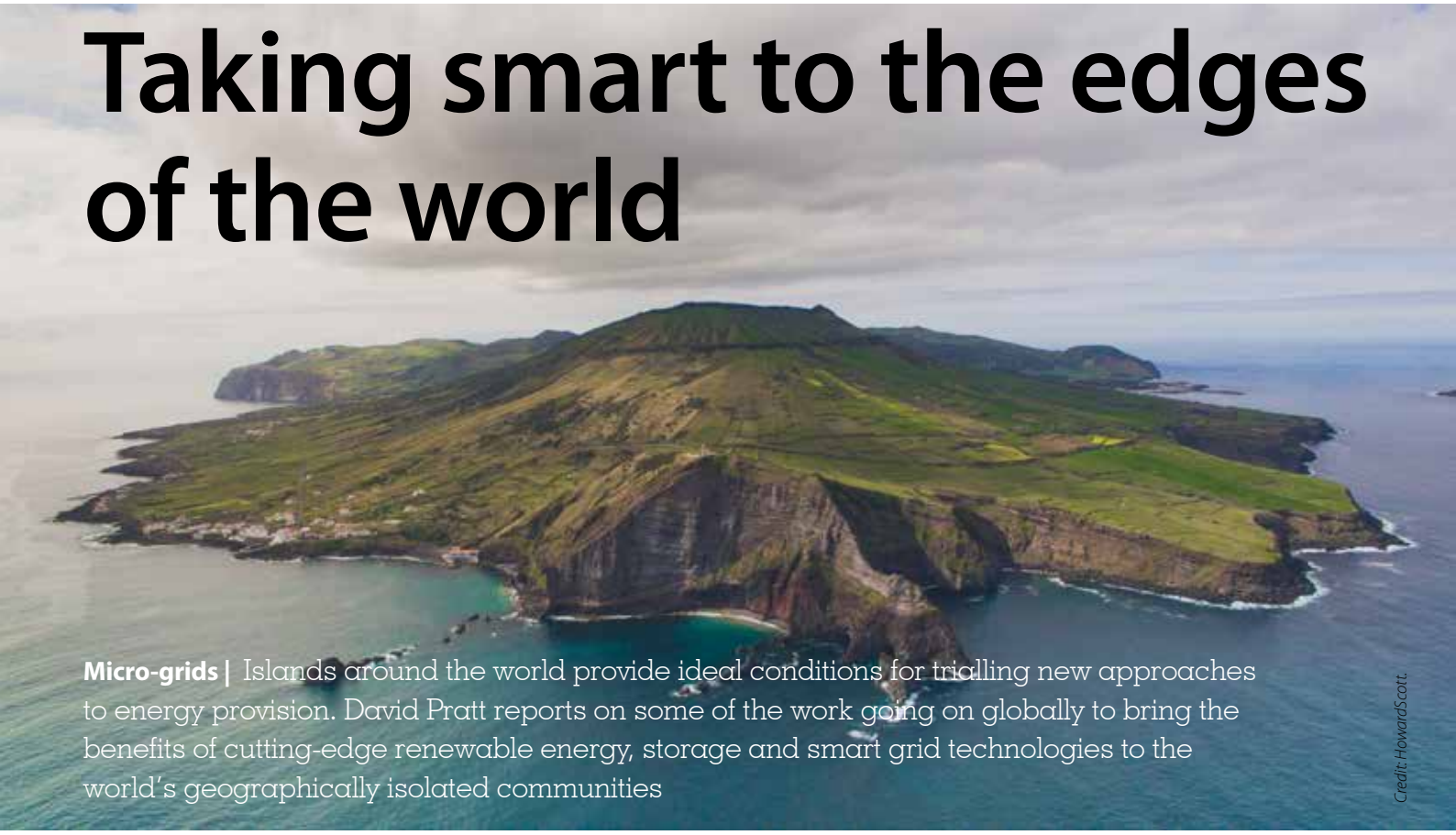
Taking smart to the edges of the world



Credit: HowardScott.

Micro-grids | Islands around the world provide ideal conditions for trialling new approaches to energy provision. David Pratt reports on some of the work going on globally to bring the benefits of cutting-edge renewable energy, storage and smart grid technologies to the world's geographically isolated communities

It's been a whirlwind few years for energy storage technologies, with the proliferation of renewable energy around the world and continually falling costs leading to new and innovative business models coming to the fore.

But where front-of-meter, grid-scale batteries have emerged in the last few years, in particular on mainland locations, as well as growing numbers of domestic installations and behind-the-meter applications, one area of deployment has had the perfect conditions for the technology for much longer.

Islands have suffered under conditions imposed by traditional generation and grid technologies for decades. Where coal- and gas-fired power stations offered cheap forms of energy on the mainland, such technologies have come at great cost to island inhabitants.

These locations have been subject to higher energy prices owing to the cost of importing fuels to them, all while suffering from the more acute environmental impacts of burning fossil fuels.

Emanuele Taibi, of the International Renewable Energy Agency's (IRENA) power sector transformation strategies team, says: "The impact of pollution from fuel transport, storage and combustion is especially evident in a small place. In a densely populated small island the diesel power plant has a significant environmental impact for the delicate ecosystem."

Combined with weak grid systems, islands have been calling out for an alternative much longer than those on mainland geographies.

At the same time, they have also been far more suited to the benefits of renewables, energy storage and smart systems than larger grids. A study published by IRENA in 2015 of Fiji, the Marshall Islands and Vanuatu found that using the likes of solar, wind, geothermal, marine, biomass and biofuel could lower power generation costs, while improving access to energy and energy independence.

The environmental case

As part of their efforts to overcome the polluting presence of traditional generation, many island territories are looking to adopt 100% renewables in the coming years.

John Jung, president and CEO at Greensmith, explained: "People are implementing and transitioning grids from base load generation into intermittent resources very quickly, where you almost want solar and wind to become the new base load.

"As islands or other localised grids get anywhere in excess of 70%, up to 90% renewables, I think you need to start thinking about large quantities of batteries and inverters as well."

Islands stand to benefit significantly from new decentralised energy technologies

Such ambitious targets can be found on the French island territories, where very ambitious targets would see these islands reach 50% renewables in 2020 and absolute energy independence in 2030.

The economic case

These targets have been helped, and in some ways brought about, by the fact that costs have come down so sharply for renewable and associated technologies – a stark contrast to the high costs of diesel gensets on island locations.

Taibi continues: "It's just cheaper. How much cheaper depends on how you design the project but a well-designed project is typically modular, so you start going the

Twelve solar-plus-storage projects on Martinique were awarded contracts in French island tenders in 2015 and 2016

Credit: Flickr/_dChris.

Territory	Number of projects	Allocated power (MW)
Corsica	20	8.4
Guadeloupe	16	15.6
Guyana	4	11.1
La Réunion	17	22.3
Martinique	4	2.5
Mayotte	6	3.4
TOTAL	67	63.3

Table 1. French Island tender winners 2016/17.

first mile as a least cost system today. Then tomorrow renewable technologies will keep getting cheaper, the price of oil will probably keep going up so you expand the amount of renewables in the system.

"You can also definitely do a one-off project, which may be more costly initially but it gets you off the diesel fuel supply chain completely and that makes a lot of sense from an economic perspective."

This can be seen clearly on the French islands, where a tender for solar-plus-storage projects on territories including Corsica, Guadeloupe and Martinique saw winning bids announced in August 2017 often 40% lower than the victors of previous reverse auctions.

The 67 projects that include PV panels and batteries totalling 63.3MW attained a guaranteed purchase price for their generated power of €113.6 (US$133.97) per MWh (Table 1).

By comparison, a 52MW tender in June 2016 awarded feed-in tariffs (FiTs) at a weighted electricity price of €204/MWh (US$229.77/MWh), while France's ministry of ecology, sustainable development and energy has previously stated power prices on the islands stood at around or over €200 per MWh.

Corentin Baschet, analyst for Paris-based technical consultancy Clean Horizon, says: "The motivation is that in the French islands, as in a lot of other islands, electricity production costs are very high because it relies on fuel, like imported diesel which is then burnt in a very low efficient engine or even worse, that engine is a gas turbine that burns oil.

"So we're talking about 20% efficiency, and it's a small engine so it can be even more inefficient. That results in the cost of electricity being probably three times as high as in continental France. What is shown by the reduction in PPA prices for PV-plus-storage is that it is less expensive than conventional generation on the islands."

Such progress shows the course that renewables and batteries are likely to follow. In the French islands, 50MWh of energy storage had already been deployed by September 2017. However, 140MWh has been contracted to 2020 and according to Baschet, this could edge closer to 200MWh by the end of the decade – four times that of current deployment.

Will fossil fuels endure?

So while islands are increasingly able to latch on to the environmental and economic benefits of renewables thanks to advances in energy storage and connected systems, going 100% renewable still offers its challenges, and they remain centred on cost.

Philip Hiersemenzel of Younicos, which has been working on the Azorian island of Graciosa since 2012, claims increased renewables penetration, and the resulting need for batteries, may never reach a fully economic case.

"You still need back-up generation simply for economic reasons. Wind and solar are cheap, storage has become cheap too but we've run simulations here and depending on the load and geographic conditions, the economically optimum result is usually between 60-80% renewables share," he says. "The farther you go to 100%, the more expensive it becomes.

"What makes sense is to have some sort of back-up thermal capacity and then to integrate that into the grid. Since the thermal capacity no longer has to play the role of stabilising the grid, it can do what it likes best, which is to run at its most fuel-efficient point."

Taibi adds: "The diesel itself doesn't have to stay there but some form of thermal generation such as biodiesel could really help in reducing the size of the battery.

"It's much more efficient to keep some sort of dispatchable generation and given it's so little, a little bit of biodiesel stored somewhere for those cloudy days of the year in a row makes a lot of sense because it minimises system costs."

The exception to this can be found in high levels of pumped hydro storage, such as in Iceland which is thought to be the only country in the world to obtain 100% of its electricity and heat from renewable sources – namely hydro and geothermal.

However, in smaller cases there remains a critical need for batteries such as on Kodiak Island, Alaska. The Kodiak Electric Association (KEA) set a goal in 2007 to produce 95% of Kodiak Island's energy from renewable sources by the year 2020 – a goal it reached in 2012.

Younicos integrated a 3MW lithium-ion battery last year to replace a lead-acid solution it had previously installed to work alongside the island's 9MW wind park and two 11.5MW hydroelectric turbines.

According to Hiersemenzel, the hydro can meet many of the island's needs aside from dealing with the fluctuations brought on by the wind generation. However, where traditionally a thermal generator would be called on, the battery solution offers the missing piece of the puzzle.

"The hydro isn't thermal but it's still a rotating mass with all the advantages and disadvantages that brings. You then have the variability of a wind farm so this is really again where the battery and its grid forming ability is of critical importance.

"It stabilises the grid in the short [term] which allows the hydro then to react. That also allows you to become an almost 100% renewable energy system if you have a huge pumped hydro," he explains.

Credit: Younicos

Kodiak Island, Alaska, has a critical need for batteries

The missing piece

Therefore much like on mainlands across the world, the energy storage element is key to integrating renewables on island locations, to dealing with inherent fluctuations within the generation profiles of these technologies and shifting generation to times of need.

"There's always storage in an isolated power system where your main resources are variable and if your footprint is very small. The debate of storage versus transmission ongoing in continental systems is not necessary in an island as very often there is no option for interconnection to the mainland so you do need some sort of storage to get close to 100% renewables," Taibi explains.

As this continues, with more and more players entering the smart islands market, Baschet suggests that this could see the nature of the storage deployed change to meet the impacts of ever increasing levels of renewables.

"The first problem you see on the grid is intermittency, so the first business case for storage on islands is frequency regulation and that, usually speaking, is short duration storage.

"As you move forward, with the intermittency of renewables, there is a need for a bit longer duration storage and that's what you can see in Hawaii for instance, which started with frequency regulation batteries and that now has a PPA for a four-hour storage system to really shift PV energy from the day to the night.

"That's the logical trend; to start with a bit of short-term duration storage and as you increase the share of PV or wind, to put in a bit longer duration storage."

However while energy storage no doubt plays a significant, almost grid-forming role in smart island projects, there is debate over whether or not it is in fact the grid-maker.

The grid-maker

With all these technologies seeking to work in unison, a battery is just one more resource bringing them all together. But a new market is emerging for another resource, namely the software platform that brings them all together.

Greensmith's Energy Management System (GEMS) on Graciosa is able to integrate any generation source with batteries and bi-directional inverters to optimise the different sources against load predictions and weather forecasts for wind and solar output. It also provides a supervisory control layer providing controls across the grid system.

"An island grid is an ideal application because they have less conventional legacy tools to solve grid congestion issues, which is why not only energy storage but something like a GEMS platform that can basically optimise an entire island grid is what we're really excited about delivering on Graciosa," Jung explains.

These systems can also add an element of synchronicity to renewable generators that can overcome a key criticism often levelled at them, namely that they fail to offer continuous generation deemed as an essential part of mainstream energy production.

Jung continues: "The virtual synchronous generator mode is essentially what you need to form a proper grid. It's actually a lot more important than if you have a spinning mass or not, and simply by the nature of the intermittency of these resources, they have an almost take it or leave it kind of generator quality to them that requires additional help in voltage frequency from the grid.

"Whenever you have inverter-based power being generated, you need additional things to compensate for it especially around voltage and frequency.

"One of the key challenges is establishing the right controls and set points to ensure that when multiple assets are forming the grid together they aren't working against one another but toward a common goal. Unless you have the right software delivering the right business model, it's not going to deliver a lot of value."

Case studies: Graciosa

- Integrating more than 1MW solar, 4.5MW wind, 3.2MWh battery with around 6MW of thermal generation.
- Aims to use renewables-plus-storage system to stabilise the grid network and greatly reduce the need for thermal power generation and costly fuel imports to the island, reaching 65% renewables by the time the project is fully up and running.
- Status – technologies deployed, final testing underway before being commissioned within weeks (at time of writing)

Dubbed "ground-breaking for the entire industry" by Younicos' Philip Hiersemenzel, this project was one of the first smart islands announced back in 2012. Having undergone a series of setbacks since, not least as a result of the financial and Euro crisis, Graciosa is now ready to test the theories that have gone into it.

"Graciosa stands apart because it's of a certain size [over 60 square kilometres, around 4,500 inhabitants]. When you have smaller islands that have gone more or less towards 100% renewables, it's a different story because it's all solar which in a way is somewhat easier and they have a lot less fluctuations.

"Graciosa has villages, a little industry, a dairy farm so you have load jumps which does set it apart," Hiersemenzel said.

It had been intended that Graciosa would reach 100% renewables however Younicos found that a diesel engine was still needed to cover the periods of bad weather not served by wind and solar.

There would also be the result of excess renewables in comparison to the amount of energy storage that could be economically envisaged. Despite this, John Jung of software platform provider Greensmith maintains the importance of the project.

"Graciosa may represent the most advanced micro-grid anywhere in the world [and] reflect the spectrum of complexity on any grid," he says.

"Issues like harmonics and dynamic instability can cripple high renewable energy penetration, particularly on an island like Graciosa where most of the electricity generating will probably come from wind and solar.

"So this is why we pay close attention to these issues and challenges and needs, but we ensure that our knowhow and our integration and design but also our GEMS can actually mitigate these risks in real time, and I mean milliseconds."

Credit: HowardScott.

The Graciosa project integrates solar, wind, energy storage and thermal generation under a management software platform

It's therefore no surprise that for Jung, Greensmith's fifth-generation platform offers more value to a smart island project than the sum of its parts, suggesting that such a system would still be able to deliver value to a project even without battery storage.

Others are seemingly taking on this view, with domestic battery manufacturer Moixa developing the integration software for the Hitachi-led Smart Energy Islands project on the Isles of Scilly, off the coast of the UK.

This project is looking to double Scilly's renewables capacity through both rooftop and ground-mount solar, add 1MW of energy storage and integrate a higher percentage of electric vehicles to the isles.

Working with Hitachi and its Internet of Things platform to use these technologies to balance supply and demand of electricity, Moixa's project lead for the venture, Johnathan Linfoot, explains that the key is to ensure as many varying technologies as possible can be controlled under one system.

"Our aim is for the platform to be able to manage, agnostic of device. Our technology really focuses on managing a heterogeneous set of assets and doing that intelligently," he says.

"If you look at the ways to tackle the energy issues around Scilly, we think it's best to look at a distributed smart system because you can ultimately tailor that to exactly what the problem is rather than applying some sort of large network-scale asset to solve the problem."

Testing out the future

This ethos is one that will be familiar to anyone involved in planning the energy system of the future, with smart islands offering a glimpse at what the world could look like one day on a macro-scale.

It's no secret then that many of these projects are being carried out with that in mind, with Hitchi's involvement in Scilly predicated on its future plans for smart city applications.

Taibi says: "They are indeed living laboratories for testing technologies that are not possible to test in a large continental system in the way that you can do it in an island.

"There's a lot of need for system integration not only in the island systems, however you can test it better there in a system where you leave the hardware to operate in the real world, often in harsh environmental conditions."

How this can be applied in the future is not yet clear, but with cities around the world implementing their own renewable energy, storage and carbon targets, it's not out of the question that these metropolises could use the technologies being applied on islands to become islands themselves.

"Cities are at the moment one of the hot topics for the energy transition. [If] you want to start having the possibility of operating the city as an islanded power system, with the distribution system disconnecting from the transmission and running stand-alone, for instance in the event of extreme weather events, I see a convergence between islands, energy access in off grid systems and cities," Taibi concludes.

For Jung, the question remains – why stop there?

"The US is an island too and I think we'll see a time when control platforms are going to increasingly integrate the different control systems that grid operators are really not only contending with but are challenged by right now, because they're not getting maximised orchestration of these resources.

"There's also a desire and need for grid operators in many parts of the world to select one common platform so they can almost plug and play these different assets on the grid, including network assets. I feel like that's what we're getting to and is what we continue to invest in." ■

Case studies: Isles of Scilly

Key facts

- Doubling renewable capacity to 449kW through the addition of rooftop solar and two commercial-scale solar arrays, at least 1MW of storage added across households and V2G charging a large storage solution.
- Its goal is to provide 40% of electricity demand using renewables, to cut electricity bills by 40% and for 40% of vehicles on the islands to be electric or low-carbon – all by 2025.
- Status – software development underway alongside consumer engagement.

Hitachi gave *PV-Tech Power* an update on breaking new ground:

PV Tech Power: What are the specific benefits to island inhabitants of transitioning to a smart energy system?
Hitachi: The expected outcome of the Smart Energy Islands project is to enable the more efficient use of locally produced energy with home batteries, electric vehicle management and smart heating technologies matching supply with demand.

The Smart Energy Islands project will be installing solar PV arrays this summer on the islands. When these are connected to the internet, communications and data will combine to allow a much more intelligent use of energy resources. The benefits will be shared through a community venture, which will offer an energy tariff to islanders and reliance on mainland power and local energy costs will be reduced.

What is the importance of a high-level software platform using IoT, machine learning or AI in bringing these together?
At the heart of the Smart Energy Islands project is a simple idea – that an Internet of Things (IoT) platform for the Isles of Scilly, which will respond digitally to balance electricity demand and supply, will enable the more efficient use of locally-produced energy.

The Internet of Things platform will monitor electricity loads in houses and businesses, as well as electric vehicles, home batteries, smart heating technologies and other infrastructure, to optimise local energy use. Without a solution like this, the Smart Islands' ambitions could not be met.

What are the lessons Hitachi hopes to get out of the project and how are they likely to be applied?
The Smart Islands Programme aims to improve buildings and public infrastructure on the islands with additional energy generation and a community venture to channel the benefits of local energy generation to consumers. The community venture will facilitate the wider rollout of renewables, energy efficiency and smart energy technologies on the islands.

The Isles of Scilly, the focus of Hitachi's Smart Energy Islands project