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Berenberg Thematics

Micro-grids at the threshold

2 August 2017

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What is Berenberg Thematics?

Under our Thematics brand, we will focus on big, longer-term themes – specifically, disruptive technologies, demographics and corporate governance issues – which we feel investors should be looking at. Within each note, we will highlight trends and issues that we believe to be of interest to investors, and the effect of these on sectors and stocks, which we view as beneficiaries or at risk from the specific theme. The companies that we will consider will include those already under coverage, those not covered and also relevant privately-owned businesses, which we believe will be affected.

THE TEAM

Asad Farid joined the Thematics team in 2015 and covers batteries and the digital health space; he joined Berenberg in 2011. His previous focus was on the oil and gas sector where he was the lead analyst for oil field services. Before joining Berenberg, he worked as an economist and banking analyst at AKD Securities and has 10 years of sell-side research experience. Asad is an MBA from University of Cambridge and is a CFA charter holder. As part of his MBA programme, Asad completed internships at Google and with Berenberg's Technology Hardware team.

Nick Anderson joined the Thematics team in 2016 having previously built up and led the Banks team; he joined Berenberg in 2010. Nick has more than 20 years' experience as a top-ranked sell-side equity analyst including spells as co-head of the Lehman Brothers European banks team and as a transport analyst at both Lehman Brothers and HSBC James Capel. In addition, he has worked as a management consultant at McKinsey. Nick has degrees in economics and management studies from the University of Cambridge and in wine production from the University of Brighton.

Chris Armstrong has 20 years of experience on both the buy-side (as an analyst and portfolio manager) and on the sell-side, most recently as industrial specialist sales. Chris joined Berenberg as a Swiss equity salesman in 2006, before specialising in industrials in 2009. He has previously been a portfolio manager/analyst at Axa Framlington, Bank of Tokyo-Mitsubishi and NatWest, and holds a BA in Economics from Durham University.

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- The path towards the creation of a "smart" grid is becoming straighter and wider. We think micro-grids are the building blocks of the grid of the future. They are now becoming both radically cheap and versatile in the services they can provide due to plunging lithium ion battery costs. We forecast a sixfold increase in global micro-grid capacity by 2021 driven by the growth in storage. This opens new avenues for start-up companies based on innovative business models around micro-grids, storage, electricity trading and virtual power plants (VPP).
- **Why now? Batteries are here:** Lithium ion batteries are already economic for most power sector applications and are experiencing exponential growth in adoption levels. In 2016, battery installations rose fourfold on the back of ~30% reduction in costs. Batteries reduce the levelised cost (LCOE) of micro-grids to a third by increasing efficiency of the generation assets by 10 times. With storage, LCOE of micro-grids falls to ~$0.09/kWh and will likely fall below $0.07/kWh by 2021. At these levels, micro-grids are a much more efficient way of integrating renewables and negate the need to invest billions in upgrading the central grid.
- **Batteries allow micro-grids to tap multiple revenue streams:** Storage is helping micro-grid to transition beyond suppliers of just back-up power. Aggregation of storage and generation assets within a micro-grid creates a VPP and is capable of providing much-needed resiliency services to the central grid. Demand for these services is more than doubling every five years due to rising renewables in the generation mix. In Europe, this trend will likely continue considering targets to increase renewables by 20% by 2020.
- **Block-chain and batteries make electricity trading possible:** Utilities in the US and Europe are trialling block-chain technology, which, coupled with storage, can enable electricity trading within and also between micro-grids. Unhindered electricity trading is necessary if we are to overcome the intermittent, geographical and seasonal limitations of renewables. Batteries only offer a limited solution as overcoming these issues in the absence of fossil fuel generation would need uneconomic oversizing of storage capacity.
- **Smart grid will be based on storage, micro-grids and electricity trading:** We forecast the grid-connected micro-grid market globally to grow to $10bn by 2021 from under $0.5bn in 2016. Battery storage (residential and large) is estimated to play a major role and we expect 30GWh of micro-grid, which translates into a $5bn market opportunity by 2021. Fuel cells could be important for micro-grids as they are the most efficient generation technology – 15% adoption of fuel cells in micro-grids will translate into 7.5Gw of demand and a market worth more than $2bn.
- **Stock implications:** We think that control systems and technology will be key value additions to make this transition towards smarter and more effective micro-grids. These control systems will become more complex and increasingly customised. We hence believe that that leading micro-grid technology providers – Siemens (rated Buy), Schneider (rated Buy), ABB (rated Sell) and PSI (not rated) – with the best expertise in power electronics will benefit. We also believe that battery manufacturers Tesla (rated Buy), BYD (not rated) and invertor companies such as SMA Solar (not rated) have the expertise to provide services beyond just batteries. Fuel cell provider Ceres (rated Buy) looks interesting to tap the promising market of combined heat and power micro-grids.

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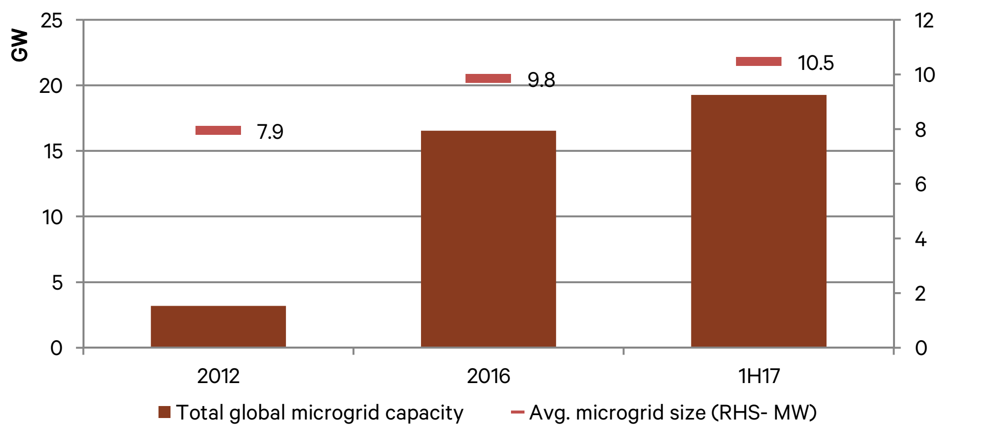
Micro-grids at the threshold

Last week, UK power regulator Ofgem announced far-reaching measures that will reduce barriers on battery storage, and make the grid more flexible and resilient by allowing aggregators/micro-grids to monetise numerous revenue streams (also called revenue stacking) by taking part in ancillary and capacity markets. This followed Tesla announcing the world's biggest 129MWh battery storage project in Australia, capable of providing electricity to 30,000 homes during a central grid blackout. On another front, Siemens, which is one of the leading providers of micro-grid controls, created a joint venture (JV) called Fluence, with US utility AES, which has the largest installed base in energy storage among the utilities. Tesla's huge contracts as well as this JV clearly show that batteries are helping micro-grids move towards mass adoption.

While micro-grid adoption has risen more than fivefold to near 20GW capacity (global power generation capacity at 3.5TW), it remain on the fringes of the power sector, catering to remote locations and small island economies. We believe that batteries and solar photovoltaics (PVs) can radically improve the economics of micro-grids and lead to a future where national power grids become an aggregation of many micro-grids. Local generation, storage and peer-to-peer electricity trading is the future, in our view.

Utilities will need to transition into developers of micro-grid networks and managers of electricity trading, which occurs between micro-grids through the transmission network. Instead of micro-grids currently focusing on providing back-up power to consumers when the centralised grid fails, we are transitioning towards utilities taking the role of providing back-up power to micro-grids.

Total global micro-grid capacity has risen more than fivefold since 2020 and currently is near 20GW



Source: Berenberg estimates, Navigant, GTM

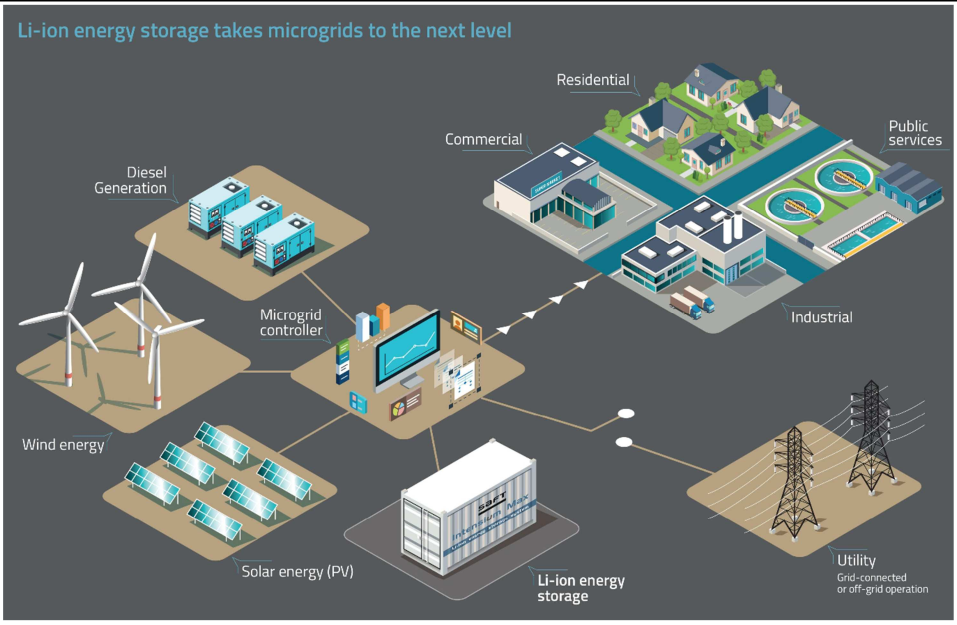
What is a micro-grid? Current ones are "dumb"

- Micro-grids currently predominantly exist in remote areas lacking a central grid, or in areas to provide back-up power to critical infrastructure, such as hospitals, data centres, university research centres and telecom stations when the central grid fails. Only 10% of micro-grids are connected to the central grid.
- The cost of advanced grid-connected micro-grids can be up to twice as much as standalone systems in remote locations. Regulatory barriers significantly add to these costs.
- Without monetising the numerous benefits a micro-grid can provide to the central grid, grid-connected micro-grids will remain economically unviable.

While there are varying definitions for what is a micro-grid, in essence it is a small network of localised loads (ie demand) and generation that can work in an island state (ie disconnected from the main grid). Micro-grids are the most economic in countries where:

- **The centralised grid is weak and there is a large land mass:** This would include countries such as the US, Australia, China and India, and other emerging Asian and African countries.
- **There are high adverse weather events:** This would include coastal economies experiencing high hurricane activity, such as the US states of Florida, Texas and Mississippi, and central land regions such as US Tornado Alley, which includes the states of Kansas, Missouri, Nebraska and Iowa.
- **Retail prices are very high:** This would include Germany, Denmark, Italy, Spain, Portugal, Hawaii and Australia, which all have high retail tariffs. However, it needs to be taken into account that the tariffs are high in these countries also because of high taxes to subsidise renewables.
- **There are high varying loads:** This would include medical centres, data centres and telecom towers for example.

Storage can substantially improve the cost effectiveness of micro-grids and allow them to emerge as electricity trading platforms



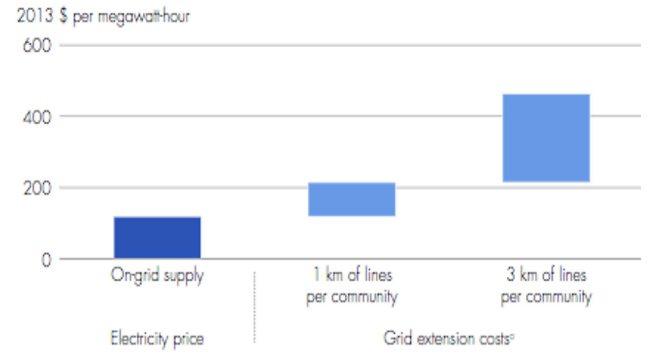
Source: SAFT

Micro-grids have existed for a very long time in remote locations especially used by the military. Despite rapid growth over the past five years where the overall micro-grid capacity has risen by more than fivefold, they currently remain basic and retain the following drawbacks.

1. Most are not connected to the central grid

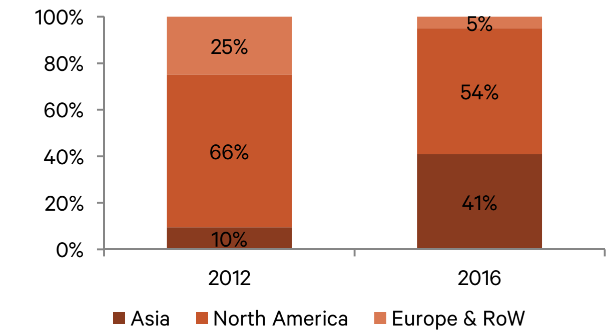
The biggest micro-grid market remains remote locations where grid expansion does not make economic sense – on average it costs more than $80/MWh to add 1km to the grid. Remote locations in countries with large land masses and/or sparse rural populations, such as Australia, the US, China, India and those in Africa, have until now been the main market for micro-grids.

Grid expansion is expensive – costs more than $80/MWh per km



Source: Simusolar presentation at Intersolar conference 2017

North America and Asia are the two main markets for micro-grids because of relatively weak grids

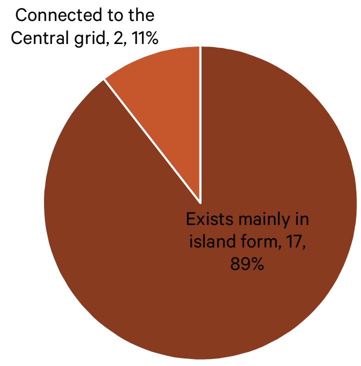


Source: Berenberg estimates, Navigant, GTM

2. "Dumb" and used mainly for back-up power when connected to the grid

Out of the 19GW of global micro-grid capacity, only 2GW is connected to the main grid. Even when connected to the centralised grid, the micro-grid is primarily serving purpose is to provide back-up power to its customer when there is central grid blackout. These "dumb" micro-grids have a weak interface with the central grid and do not take part in balancing and wholesale markets.

Only 11% of micro-grids are connected to the central grid. Even when connected, they are only providing back-up power to their consumers when the central grid fails

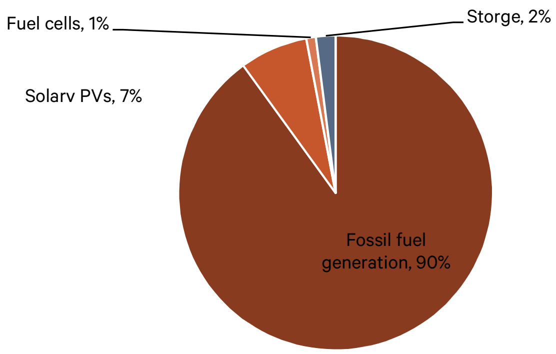


Source: Berenberg estimates, Navigant, GTM, ABB, expert interviews

3. Single fossil fuel-based generation source

Most of the micro-grids currently have a single generation source and more than 90% are either based on micro gas turbines and diesel generators. Fewer than 10% have solar PV and wind generation. Only 3% of the micro-grids currently use stationary storage and fuel cells. Lack of storage is a key reason why they lack the ability to provide any grid-level services.

Currently only 2% of the micro-grids use battery storage. The dominant generation source remains gas and diesel



Source: Berenberg estimates, Navigant, GTM, ABB, expert interviews

Cost structure of a micro-grid

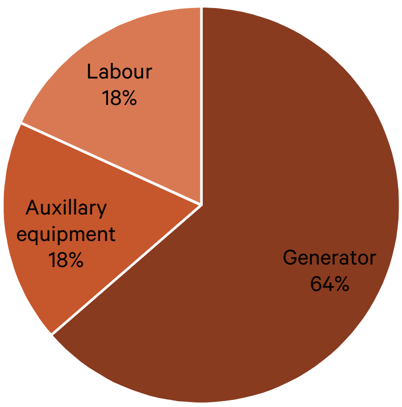
The cost of a micro-grid project can be divided into three parts:

- auxiliary equipment comprising of protection equipment, such as breaker and automatic sensor switch, cabling and ducting;
- generation system – gas and diesel being the two dominant ones; and
- labour for installing the hardware.

The control system for island-based single-generation based micro-grid is very simple and is usually part of the diesel or gas turbines provided by the likes of Cummins.

Assuming a 10MW micro-grid system, auxiliary equipment will cost ~$200,000, labour $200,000-300,000 while the 10MW generation system will cost upwards of $700,000. The overall cost of the hardware and installation a 10MW island grid system can be more than $1.2m.

The cost of the diesel/gas generation forms the bulk of the capex for micro-grid in remote locations. The overall cost of a 10MW system is more than $1m



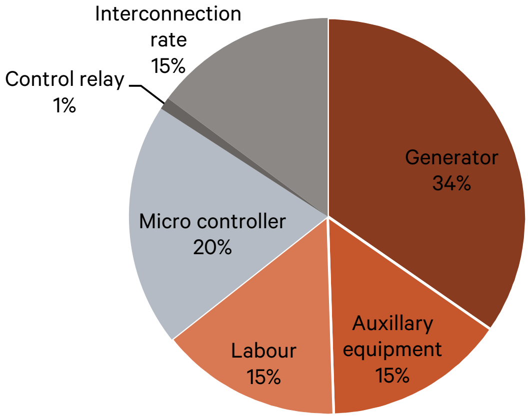
Source: Berenberg estimates

Costs will be a lot higher if the micro-grid is connected to the grid and provides grid services. Additional costs will include the cost of the complex microcontroller, which is able to interface with the grid, optimise generation assets (curtailing solar and increasing fuel input to generation asserts when needed) and provide grid level services. A small 10MW provided by the likes of Schneider, Siemens, ABB and others will cost anywhere between $200,000 and $400,000 depending on functionality.

Another important cost to consider is the interconnection charge that the utility or the distribution network operator will charge to connect the micro-grid to the distribution network if it is low-voltage connection (less than 12,000 volts) or the transmission network for high-voltage connections. This will vary from region to region and from utility to utility.

According to our discussions with industry experts with years of micro-grid installation experience in the US and Europe, the interconnection rates could be anywhere from low tens of thousands to hundred of thousands of dollars. The upper part of this broad range depends on whether the local utility will need to upgrade the grid to accommodate additional supplies from the micro-grid. This might involve setting up a new and bigger transformer, thicker wires and voltage regulator. In addition to the interconnection charges, the utility might require the micro-grid owners to install a breaker relay to the micro-grid. This is a control system that can be used by the utility break connection of the micro-grid from the central grid when needed. The relay system is an additional cost of at least $10,000-20,000.

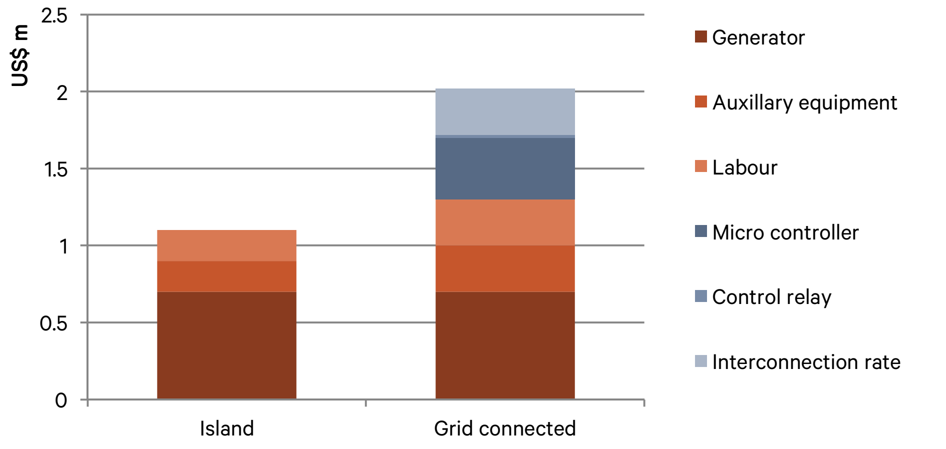
Interconnection rates and the cost of the micro-controller forms the bulk of the capex of an advanced micro-grid connected to the grid. The overall cost of the micro-grid hardware and installation (excluding the cost of generation system and storage) can reach $1m for a 10MW system



Source: Berenberg estimates

Therefore the overall cost of a micro-grid connected to the central grid could easily be as high as 2x the cost of similar island grid. Just the cost of micro-grid hardware and installation (excluding the cost of the generator, solar PVs and storage) can be more than $1m for the 10MW system. Due to regulatory barriers, micro-grids that are grid connected cannot currently monetise the numerous benefits that they can provide to the central grid. This is the reason why grid-connected micro-grids are currently not economic and most of the growth is happening in remote location with an absent or weak peripheral grid. In our view this changes sharply with battery storage, which we explain in the next section.

Grid-connected micro-grids entail nearly twice the capex versus remote island grids. This makes them economically unviable currently



Source: Berenberg estimates

Regulatory support and barriers by country for micro-grids

- There are numerous regulatory barriers for micro-grid adoption in most countries, which add to the cost of grid-connected micro-grids and makes them economically unviable.
- Regulatory reforms in New York, California and other key states in the US are boosting the adoption of grid-connected micro-grids.
- The UK has announced bold reforms to level the playing field for storage and aggregators such as micro-grids. We do not think that the UK will be an exception and expect the regulatory framework for storage and micro-grids to improve in the rest of Europe.
- China considers micro-grids as part of its vision of a smart grid while India is embracing micro-grids to reduce rampant electricity poverty.

There are numerous barriers, especially regulatory, which explains the high cost of developing micro-grids that are connected to the central grid. These differ region by region and utility by utility. In this section we discuss these barriers as well as opportunities and adoption in key end-markets for micro-grids. We find that while incumbent utilities everywhere are reluctant to adopt micro-grids, regulatory frameworks are gradually becoming more favourable to the adoption of smart micro-grids.

Despite the wide variation by countries, the following are the three main barriers that are present globally.

- **Utility franchise laws:** Micro-grids cannot string wires across a public street to serve customers as that infringes upon utility franchise rights. In Connecticut, the state allows micro-grids to sell power across a public street. Utility franchise rules are being eased in both the US and Europe to make electricity trading with a micro-grid possible.
- **High cost and complexity because of a lack of standardisation:** There is a lack of a plug-and-play control system for a micro-grid. What we have is an extremely customised product. Micro-grid development is also difficult because of the different standards and communication interfaces for different generation assets and inverters. Due to the lack of global standards, integration of micro-grids into the main grid and its interoperability currently seems to be a challenge. We expect regional standards to gradually emerge, especially for interface between the micro-grid and central grid in the future.
- **High interconnection rates with the grid:** Laws and regulations for micro-grids differ across states in the US and across countries in Europe. At the same time micro-grids face high interconnection and standby rates when connected to the central grid. Utilities have control over interconnection requests with the electricity grid and hence could slow down the adoption of micro-grids. However, in light of the aggressive renewables growth targets in Europe we think that utilities will be forced to ease these barriers.

The following graph shows the number of large and mainly central grid-connected operational and under-development micro-grid installations by country and region. As can be seen, the US is by far the biggest market followed by Canada, China and India. In this section we explore these important markets as well as the laggard Europe in context of the regulatory barriers and opportunities for micro-grids.

Large and mainly central grid-connected micro-grid projects in development and operational by countries and regions

Source: Berenberg, Microgridmap, company press releases

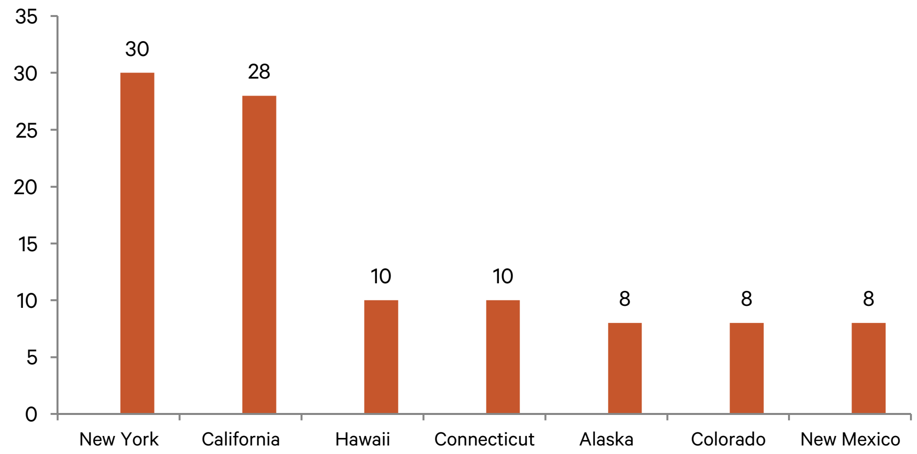
US is by far the largest micro-grid market

In the US increasing level adoption is on the back of both national and state-wide targets for micro-grid development. At the national level, the US Department of Energy (DoE) has a micro-grid initiative, which by 2020 aims to achieve:

- a reduction in time of grid outages by more than 98%; and
- an improvement in energy efficiency and reduction of emissions, both by more than 20%.

The US DoE considers the micro-grid to be the building block for the creation of a flexible "plug and play" electric grid (a "smart grid") of the future. On the state level, New York and California are the two biggest markets followed by island state Hawaii, remotely located Alaska, Colorado and New Mexico.

The number of large and mainly grid-connected micro-grids by states, either in operation or in different stages of development



Source: Berenberg, Microgridmap, company press releases

New York plan envisages utilities to be managers of electricity platform providers with less focus on asset ownership: In New York, out of the 30 large micro-grid projects, eight projects are operational while the remaining are in development. This rapid thrust to develop micro-grid projects in the state is due to the regulatory changes it announced and implemented after 2014. This power reform package is called the Reforming the Energy Vision (REV) and requires the state by 2030 to meet the following goals: 1) a 40% reduction in emissions from 1990 levels; 2) a 50% generation from renewables; and 3) a 23% reduction in energy consumption by buildings. The other aim of the programme includes improving grid resiliency and making households more responsive to pricing signals. REV hence encourages micro-grid adoption as it is the enabling technology for meeting all of these goals and the creation of a smart grid.

Under the REV, the utility distribution companies will transition into distributed system platform providers (DSPPs), which will be responsible for creating a flexible grid platform capable of incorporating increasing levels of distributed generation and energy storage into the grid. This will require DSPPs to interface with both retail customers and also the broader interface between the retail customers and the transition network operator (TNO) and the administrator of the wholesale market, NYISO. In our view this will require a transformation of the distribution network by the DSPPs, which will have to enable: 1) a bi-directional flow of electricity; and 2) real-time management of loads and generation assets whether central or distributed.

However, despite the thrust to develop micro-grids, regulatory barriers are still there. In New York, larger distributed generation systems as part of the micro-grid have to pay standby tariffs to the local distribution utility. This standby tariff is the payment for the reserve capacity that the utility needs to maintain to provide back-up power the micro-grid if their system fails. What is positive is that after significant pressure from the commercial and industrial owners of distribution assets, New York utilities have agreed to provide selective exemption to distribution energy resources (DER) based on renewables and efficient combined heat and power (CHP)-based micro-grids.

The following table shows 11 large micro-grid projects that are currently in feasibility stage in New York. What is clear is that apart from one project, all the other are "smart" micro-grids using storage and a mix of generation assets.

A number of advanced grid-connected micro-grid projects are being developed in New York as part of the Reforming the Energy Vision (REV) plan

Microgrid projects in feasibility stage in New York

Projects	Grid tried or island	Generation asset	Storage or not	Fuel cells	Blockchain	CHP
Brooklyn microgrid on President street	Grid connected	Solar	Yes	No	Yes	No
Babyloon	Grid connected	Conventional, solar & fuel cells	Yes	Yes	No	No
Huntington Microgrid	Grid connected	Natural gas and solar	Yes	No	No	Yes
East Hampton Microgrid	Grid connected	Solar & wind in addition to back up generators	Yes	No	No	No
Greenport microgrid	Grid connected	Natural gas and solar & wind	Yes	No	No	No
Port Jefferson Microgrid	Grid connected	Conventional & Solar	Yes	No	No	Yes
Bookhaven Microgrid	Grid connected	Solar, wind, fuel cells and micro turbines	Yes	Yes	No	Yes
South Hampton Microgrid	Grid connected	Natural gas and renewables	No	No	No	Yes
Long island community microgrid	No - grid constrained	Solar	Yes 25MWh system	No	No	No
Long Beach Microgrid	Grid connected	Conventional, Solar & fuel cells	Yes	Yes	No	Yes
Hamstead Microgrid	Grid connected	Solar and natural gas	Yes	No	No	No

Source: Berenberg, Microgridmap, company press releases

California has high barriers, but these are likely to come off over the next five years: According to external consultancy Navigant, there are more than 120 micro-grid projects that are either operational or in different stages of development in California. Out of these, 30 are larger operational systems that are connected to the central grid while the rest should be standalone remote systems. However, there are only four large grid-connected micro-grids that are currently under development. This low number of projects under development shows that in California, grid-connected micro-grids lack economic viability. This is due to a number of barriers that are sapping growth. These include state-specific barriers such as:

- a bar on the micro-grid from providing back-up to its participants when the central grid fails;
- utilities franchise laws that make it difficult for micro-grids to sell electricity to customers; and
- high interconnection and standby charges.

These barriers are likely to ease in the future. The state's power regulatory bodies California Energy Commission and California Public Utilities Commission are currently developing a roadmap for the growth and commercialisation of micro-grids. The road map is expected to be announced by the end of 2017. In our view, this will focus on improving the economic viability of grid-connected micro-grids by allowing it to monetise the numerous services it can provide through the aggregation of its distributed generation and storage assets.

The California Energy Commission is also working on increasing micro-grid standardisation to lower costs and hence expedite their adoption. The commission is providing $44.7m of funding with $2m-5m per standardised micro-grid project in the state.

Another important driver of adoption will be a bill that is currently being considered in California, which will aim to achieve a zero carbon grid post-2030. In our view this will require a complete shift towards distributed generation and renewables, which fails to work in the absence of both battery storage and micro-grids

The following table gives the grid-connected micro-grids currently in development in California. What is interesting to notice is that bar one, all of them are incorporating battery storage.

Most of the new large micro-grid projects currently under construction in California incorporate battery storage

Microgrid projects currently being developed in California

Projects	Grid tied or island	Generation asset	Storage or not	Fuel cells	Blockchain	CHP	Microgrid system provider	Battery provider	Utility
Blue Lake Rancheria Microgrid	Grid connected	Solar and back up generator	Yes (0.95MWh)	Yes (175kW)	No	No	Siemens	Tesla	PG&E
Bosch Microgrid	Grid connected	Renewables	Yes (Flow battery)	No	No	No		Imergy	CEC
Camp Pendletob Microgrid	Grid connected	Diesel and Solar	Yes (300kWh) + EV to grid for added	No	No	No			AES
Vandenberg Airforce base Microgrid	Grid connected	Conventional	No	No	No	No			

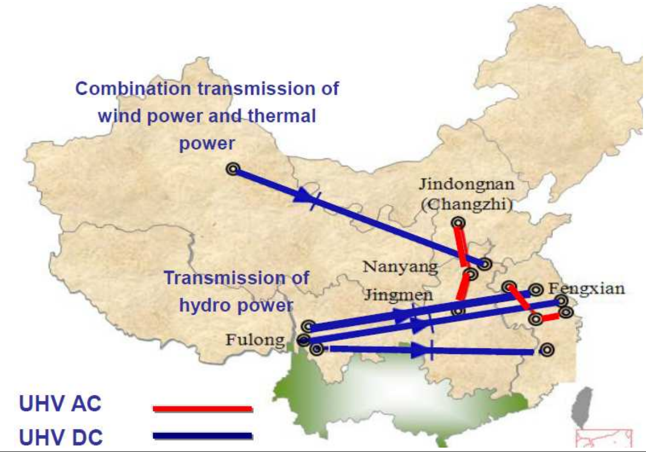
Source: Berenberg, Microgridmap

China's grid infrastructure lagging behind adoption of renewables

The growth of micro-grids in China is being driven by the rapid growth in distributed renewable energy generation, which in turn is being driven by the country's aggressive 2020 environmental targets: 1) a 15% share of renewables in the generation mix; and 2) a 40-45% reduction in CO2 emissions. Wind and solar generation capacity stood at 100GW and 21GW respectively in 2015, and is targeted to reach 200GW for wind and 150GW for solar, according to State Grid Corporation of China (SGCC), China's largest utility. What is clear is that the central grid is already failing to cope with rising renewables, which is leading to increasing curtailment of solar and wind generation. This is despite the country investing heavily in its transmission network. It currently has 13 ultra high voltage (UHV) transmission lines already in operation and nine under construction.

We think that in addition to the investment in its transmission network, Chinese authorities are likely to expedite progress towards a smart grid that is based on storage, distributed renewables and smart meters. Since 2009, the country has invested €10bn into 500 pilot projects related to development of a smart grid. The country also has the highest installed base of smart meters with 408m bi-directional smart meters installed and with the target to complete rollout by the end of 2017. As part of its smart grid development programme it has already constructed 22 large micro-grid demonstration projects and aims to construct 30 new ones.

China is investing billions in its transmission network to solve the geographic limitations of renewables. This investment includes…



Source: State Grid Corporation of China

…plans of setting up a smart grid. The country has already invested €10bn on micro-grids, smart meters and other smart grid-related pilot projects since 2009

Source: State Grid Corporation of China

India planning to develop 10,000 micro-grids to increase electricity access

India has aggressive targets to improve access to electricity in the country where nearly 400m (more than one-third) of its population has either no or poor access to electricity. The country is targeting the installation of micro-grids in both remote locations and to improve central grid resiliency to reduce blackouts. According to preliminary plan, the central government will provide funding to develop 10,000 micro-grids. Utilities will be required to set up micro-grids with total capacity of 500MW. The government will need to move ahead quickly on the development of micro-grids if it is to come close to achieving its ambitious goal of eliminating blackouts by 2019.

Europe – a laggard, but winds of change are starting to blow

Until now not much has been happening on micro-grid adoption in most of Europe. This is despite the sharp growth in renewables and aggressive 2030 target of a 45% share of renewables in the generation mix. A strong centralised grid and regulatory barriers, with especially very high standby charges and interconnection rates, make grid-connected micro-grids economically unviable. The following table shows that micro-grid projects carried by European utilities since 2012. What seems clear is that all the micro-grid projects based in Europe are island grids and not connected to the main grid.

Enel and ENGIE are leading the development of smart grid-connected micro-grids in Europe. What is also clear is that European utilities have been mainly investing in micro-grids (especially those with central grid connection) outside of Europe

Company	When	Location	Island/Grid Connected/VPP	Storage Type
Enel	2017	Antofagasta, Chile	Grid	Lithium & Hydrogen
	2017	Ceará, Brazil	Grid	
	2016	Kisii/Nyamira, Kenya	Island	
	2016	Ventotene, Italy	Island	Lithium-ion
ENGIE	2016	Tahiti	Grid	
	2016	Tanzania	Island	Lithium-ion
	2016	Rivesaltes, France	Grid	Lithium-ion batteries
	2015	Corsica, France	Grid	
Terna	2012	Sicily/Sardinia, Italy	Island	Sodium-ion
	2016	Sicily/Sardinia, Italy	Island	Lithium-ion titanate
National Grid	2014	Potsdam (NY), USA	Island	
Endesa	2016	La Graciosa, Spain	Island	Lithium ion

Source: Berenberg estimates, press releases, new reports

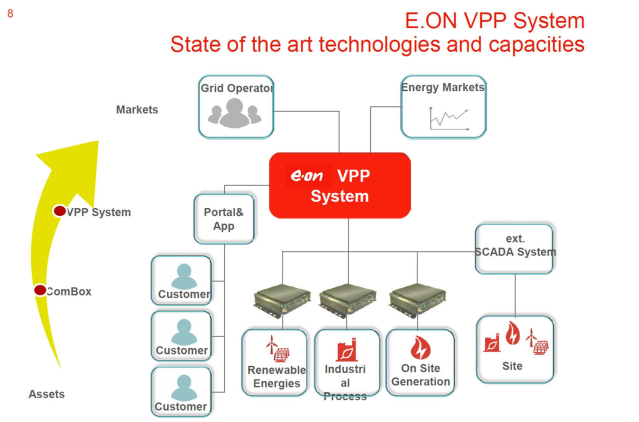
However over the past few years, some European utilities have been carrying out advanced grid-connected micro-grid projects where the generation and storage assets within the micro-grid are aggregated as a VPP to provide grid-level services. RWE, Fortum and SSE are the most active in this area. While we were unable to identify any past VPP project by E.ON, it, too, has actively pursued this market and is currently perfecting its technology. National Grid has also partnered with a start-up, Limejump, which provides the technology for aggregating distributed generation to act as a VPP and also for demand response.

RWE, Fortum and SSE are leading in VPP development in Europe

Company	When	Location	Island/Grid Connected/VPP	Size
RWE	2015	Germany	VPP	
Fortum	2016	Finland	VPP	100kW
SSE	2016	UK	VPP	
Veolia	2012	Ireland	VPP	>1MW

Source: Berenberg estimates, press releases, new reports

E.ON, too, is focused on perfecting its VPP technology



Source: E.ON

Within Europe, we think that winds of change have started to blow. The UK electricity regulator announced last week a major plan to overhaul the country's power network and make it flexible by removing barriers on smart technologies, such as battery storage, micro-grids and electricity trading. Ofgem estimates that the adoption of these technologies can help save consumers and businesses £40bn in energy bills. The changes include:

- making the ancillary market for aggregators more accessible by moving to real-time auctions;
- reducing barriers to demand-side response services provided by aggregators by simplifying metering requirements, and allowing the stacking of revenues by allowing them to provide services to both capacity and ancillary markets;
- simplifying metering requirements for providing demand response services and also allowing revenue stacking for battery storage operators so that they can target the capacity and ancillary markets; and
- removing demand residual charges at transmission and distribution level on battery storage. Storage will also not face two sets of balancing system charges and consumption levies will be removed from storage.

Distribution network operators (DNOs) will be encouraged to explore market-based solutions such as storage and micro-grids as an alternative to investing in the central grid. We think that these measures will result in the reduction in the standby and interconnection rates faced by micro-grids to connect to the central grid in UK.

We also think that these reforms (especially those linked to storage) ought to result in grids that allow peer-to-peer electricity trading. The UK is already operating a peer-to-peer electricity trading platform called OpenUtility, which allows larger distributed electricity generators to sell their electricity on the market place. With an increase in residential battery storage, OpenUtility will allow households to trade electricity with each other.

While there are differences between the power system of the UK and the rest of Europe, we do not think that the UK will be an exception. We see no reason why other European countries will not be forced to go down a similar route over the next five years considering: 1) the declining cost of renewables and storage; 2) increasing renewables in the generation mix and aggressive 10-year targets across Europe; and 3) the phasing out of nuclear in a number of European countries. These are factors that are driving change in the UK and will eventually have a similar impact in the rest of Europe.

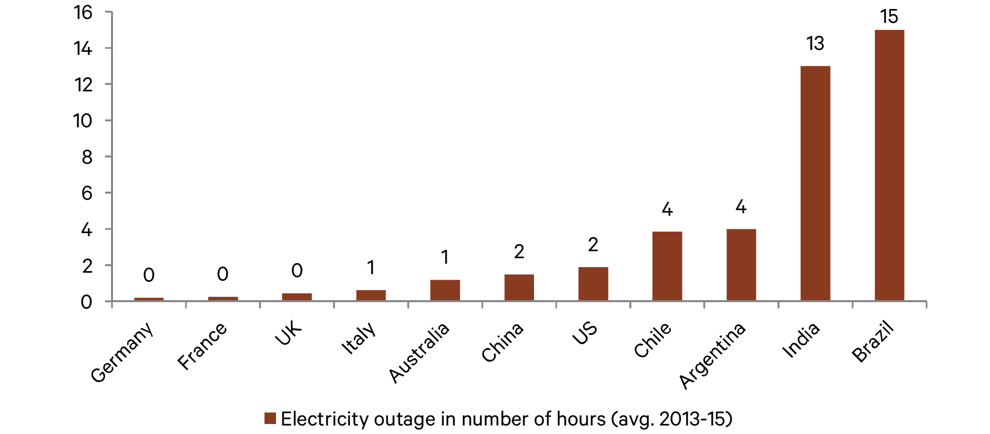
Batteries help the micro-grid become more effective and cheaper

- Battery storage (while adding to the capex outlays) improves the efficiency of a micro-grid by 10x (reduction in fuel consumption and 100% utilisation of generation assets) and hence reduce its levelised cost to below $0.1/kWh.
- Storage costs are falling rapidly. The levelised cost of stationary storage based on lithium ion and flow batteries is likely to fall below $0.02/kWh/cycle by 2021. By 2021, we expect the levelised cost of micro-grids to be ~$0.07/kWh, which is very close to just the fix grid charge in some countries.
- Micro-grids can provide numerous benefits to the central grid – improving resilience, incorporating renewables and improving efficiency being the three key. We think that if micro-grids are allowed to revenue stack and monetise these benefits, their economic viability and adoption will improve massively.

We think that incumbent utilities in the US, Asia and also Europe could drive the development of micro-grids, storage and VPPs. This is because of the numerous benefits micro-grids bring to the central grid, such as helping to postpone investment required in the ageing distribution and transmission network. For example, it is estimated that the US ageing grid requires an investment of $57bn, according to the American Society of Civil Engineers. This is because micro-grids with storage can massively improve the following.

- **Grid resiliency:** Micro-grids can substantially improve grid resiliency to adverse weather events. In the US, the cost associated with blackouts is estimated to be $40bn-75bn per year. The following graph shows grid outages by countries. In counties across Asia and Africa, micro-grids can play an instrumental role in improving grid resiliency.

Electricity outages in number of hours (average for 2013-15) for selected large economies

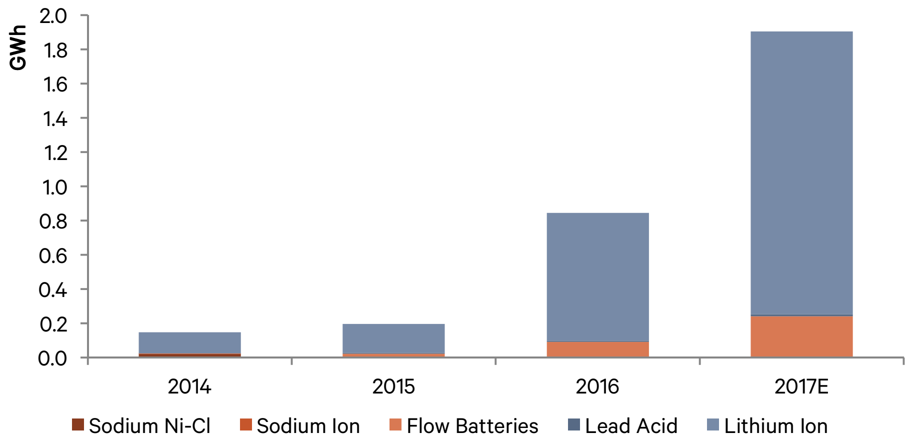


Source: "Electricity tariffs, power outages and firm performance" by Jean Arlet, published Mar 2017, The World Bank

- **Efficiency of centralised generation and transmission with DC micro-grids:** In contrast to conventional expectations, micro-grids can have better efficiency versus what the traditional grid offers, despite its scale. One important and obvious factor for this is the localised consumption of localised generation means that that the system does not face high transmission losses. This is especially the case for DC micro-grids. Losses over the transmission network can be up to 10%. In addition, changes in phase from DC to AC and then AC to DC again can lead to losses of up to 2.5% at each step. DC-based micro-grids do not experience these losses.
- In addition, heat in centralised generation is wasted. Micro-grids in contrast can use this heat for local heating requirements or use it to power chillers to meet cooling requirements. The combined power and heating/cooling-based systems can improve the efficiency of conventional micro-grids from between 30-40% to more than 80%.

Large-scale storage has been growing rapidly. In 2016, there was a fourfold increase in the large-scale installation of storage linked to the grid (see graph below). Storage, in our view, can make the micro-grid "smarter" and ease grid concerns regarding integration of renewables. It also allows new business models being adopted in the power sector to monetise services that can be provided through peer-to-peer trading and through the creation of a VPP.

Large-scale storage rose fourfold in 2016 – lithium ion and flow batteries dominate

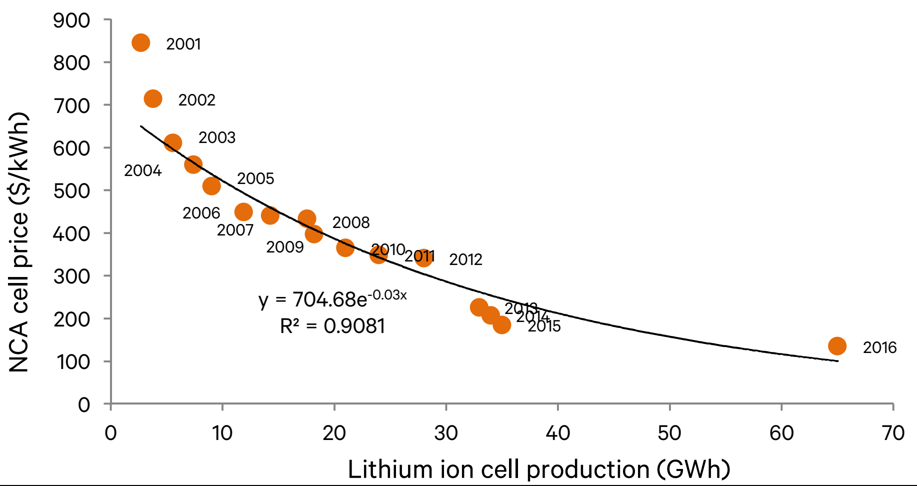


Source: Berenberg estimates, US DoE

Stationary storage is becoming dirt cheap: As can be seen in the graph above, the two main technologies that are being used for large-scale storage are lithium ion and flow batteries. The cost of both technologies is declining rapidly. Lithium ion cells based on NCA (nickel cobalt aluminium) would cost c$140/kWh, while LFP (lithium iron phosphate) - based cells manufactured in China are less than $100/kWh. Adding the cost of the cooling system, battery management system, invertor and power electronics, the cost right now for an LFP-based stationary system should be close to $300/kWh. Assuming a cycle life of 8,000 cycles and depth of discharge of 80%, this translates into a levelised cost of ~$0.05/kWh per cycle. By 2020, we expect the cost to fall by ~40% to $0.03/kWh/cycle (based on system cost of $180/kWh).

Flow batteries offer even further reductions in the cost of storage. The main reason for this is while the overall cost of the system could be similar to lithium ion at $300/kWh, it can be cycled indefinitely as the electrolyte that stores energy in the system does not degrade with time. Let us assume that a conservative 20,000 cycles (and 100% depth of discharge) for a flow battery system would translate into a levelised cost of $0.015/kWh. This is the reason why in the **US power purchase agreements of solar plus flow battery-based systems have been signed at $0.045/kWh.** A US flow battery company claims it can provide solar plus storage system at a levelised cost of as low as $0.04/kWh. **This is nearly free and reliable electricity and shows that there is no reason why renewables with storage cannot be much cheaper than central generation and transmission.**

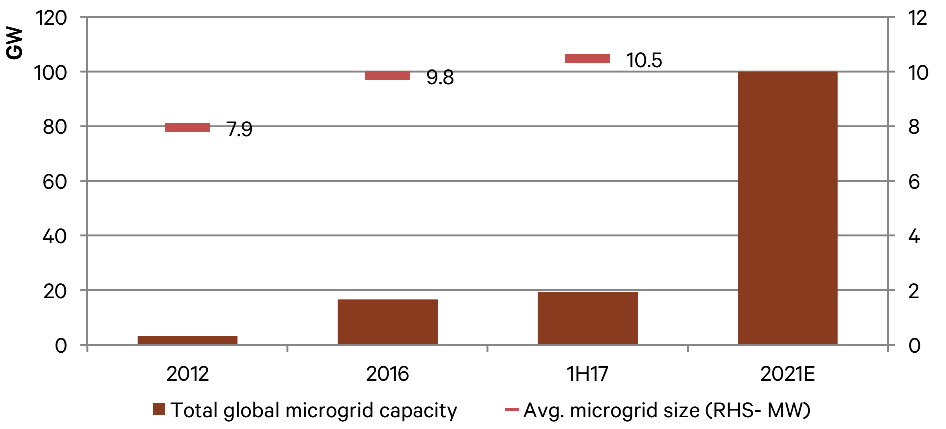
Lithium ion battery costs are fast falling and production levels rise. We expect the cost of stationary storage systems based on lithium ion batteries to fall to $180/kWh by 2021



Source: Berenberg estimates

With the growth of batteries declining rapidly, we expect their continued adoption to drive growth and radically improve the functionality of the current "dumb" micro-grids. We expect rapid growth in micro-grid adoption over the next five years and expect global capacity to easily cross 100GW by 2021 from the current level of 19GW. While 100GW is meaningless when compared to the global electricity generation capacity or that for renewables, it offers numerous growth opportunities to start-up companies, which can offer new services for the power system and to households based on storage, micro-grids, electricity trading platforms and VPPs.

We expect global micro-grid capacity to easily cross 100GW by 2021 from the current level of 19GW



Source: Berenberg estimates

We think that three key trends will support and also characterise this rapid growth in micro-grid development.

1. Cost of micro-grid development can fall by 80% over the next five years with the help of storage

There are numerous factors that impact the cost of setting up a micro-grid. These include the following.

- **Type of generation assets:** Micro-grids can be based on different combinations of generation assets. Solar PV and renewables have higher upfront capex, but have lower operating costs. This is reverse for micro-grids based on fossil fuel generation. Operating costs for diesel and gas generation assets are volatile and are determined by fuel prices.

- **Number of generation assets:** The controllers and the interfaces required will be more complex when a number of generation assets are used in the micro-grid. Control systems for micro-grids are customised and are generally more complex for fossil fuel generation systems compared to invertor-based system for renewables.
- **The services provided to the central grid:** The micro-grid needs to interface with the centralised grid. The costs for equipment and more importantly for software will be higher if the micro-grid is to provide multiple services to the grid.
- Other factors that impact the costs will be **financing costs and government incentives.**

Battery storage can radically lower the levelised cost of electricity for a micro-grid by increasing the efficiency of the generation asset, whether fossil fuel driven or that based on renewables. According to leading technology group ABB, storage can increase the utilisation of generation assets from 7% to 100%. This is important, especially for fossil fuel-based systems that require an ideal generation of 70-80% to achieve their nameplate efficiency. Without storage, they are unable to achieve this as they have to follow the load, which fluctuates substantially throughout the day and across seasons. Battery storage-based micro-grids allow running the generation asset consistently at its ideal level.

Battery storage increases utilisation of distributed generation assets to 100%, according to ABB

Wind/Solar/Diesel Systems	Annual Average Contribution	Peak Penetration
No Integration	7%	20%
Automated Dispatch (MGC600)	10%	22%
Grid Stabilizing (PowerStore)	50%	100%
Automated Demand Response	60%	100%
Energy Storage	100%	100%

NOTE: General industry accepted figures. All systems are unique and dependent upon the generation mix, load profiles and renewable resource.

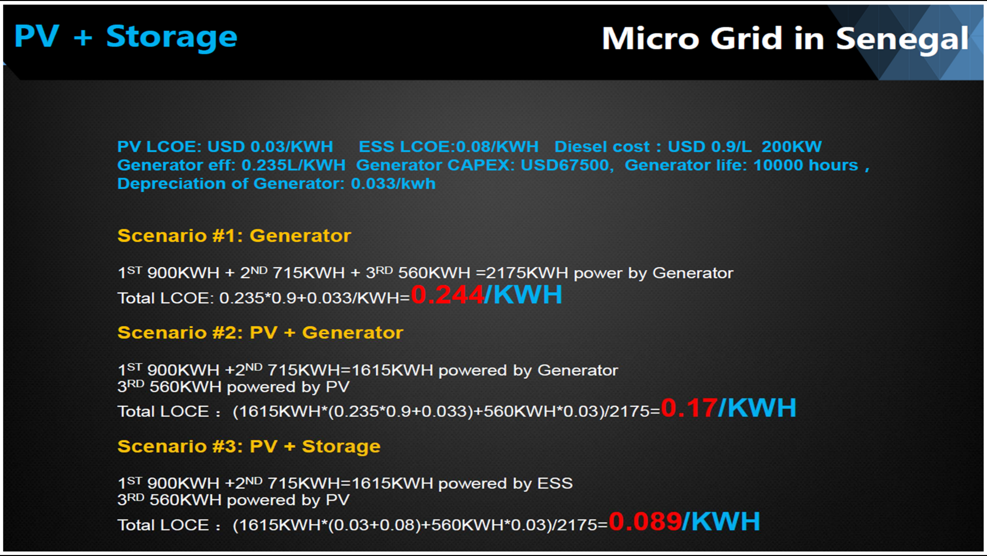
ABB

Source: ABB

The impact of storage on the cost of a micro-grid could be substantial. The following are Chinese company BYD's levelised cost of electricity (LCOE) estimates for different types of micro-grids it considered for a micro-grid project in Senegal covering 80 homes. What can be seen is that the **LCOE of a lithium ion storage-based micro-grid is a third of the cost versus that based on just diesel generation.**

According to the cost estimates of the BYD project, **the LCOE of storage plus solar PV-based micro-grid system was less than $0.09/kWh. This level is lower than the retail cost of electricity in most countries in Europe and states in the US.** Assuming a 40% reduction in the cost of lithium ion batteries by 2021, we expect the LCOE of micro-grids can fall by at least 80% versus current micro-grids not using storage. This translates into an LCOE below $0.07/kWh, which is near to just the fixed grid charge in some countries such as Germany and Australia.

Storage can reduce the LCOE of micro-grids by at least 80% by 2021 versus current micro-grids not utilising storage



Source: BYD

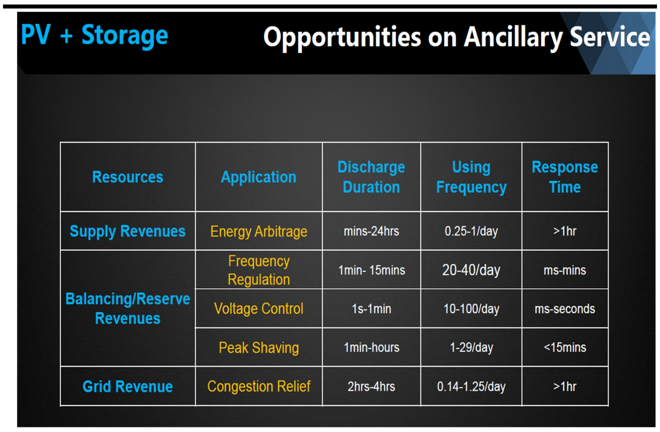
2. Grid-connected micro-grids to see strongest growth

Although island micro-grids have dominated the space, we expect the strongest growth in central grid-connected micro-grids. This is because storage makes micro-grids "smarter", allowing them to tap more value streams when connected to the centralised grid.

Through aggregation of distributed generation and storage resources, as well as smart meters and pricing signals, the micro-grid can provide:

- **A demand response service:** Through the use of smart meters and pricing signals, a micro grid operator can incentivise its users to alter demand load in order to alleviate congestion in the central grid.
- **Grid balancing ancillary:** Frequency smoothing and voltage support.
- **Re-dispatch:** Micro-grid generation and storage resources can provide re-dispatch volumes to reduce grid congestion.
- Trade in **the wholesale market.**

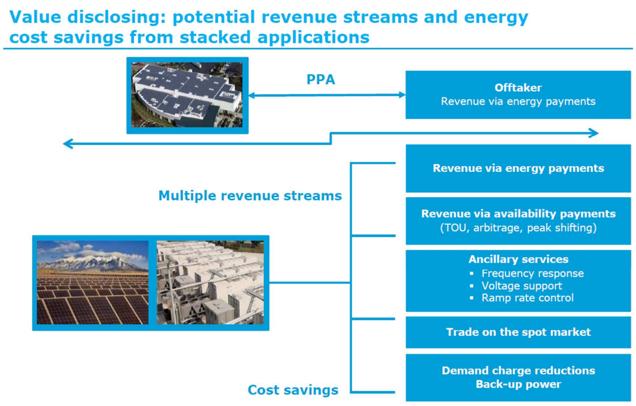
Storage-based micro-grids can provide grid-balancing services, which are growing as a result of rising renewables whose production is intermittent



Resources	Application	Discharge Duration	Using Frequency	Response Time
Supply Revenues	Energy Arbitrage	mins-24hrs	0.25-1/day	>1hr
Balancing/Reserve Revenues	Frequency Regulation	1min- 15mins	20-40/day	ms-mins
	Voltage Control	1s-1min	10-100/day	ms-seconds
	Peak Shaving	1min-hours	1-29/day	<15mins
Grid Revenue	Congestion Relief	2hrs-4hrs	0.14-1.25/day	>1hr

Source: BYD

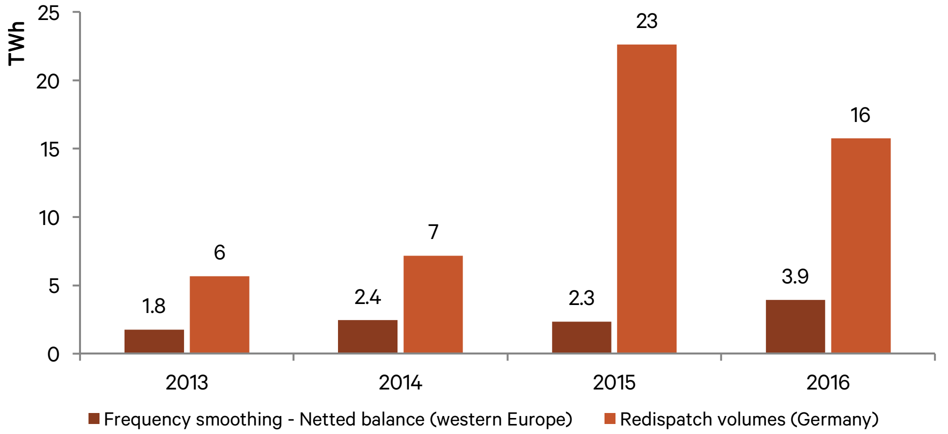
Other services include taking part in pricing arbitrage, providing power into the wholesale market and reducing demand charging for commercial and industrial customers



Source: BSW Solar

As explained earlier, these services represent a substantial and a growing earnings opportunity to micro-grid developers. The following graph shows the rising demand for ancillary services in western Europe – just the UK spends more than £1.2bn on ancillary services per year.

Demand for ancillary services is growing in Europe and in regions with rising share of renewables in the generation mix



Source: Tennet Market Review 2016

3. Micro-grids will evolve into electricity trading platforms through the block-chain technology

We believe that peer-to-peer trading will be enabled through the growth of storage, micro-grids and VPPs. This has already started to happen in Germany where the largest residential battery storage provider, sonnen (private), has initiated a trading programme called sonnenCommunity, which allows households with battery storage to trade electricity with one another.

"Enerchain" for peer-to-peer trading: In our view, the ongoing development of the block-chain and distributed ledger technology, which lowers counterparty risk (through smart contracts), could expedite the transition to electricity trading platforms. Twenty-three utilities, distributed network operators and aggregators in Europe are currently partnered and working together on making peer-to-peer electricity trading in the wholesale market through blockchain possible. These companies are using a block-chain platform called Enerchain, which has been developed by German private software company Ponton. It is expected that companies will begin trading electricity live on the platform by the end of 2017.

RWE, Enel, Innogy, EDF and Iberdrola are working the most on the blockchain technology and are also members of Enerchain. RWE has also been testing the Etherium public blockchain platform.

We think that the same technology will be even more beneficial in allowing household-to-household trading within a micro-grid as the counter-party risk is higher versus electricity trading between utilities. At the same time, it can be used for micro-grid-to-micro-grid electricity trading.

Traditional power grids are under duress due to rising renewables

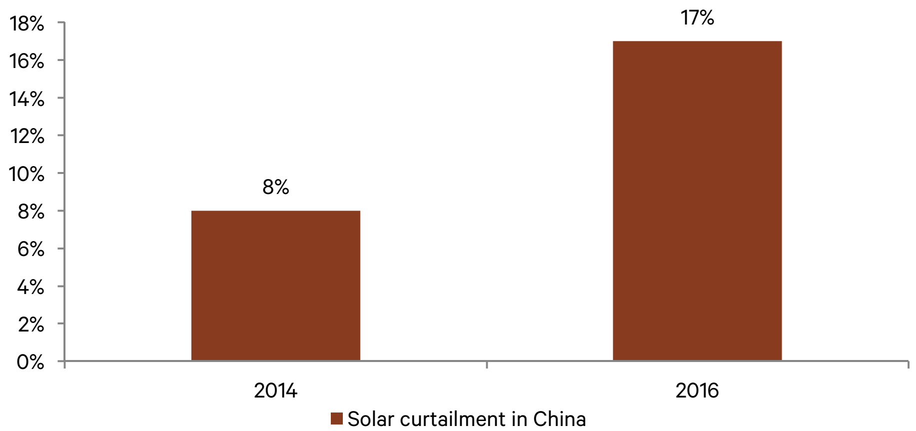
- The need for grid-connected advanced micro-grids is rising as the central grid is failing to cope with rising renewable generation.
- Solar curtailment in China has doubled to 17% in 2017 despite billions of dollars of investment in a ultra high voltage (UHV) transmission network. We expect similar problems to emerge in other countries such as Germany with rising renewable generation.
- Reserve requirements for fossil fuel-based central generation systems to meet the ramp-up requirements in the evening, when electricity demand is high and solar generation low, are rising. Storage, micro-grid and electricity trading can resolve these issues.
- Grid balancing is becoming difficult and demand for ancillary services is doubling.

While historically micro-grids have predominantly existed in island mode, we expect the share of micro-grids connected to the main grid to sharply rise over the next five years. Renewable generation in Europe has already reached those levels where the traditional grid network cannot cope, even in countries where the grid is very strong such as Germany. The following are three clear signs that the centralised grid will be unable to cope with the growth in renewables without massive and, in our view, unnecessary investment to upgrade the central grid and increase fossil fuel generation assets.

1. Solar and wind curtailment is rising

Germany is currently considering curtailing the electricity that can be taken for renewable systems that are larger than 0.5MW when there is excess supply. China, which has experienced rapid growth in solar generation with annual additions of up to 20GW in recent years, is being forced to increase the curtailment on solar electricity that is generated, but not accepted by the centralised grid. The solar curtailment in China has more than doubled from 8% in 2014 to nearly 17% in 2016. Curtailment on solar and wind substantial erodes earnings on renewable projects. We think that localised usage of distributed generation through micro-grids is a must to maintain grid stability.

Solar curtailment has more than doubled in just the last three years. This has a negative impact on earning streams from solar projects whose output is increasingly not accepted by the central grid

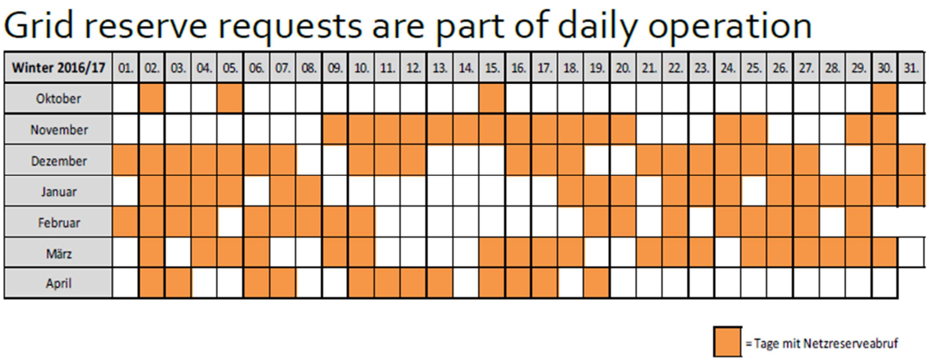


Source: BYD

2. Renewables are increasing demand on centralised fossil fuel generation resources

The inherent intermittent nature of the renewables is increasing the reserve generation requirements from centralised resources. According to the German transmission company Transnet, grid reserve requests rose from less than 50 days in 2010 to more than 290 in 2015. In California, electricity ramp-up requirement from fossil fuel generation is projected to rise by 50GW by 2020 if solar generation keeps increasing.

Growing renewable generation is increasing requirements for electricity generation reserves (powered through fossil fuels) to overcome the inherent intermittent nature of renewables

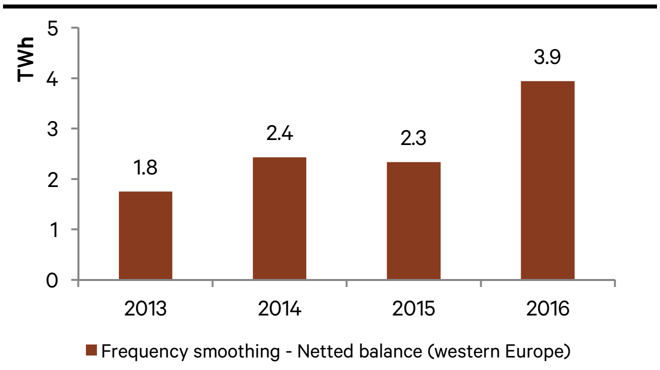


Source: Transnet

3. Ancillary market is growing as renewables are making grid balancing difficult

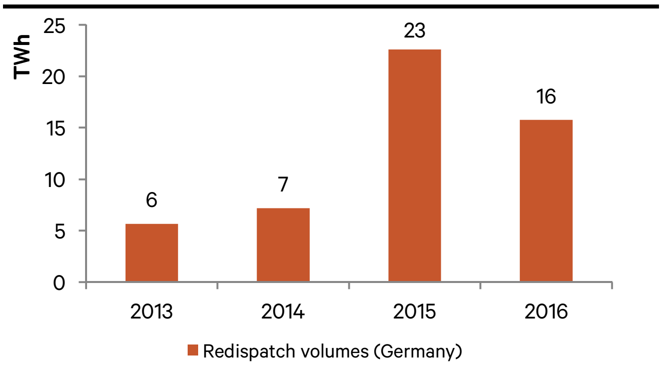
Ancillary services requirements are also rising as a result of growing renewable penetration. The following graph shows that the frequency smoothing requirements in western Europe has doubled from 1.8TWh to 3.9TWh. Re-dispatch volumes, which are required to reduce grid congestion in Germany, rose from 6TWh in 2013 to 16TWh in 2016. This clearly shows that growing renewables are making grid balancing increasingly difficult.

Frequency reserve requirements have more than doubled since 2013 in western Europe



Source: Berenberg estimates

The re-dispatch volumes required to ease grid congestion has risen from 6TWh in 2013 to 16TWh in 2016



Source: Berenberg estimates

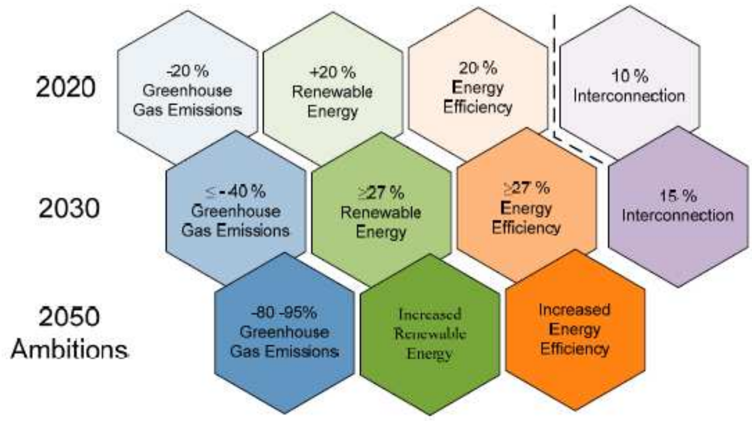
Massive investment in the transmission network required to overcome renewables' geographical mismatch and its rising share in total generation

Another issue is renewables such as wind cannot be put anywhere. For example, Germany is struggling to shift wind generation, which is mainly in the north with the demand centres in the south. This is increasing investment requirements for the transmission network. According to research estimates, nearly €80bn will be required in Germany for upgrading the grid to cope with rising renewables.

These requirements in electric infrastructure spending will be dramatic considering the European Union's aggressive medium and long-term targets for:

- increasing renewable generation and energy efficiency;
- lowering greenhouse emission; and
- increasing grid interconnections.

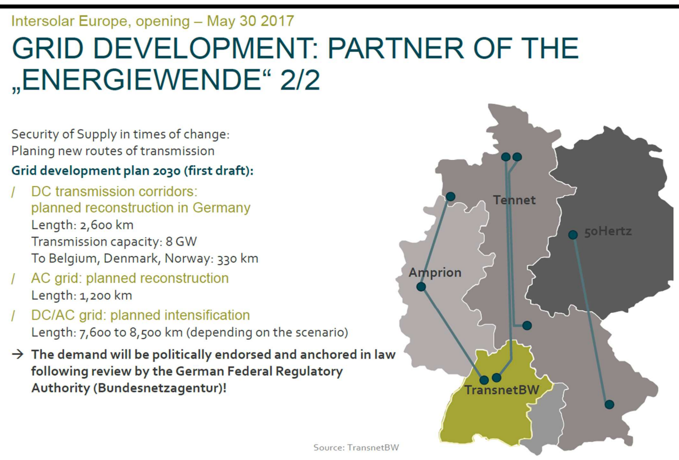
Massive investment in transmission infrastructure will be required to meet the medium and long-term targets for increasing the share of renewables in total electricity generation



EU 2020 and 2030 target for renewable energy technologies penetration with GHG reduction.

Source: "Overview of current micro-grid policies, incentives and barriers in the European Union, United States and China" by Amjad Ali, Wuhua Li and Rashid Hussain, published June 2017

Germany will need to invest massively in its transition network to sustain the energy transition towards renewable. We think that micro-grids are a much cheaper and a more effective alternative



Source: Transnet

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Who wins and who loses? Analysing the micro-grid value chain

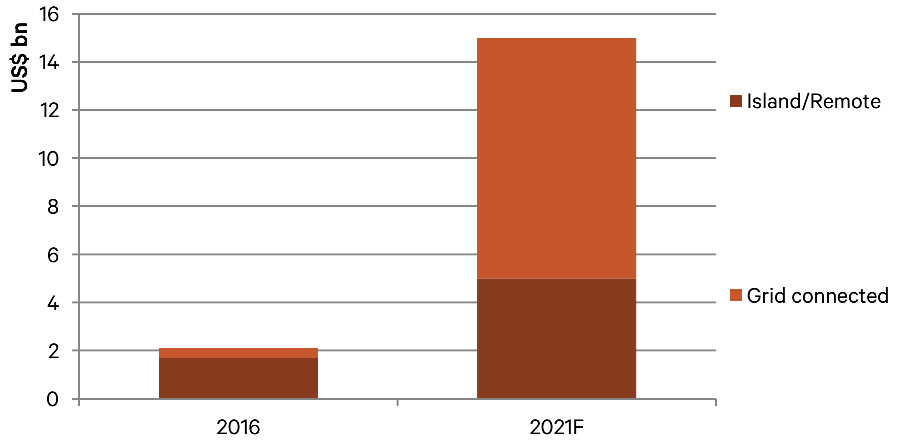
- We project micro-grid installation to increase from the current 19GW to above 100GW by 2021. We estimate that the total market for micro-grid hardware and installation (excluding storage) to be $15bn by 2021 versus $2bn in 2016.
- We also expect central grid-connected advanced micro-grids to be 50% of all micro-grid installations by 2021. This will translate into a market size of $10bn by 2021 versus less than $0.5bn in 2016. We expect the main beneficiaries of this growth to be technologically advanced micro-grid technology providers Siemens, Schneider, ABB and PSI.
- We also expect 30% of all micro-grids by 2021 to incorporate battery storage, which will translate into 30GWh of storage and a market opportunity of $5.4bn by 2021. We think that battery manufacturers such as Tesla and BYD, as well as leading invertor manufacturers such as SMA Solar, which have capacity to offer services on top of just hardware, will benefit.
- Fuel cells adoption in micro-grids is expected to increase, too, as it is the most efficient generation resource – 15% adoption in micro-grids by 2021 translates into a $2.25bn opportunity.

We expect rapid growth in micro-grid adoption over the next five years and expect capacity to easily cross 100GW by 2021 from the current level of 19GW. Assuming an average micro-grid size of 10MW, this translates into 10,000 micro-grid projects globally by 2021. Assuming that the share of grid-connected micro-grids increases to 50% from the 10% currently, this will translate into 5,000 large advanced micro-grid projects. With the cost of hardware, software and installation of micro-grids at ~$2m, this translates into an addressable market size of $10bn by 2021 for grid-connected versus less than $0.5bn currently. The overall micro-grid market including island/remote grids is expected to grow to ~$15bn by 2021 from $2bn in 2016. We think that the advanced grid-connected micro-grid market will be captured predominantly by larger and technologically advanced micro-grid controls suppliers, such as Siemens, Schneider, ABB and GE.

We also think that 30% of all micro-grids will incorporate a battery storage system. Assuming an average size of battery storage at 5MWh (with peak power output at 10MW) for a 10MW micro-grid, we think that the battery storage used in micro-grids will grow to 30GWh. With an average battery system cost of $180/kWh, the market for batteries used in micro-grids should increase to $5.4bn.

As we explained earlier, we think that fuel cells have an important role to play in micro-grids. This is because combined heat and power systems based on fuel cells have at least twice the efficiency versus micro-grids based on conventional diesel and gas turbine-based systems. Assuming 15% of the micro-grids in the future opt for fuel cells and assuming an average size of 5MW and cost of $300/kW, we estimate that the demand for fuel cells used in micro-grids can grow to 7.5GW and a market size of $2.25bn by 2021.

We think that the micro-grid market will grow to ~$15bn by 2021 from the current $2bn. Grid-connected micro-grids could account for $10bn of this market. We think that the larger and technologically advanced micro-grid controls suppliers such as Siemens, Schneider, ABB and GE will dominate this market



Source: Berenberg estimates

We hence identify three sectors and the leading companies within them that are likely to benefit from the growth in micro-grids over the next five years.

1. Micro-grid controller equipment and software providers

The biggest challenge and value addition are the control systems required for the micro-grid. The challenge at the lower level is to manage and coordinate the different generations and storage assets, each of which has different communication standards. At the higher level the challenge is to aggregate these assets, interface with the centralised grid and effectively provide a range of grid-level services. The micro-grids will need to have the forecasting capability to predict loads over the next few hours or days, and optimise how it uses its assets to provide grid services.

On the hardware side, the control systems would includes things such as sensors, meters, processors, servers, switches and breakers. The software side would include things such as algorithms for control logic, load forecasting and human interfaces for the generation assets and to coordinate activities with the grid. What is obvious is that this is highly customised. While there are a number of companies that provide micro-grid controllers, we think that the larger players with strong power electronics expertise, hardware manufacturing capabilities and software offering will be winners in the long term. This is because micro-grids are becoming a lot more complex versus the simple diesel generator-based systems mainly providing back-up power. Micro-grids are increasingly based on multi-generation assets in order to effectively take part in the complex balancing, arbitrage and wholesale grid markets.

Companies with a holistic portfolio offering of micro-grid control (hard ware and software) include Schneider, Siemens, ABB, GE and Mitsubishi. Siemens recently entered into a JV with AES to create Fluence, a utility with the largest exposure to stationary storage and micro-grids. We think that this JV could give an edge to Siemens versus its rivals in growing its micro-grid business over the next five years. In Europe, Siemens, Schneider and ABB are carrying out most of the micro-grid projects and will likely be the main beneficiaries as adoption levels pick up.

Siemens, Schneider, ABB, PSI etc are likely to be the main beneficiaries of the growth in micro-grids

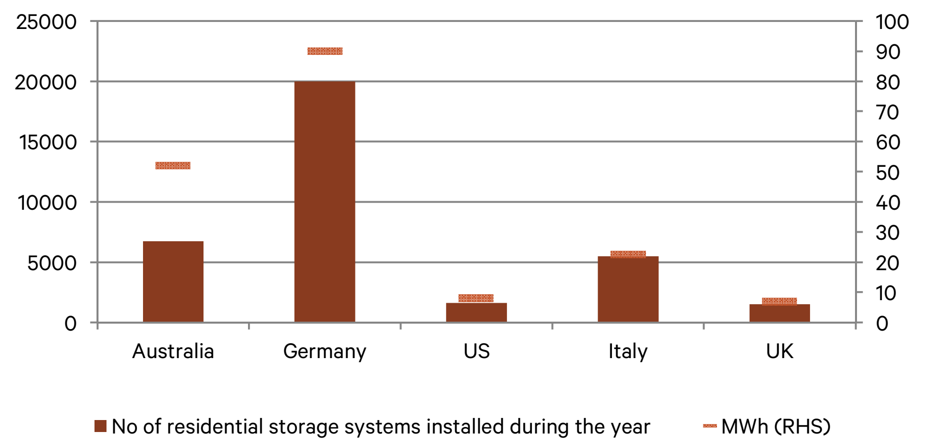
Company Name	Country	Overall score
Siemens	Germany	★★★★★
Schneider	Germany	★★★★
ABB	Switzerland	★★★★
GE	US	★★★
Mitsubishi	Japan	★★★
Power Solutions International (PSI)	Germany	★★★

Source: Berenberg estimates

2. Residential and commercial battery manufacturers moving to virtual utility model

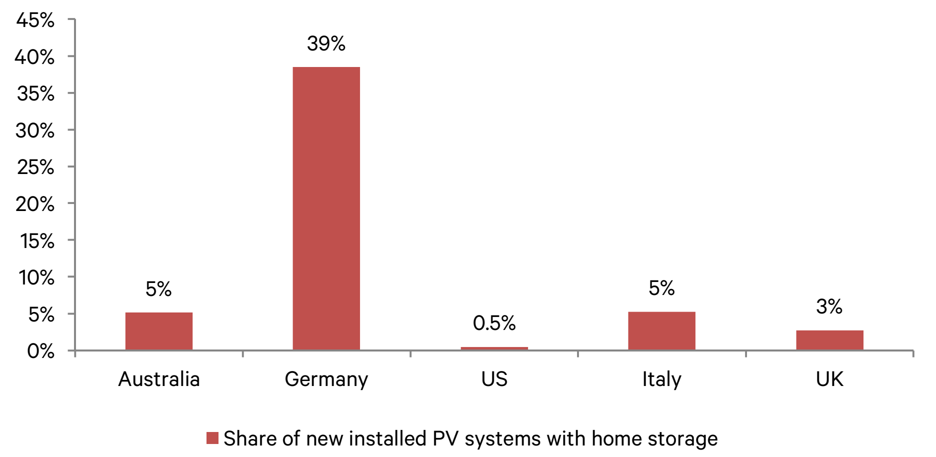
The residential battery storage market is yet to move into the mass market. As can be seen in the graph below, less than 2,000 stationary storage products were sold to households last year. This means that only 0.5% of households that bought a solar panel system bought a storage product with it.

Germany is the most attractive residential storage market followed by Australia and Italy



Source: Berenberg estimates

~6,000 homes in Germany have battery storage with 0.24GWh capacity



Source: Berenberg estimates

There are two reasons why residential battery storage products are failing to gain traction outside of the German market.

- **Net-metering rules:** Most states in the US, apart from California, Hawaii, Maine, Vermont and Washington, have net-metring rules. In Europe, Belgium, the Netherlands, Norway and Sweden have a mixture of net-metering and quota regimes. In countries with net-metering the grid acts as zero/low-cost storage with those with renewables negating the need for batteries.

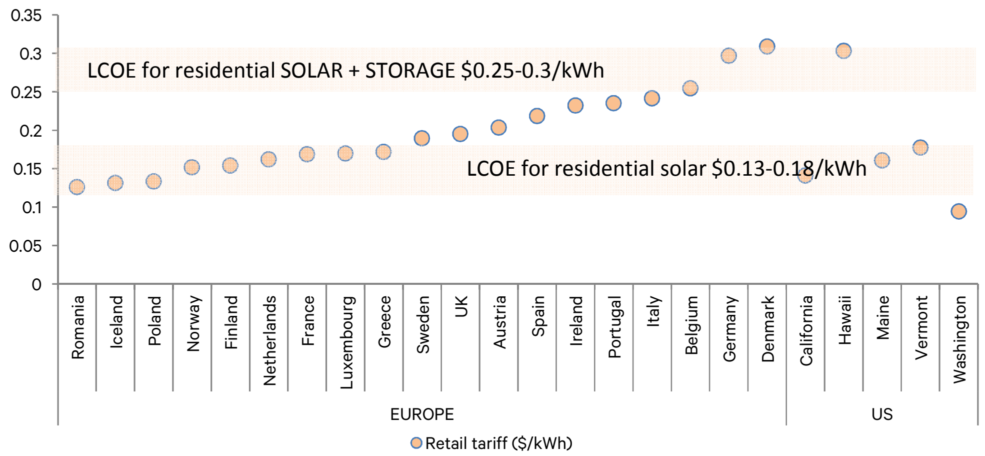
In countries with net-metering rules, residential battery storage does not make any economic sense

FIT	Net metering/Quota
Germany	Belgium
Australia	Netherlands
UK	Norway
Italy	Sweden
France	US - all states except:
Portugal	California
Spain	Hawaii
Switzerland	Maine
Denmark	Vermont
	Washington

Source: Berenberg estimates

- **High residential storage costs:** Currently the cost of residential battery storage varies anywhere between $0.13-0.18/kWh. We estimate that the LCOE for the 14kWh Tesla Powerwall is $0.12/kWh. So overall, the LCOE of the solar plus storage system is between $0.25-0.3/kWh. As can be seen in the following graph, apart from Germany, Denmark and Hawaii in the US, a residential battery system cannot compete with the grid.

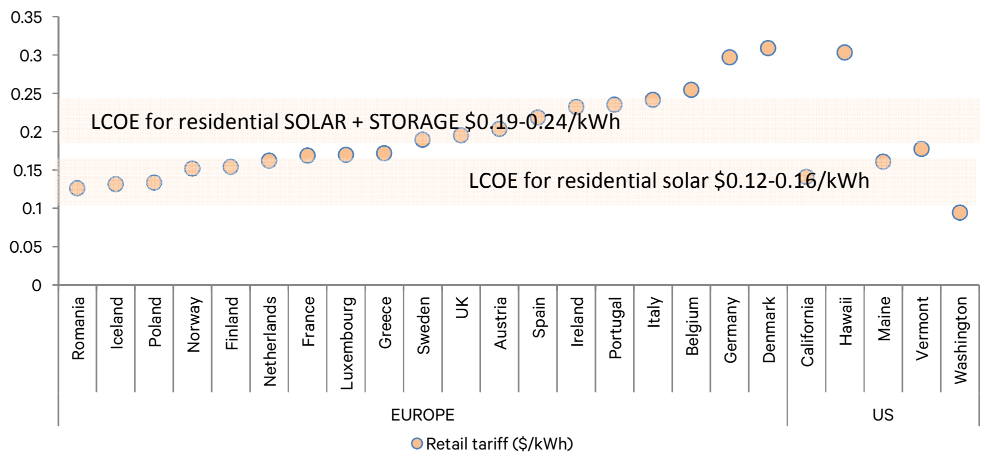
End 2016: residential storage is only competitive in Germany, Denmark and Hawaii



Source: Berenberg estimates

What is interesting to note is that the economic competitiveness of residential battery storage systems does not massively improve over the next five years. Assuming that there is a 40% reduction in the cost of residential battery storage systems, the LCOE of battery storage plus solar will decline to $0.19-0.24/kWh/cycle. As can be seen in the graph below, this will additionally only make solar plus storage competitive in southern European countries, such as Italy, Spain and Portugal, with high solar irradiance and high retail costs of electricity. In northern European countries, including the UK, residential storage will be hardly competitive. In the US the situation will be grimmer, with Hawaii remaining the only state where residential battery storage can be economic.

End 2021: with a 40% reduction in battery costs, solar plus storage will be competitive in Denmark, Germany and southern Europe. In US, this will only be Hawaii



Source: Berenberg estimates

Despite this grim prognosis, we continue to believe there will be rapid growth ahead for residential and commercial storage projects, which together we expect could cross 20GWh by 2021. This is because the aggregation of small-scale storage through micro-grids into a virtual power plant can massively alter their competitiveness. An example of this can be seen with the sonnenFlat VPP, which provides electricity for free to households in Germany, Italy, Austria and Switzerland in exchange for providing sonnen with control over their residential battery system. Sonnen then makes money by aggregating the residential storage assets in the programme to provide grid-level services. For households with solar but lacking a storage system, sonnen provides its storage system for a subsidised cost and then charges a fixed monthly rate, which is lower than the retail tariff of electricity. The attractiveness of the model is clear from its rapid adoption where over the past 12 months the number of households under the sonnenFlat programme in Germany has grown to 6,000 with outstanding orders of more than 10,000 households that want to move onto the programme. Sonnen recently introduced the plan in Australia and aims to sign-up 2,000 households by the end of the year.

We think that residential battery manufacturers such as sonnen that offer more than just hardware will be the winners in the long term. Hardware is commoditised and money is the growing revenue streams the aggregated storage systems as a VPP can provide to the grid. Tesla, too, has a similar exposure through its Solar City, where it has long experience in the operating leasing model for its solar PV system. We think that combining its solar leasing expertise with storage will help it to tap into the grid-balancing market in the future. Other battery manufacturers with similar capabilities would be BYD and to a lesser extent LG Chem.

Sonnen, Tesla, BYD and SMA are likely to benefit

Company Name	Country	Battery storage competitivene	Solar PV offering	Experience with leasing model	Virtual power plant expertise	Electricity trading platform	Overall score
Sonnen	Germany	★★★★		★★★★★	★★★★★	★★★★★	★★★★
Tesla	US	★★★★★	★★★★★	★★★★★	★★★	★	★★★
BYD	Chinese	★★★★★	★★★★★	★★★	★★★	★	★★★
LG Chem	South Korea	★★★★★	★★★★★	★	★★	★	★★
SMA Solar	Germany				★★★★★	★★★★★	★★★

Source: Berenberg estimates

3. Fuel cell manufacturers

While we do not think that fuel cells will ever gain traction in the automotive sector, we think they will have an important role to play in the future of grid-based micro-grids. This is because fuel cells are effective at providing combined power and heating requirements for customers in a micro-grid. As explained earlier, combined heat and power-based micro-grids can achieve efficiencies of above 80% versus 30-40% for a traditional micro-grid. This massively reduces the LCOE of the micro-grid.

While the list of fuel cell companies is expansive, most of them are primarily hydrogen based and targeting the automotive market. Two companies are dominating fuel cells being used in micro-grids: Bloom (private) and Fuel Cell Company (listed). The fuel cells used by both companies are based on solid oxide fuel cell (SOFC) technology, which has a number of drawbacks such as: 1) high operating temperature; 2) high cost; and 3) fragility. An interesting UK company, Ceres Power (listed), is working on commercialising its steel-based SOFC, which are more robust versus SOFC and could potentially be substantially lower cost.

We do not think that the expensive proton exchange membrane (PEM) produced by the likes of Japan's Panasonic and Aisen has a bright future in micro-grids. This is because PEM technology is inherently inflexible as it can only run on hydrogen. Currently Panasonic and Aisen are the two leading companies providing micro heat and electricity generation systems in Japan.

Fuel Cell Company is the leading provider of fuel cells to micro-grids. We think that Ceres' fuel cell technology is best for micro-grids

Company Name	Country	Fuel cell technology	Market share in microgrids	Cost effectiveness of technology	Durability of technology	Technology flexibility in fuel intake	Overall score
Ceres	UK	Steel based SOFC	★	★★★★★	★★★★★	★★★★★	★★★★
Fuel Cell Company	US	SOFC	★★★★	★★★	★★★	★★★★★	★★★
Bloom	US	SOFC	★★★★★	★★★	★★★	★★★★★	★★★
Panasonic	Japan	PEM	★★★	★	★★★★★	★	★★
Aisen Seiki	Japan	PEM	★★★	★	★★★★★	★	★★

Source: Berenberg estimates

Conclusion: We think that storage completely changes the economics and effectiveness of micro-grids and the benefits they can provide to the central grid. Increased adoption is likely over the next five years, which should help make the central grid more flexible and capable of incorporating increasing levels of renewables into the generation mix. This growth provides growth opportunities to numerous companies, especially those linked to advanced micro-control systems, batteries, investors and fuel cells.

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Tesla Motors Inc	6
Ceres Power Holdings plc	2, 3

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Production of the recommendation completed: 02.08.2017, 14:40

Historical price target and rating changes for Siemens AG in the last 12 months

Date	Price target - EUR	Rating	First dissemination GMT	Initiation of coverage
30 September 16	120.00	Buy	2016-10-03 06:56	03 September 15
20 February 17	140.00	Buy	2017-02-21 07:10	

Historical price target and rating changes for Schneider Electric SA in the last 12 months

Date	Price target - EUR	Rating	First dissemination GMT	Initiation of coverage
30 September 16	72.00	Buy	2016-10-03 06:56	03 September 15
20 February 17	76.00	Buy	2017-02-21 07:10	

Historical price target and rating changes for ABB Ltd in the last 12 months

Date	Price target - CHF	Rating	First dissemination GMT	Initiation of coverage
30 September 16	19.00	Sell	2016-10-03 06:56	03 September 15
02 November 16	17.00	Sell	2016-11-03 07:06	
20 February 17	20.00	Sell	2017-02-21 07:10	
05 June 17	21.00	Sell	2017-06-06 06:59	

Historical price target and rating changes for Tesla Motors Inc in the last 12 months

Date	Price target - USD	Rating	First dissemination GMT	Initiation of coverage
21 November 16	193.00	Hold	2016-11-22 06:59	02 February 16
12 June 17	464.00	Buy	2017-06-13 06:59	

Historical price target and rating changes for Ceres Power Holdings plc in the last 12 months

Date	Price target - GBp	Rating	First dissemination GMT	Initiation of coverage
13 July 17	15	Buy	2017-07-14 07:19	13 July 17

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Sell	13.78 %	0.00 %
Hold	38.35 %	22.95 %

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