Thematic Investing

Clean it, Store it, Use it - Energy Storage Primer

Bank of America Merrill Lynch

Thematic Investing

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Energy Storage market $27bn by 2030, $58bn by 2040

The annual battery energy storage (ES) market could grow at 16% 2020-30 CAGR, reaching $27bn by 2030 and $58bn by 2040. We think ES will herald the next major phase in the transition to clean energy, with 50% cost reduction by 2025 vs. 2018 a key catalyst. This will trigger new investments and business models and disrupt the fossil economy over the long term. Renewables help lower emissions, but they need ES to smooth the output and provide on-demand clean energy. Fortunately ES costs are falling, helped by EV battery cost reductions, new products are emerging and adoption is picking up, underpinned by changing policies, attitudes and needs. ES could represent 6% of global power capacity by 2040 and we believe this could be much higher by 2050.

3-way battle on CO2: renewables, storage & electric vehicles

The three interlinked solutions, renewables, energy storage and electric vehicles (EV), are credible ways to materially reduce emissions in electricity+heat and transport, sectors with two-thirds of global emissions. Annual CO2 emissions continue to rise even as we see record extreme weather – Europe's five hottest summers since 1500 have all been in the 21st century, France suffered from all-time highest temperature of c.46°C in 2019. At the current pace, the remaining carbon budget for 1.5 degrees Celsius warming could be exhausted in just c.10 years, posing risks not only to GDP but the planet itself.

Boost to renewables from storage likely underappreciated

2010-20 saw a >70% fall in wind/solar costs, leading to wide adoption. We feel 2020-30 will similarly see a rise in energy storage and electric vehicles, thanks to falling battery costs. ES is a must to materially raise renewable share – 4-6 hour storage would be ideal but even 2-3 hour storage may allow for c.10-15% higher wind + solar share than would otherwise be the case, to >60% by 2050. Fossil share in electricity is expected to decline 30 % points by 2050 already, but ES may facilitate bigger cuts. ES + renewables may even boost EVs via cleaner electricity and bring forward peak oil (2027-2030).

Multiple applications, Green alliance with wind & solar

ES solutions take multiple forms – Renewables+ES, Home ES and Grid ES offer the most promise but there are other use cases like Vehicle to Home (V2H), Vehicle to Grid (V2G) and ES in micro-grids. In 3-5 years, the cost of renewables and 3-hour ES could improve enough to create a green alliance competitive against peak fossil power.

Implications – sub segment exposures and geopolitics

The US seems ahead on ES adoption, followed by Europe while Asia is lagging. Sub-segments that could benefit from ES via higher demand are renewable equipment suppliers, renewable developers, batteries suppliers, battery materials/recycling and electrical equipment suppliers. Fossil power plant suppliers, merchant fossil generators and coal mining will be challenged longer term, although gas seems better placed than coal. ES may even influence geopolitics as renewables + ES negatively impacts regions dependent on coal mining and benefits those with abundant renewables. See Primer Picks report for stocks exposed to energy storage long term.

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Jargon Buster

ES – Energy Storage

KW – Kilowatt (measure of power capacity)

KWh – Kilowatt hour (measure of energy)

MW, GW, TW – Mega, Giga, Tera (increments of 1,000 from KW)

V2G – Vehicle to Grid

V2H – Vehicle to Home

EV – Electric Vehicle

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4 reasons why Energy Storage will win

Energy storage (ES) is set to herald the second major phase in the transition towards clean energy in the 2020s, the first being renewables reaching cost parity with fossil fuels before 2020. The share of wind and solar in power generation is already expected to rise from c10% today to >30% by 2030, but ES could speed this up and lead to a greater share of clean energy as renewables become more reliable with ES. We could see wind and solar's share of electricity demand rise to >60% by 2050 enabled by ES, 10-15% percentage points higher than would otherwise have been possible.

1 Falling EV battery costs to help deliver affordable energy storage

EV battery costs are expected to fall significantly, helped by scale from electric vehicles. Battery packs used in EVs can be used in ES, too (in different configurations), so ES system costs should also fall significantly, increasing affordability. Lithium batteries are expected to be the mainstay in ES/EV (core to our ES theme) but long term, there could be other breakthroughs like graphene capacitors, flow batteries or hydrogen storage.

2 Cheap and abundant wind + solar will require energy storage

Wind and solar are now cheaper than fossil fuels in many locations and costs keep falling. Economics and policy support a faster transition to renewables, and ES fits perfectly with this, thanks to its ability to absorb excess renewables, meet peak demand and stabilise the grids.

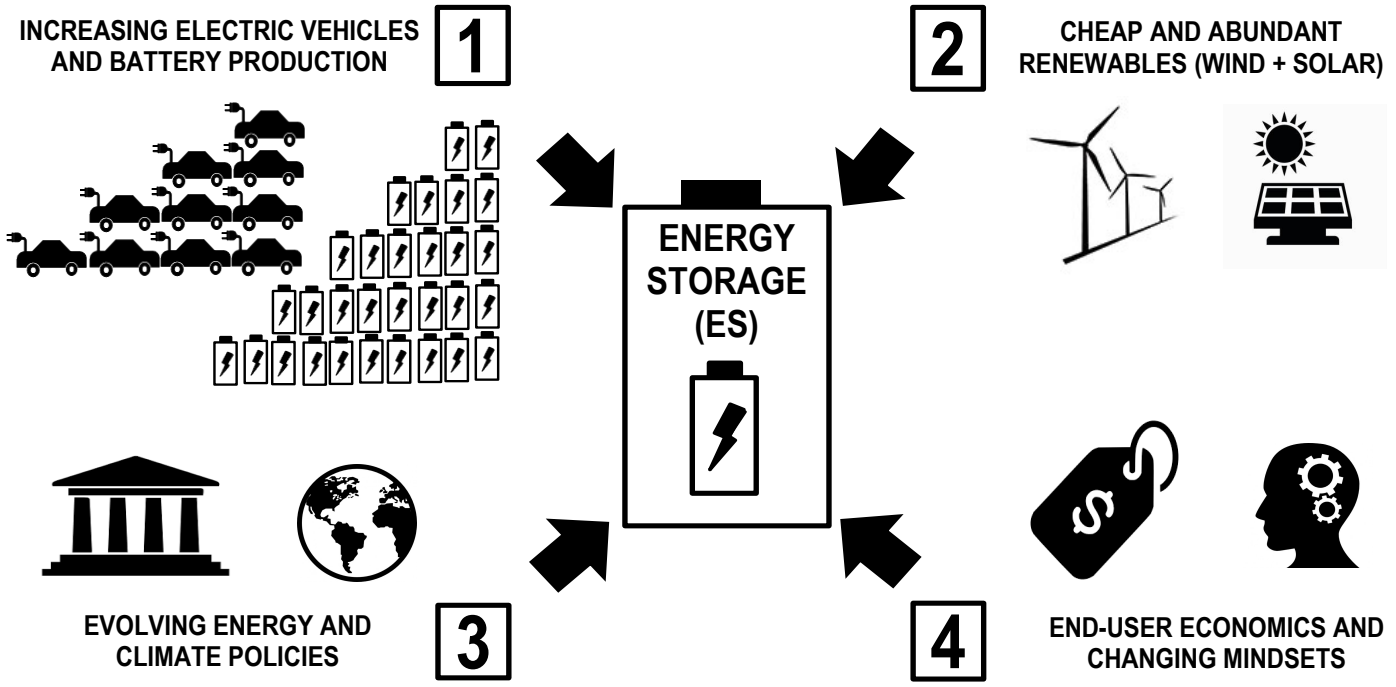
3 Government energy & climate policies to support energy storage

Some US states are embracing ES with long-term targets, allowing ES to bid vs. fossil for peak and approving plans to replace fossil with renewables + ES. Such policies are likely to spread to global markets, especially in regions with a high share of renewables.

4 Economics and consumer/corporate mind-sets to favour energy storage

Household/business consumers can lower their energy bills with ES (especially as system costs fall) and consumers are progressively favouring clean energy and self-generation (good fit with ES). Energy companies are embracing ES over fossil fuels

Exhibit 1: 4 reasons why we believe Energy Storage will win



Source: BofA Merrill Lynch Global Research

Did you know?

- Humans could exhaust the remaining carbon budget that would limit global warming to 1.5 degrees Celsius in just c.10 years (source: IPCC data, carbon budget of 420GtCO2 equivalent in the 66% probability scenario vs. annual emissions of c.42GtCO2 equivalent).

- Global temperatures are already c.1.0 degree Celsius above pre-industrial levels; reaching 1.5 degrees Celsius of warming could increase climate risks such as rising sea levels, loss of ice, loss of biodiversity and increased extreme weather (source: IPCC).

- Europe's five hottest summers since 1500 have all been in the 21st century while France recorded its all-time highest temperature of 45.9 degree Celsius in 2019 (source: BBC).

- The power sector is the largest source of CO2 emissions today, but has the potential to reduce this by three-quarters, with renewables responsible for 25% of all emission reductions (source: IEA World Energy Outlook 2016).

- 87% of countries could power themselves with renewables using less than 5% of their land (source: Green Clean Guide).

- The US needs to cover only 1.4% of its land in solar panels to power itself. The planet needs solar panels to cover only 1.1mn square kilometres to provide enough energy. That is less than the size of South Africa (source: Green Clean Guide).

- The worldwide power sector saw investment fall 1% in 2018, while energy storage investment increased 45% in 2018 to US$4bn (source: IEA 2019).

- Multiple US states have already announced targets for energy storage (e.g. California 1.8GW by 2020, New York 3.0GW by 2030, New Jersey 2.0GW by 2030).

- Some US utilities already proposed replacing old coal/gas plants with large batteries (Florida 409MW, Colorado 275MW) combined with wind/solar.

- Tesla plans a 250MW/650 MWh "Virtual Power Plant" or VPP in South Australia by installing 50,000 home batteries and rooftop solar to ease pressure on the grid (source: Bloomberg).

- Renewables + ES can already be competitive in locations with good renewable resources and high peak power prices (source: BofAML Global Research).

- Energy storage could add 10% to global EV battery demand according to our analysis (source: BofAML Global Research)

- In 2019, the UK went without coal power for a week for the first time in 137 years ever since the first plant was opened in the Victorian age (source: Guardian). This indicates that powering a country without coal is possible, unlike before (In 2006, UK got 38% of its electricity from coal as per data from UK's National Grid).

- Global battery production capacity is expected to reach almost 1000GWh by 2023 according to announced projects as of mid-2019, c.4-5x higher than in 2018/19 (Source: Cleantechnica.com)

Can Energy Storage help save the planet?

Climate metrics are worsening

Temperatures continue to rise globally, 1.5 degree warming by 2030-50

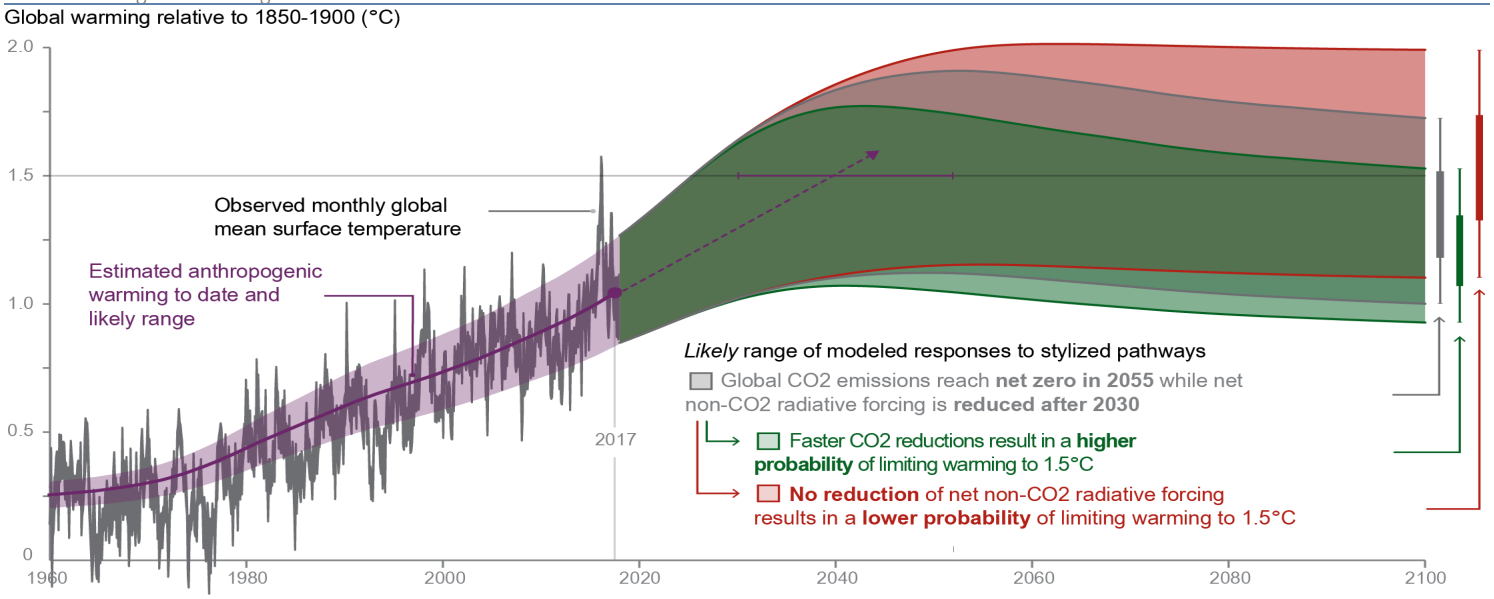
Human activity is estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C, according to a major 2018 report from the UN's Intergovernmental Panel on Climate Change (IPCC). If temperatures keep rising at current rates, global warming could hit 1.5°C between 2030 and 2052. This poses a threat to our planet (rising sea levels, loss of biodiversity, etc.), not just the global economy. Land (vs. oceans) and some regions (Arctic) are likely to experience much higher temperature increases (2-3x the average).

ES can help smooth renewables output, facilitating greater adoption

So emissions must be kept down and renewable energy generation has a central role to play, but it has been unreliable to date. This is where energy storage comes in: it can smooth renewable generation and meet a significant portion of peak demand during a year, lessening the reliance on fossil fuels. Furthermore, power grids may not cope with the intermittency from renewables in locations with high penetration (e.g. California, Germany), making the installation of energy storage unavoidable within the five years.

Exhibit 2: Even with extreme net zero emissions by 2040, there is a positive probability of surpassing 1.5°C warming

IPCC modelled global warming scenarios



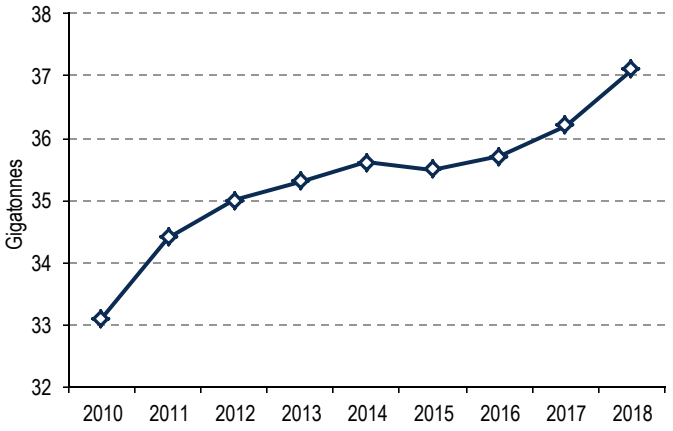
Source: IPCC 2018 (Intergovernmental Panel on Climate Change)

Annual emissions still rising, atmospheric CO2 concentration already too high

Despite the observed and forecast increases in temperatures by agencies like the IPCC, global CO2 emissions are still rising (esp. in 2017-18) and CO2 concentration in the atmosphere recently crossed the critical 400 parts per million (ppm) threshold.

Chart 1: Global carbon emissions continue to rise

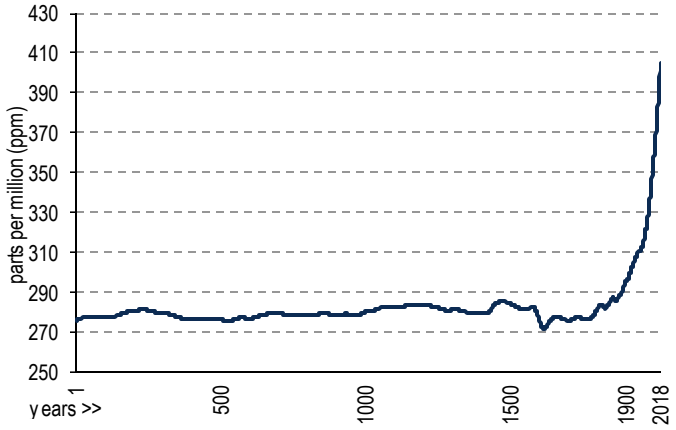
CO2 emissions on the rise in 2017-18 after stabilising in 2014-16



Source: Data from Global Carbon Project, Graphic from BofAML Global Research

Chart 2: Atmospheric CO2 concentration - the wrong kinda bull market

Atmospheric CO2 concentrations continue to rise unabated



Source: Data from NOAA (National Oceanic and Atmospheric Administration), Graphic from BofAML Global Research

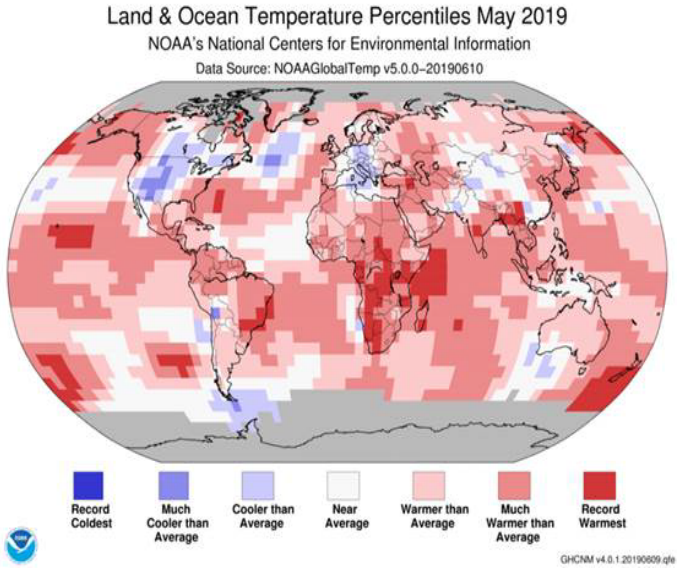
Material impact from 1.5-2.0 degrees Celsius warming

In its 2018 report, the IPPC highlighted multiple impacts from 1.5 degrees Celsius warming such as loss of ice, rising sea levels, extreme weather (heatwaves, storms, heavy precipitation), loss of biodiversity and loss of coral reefs. Together, these would endanger human life, not just the global economy. The impacts would be even worse if it global warming reached 2.0°C vs. the IPCCs 1.5°C central scenario.

Exhibit 3: Climate Risks, Extreme Events, and Related in Impacts in 2018

Source: World Meteorological Organization 2019

Exhibit 4: Land & Ocean Temperature Percentiles as at May 2019

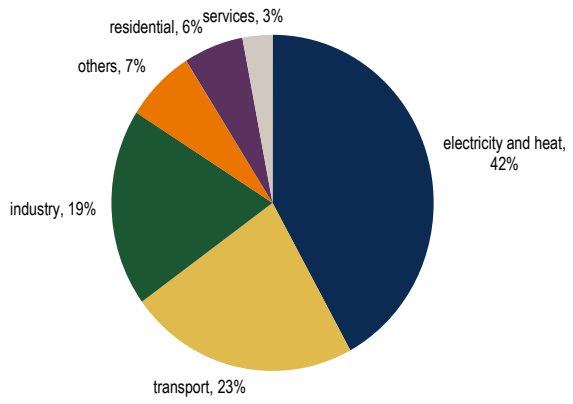


Source: NOAA 2019

Reducing electricity & transport emissions is critical

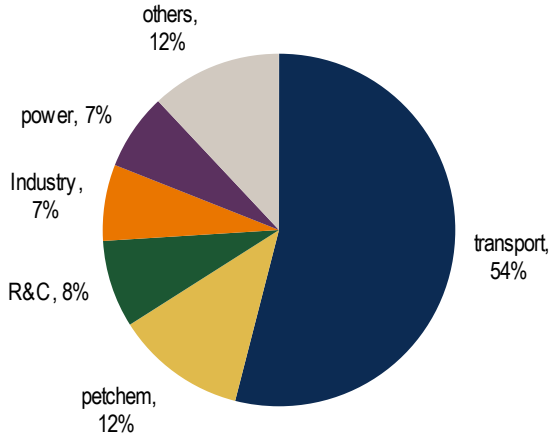
The electricity+heat and transport sectors represent almost two-thirds of global emissions, so reducing emissions from these sectors is vital. According to the IPCC data, the planet has a total remaining carbon budget of 420GtCO2eq (eq = equivalent) to limit warming to 1.5°C (with a 66% probability), while we run-rate c.42GtCO2eq emissions a year now. At the current rate, we have only around 10 years before this emissions budget is depleted. Reducing emissions drastically is the only way to "buy time".

Exhibit 5: Global emissions by sector



Source: IEA 2016

Exhibit 6: Global oil consumption by sector



Source: IEA 2015

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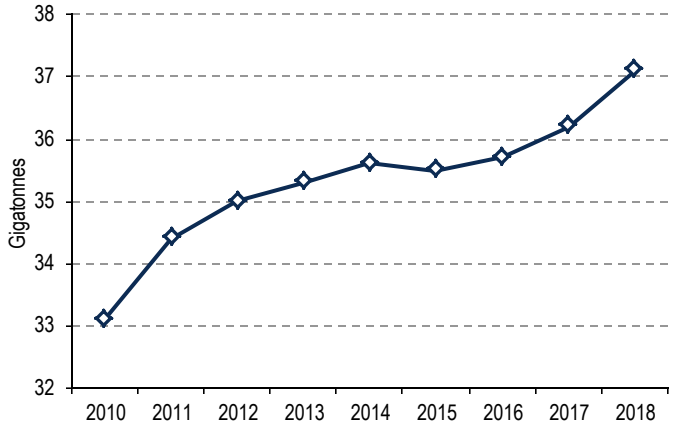

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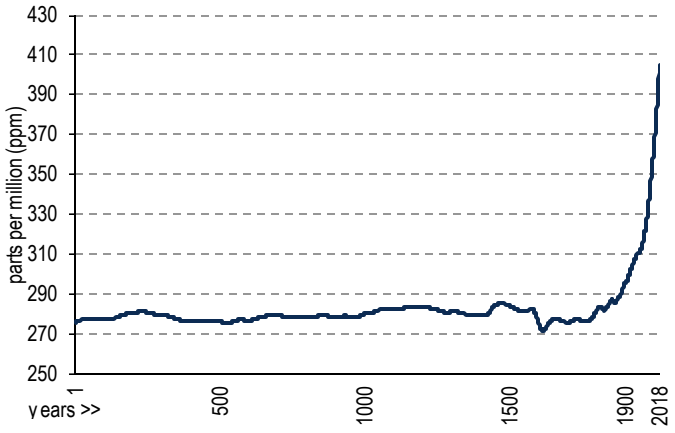


Source: Data from NOAA (National Oceanic and Atmospheric Administration), Graphic from BofAML Global Research

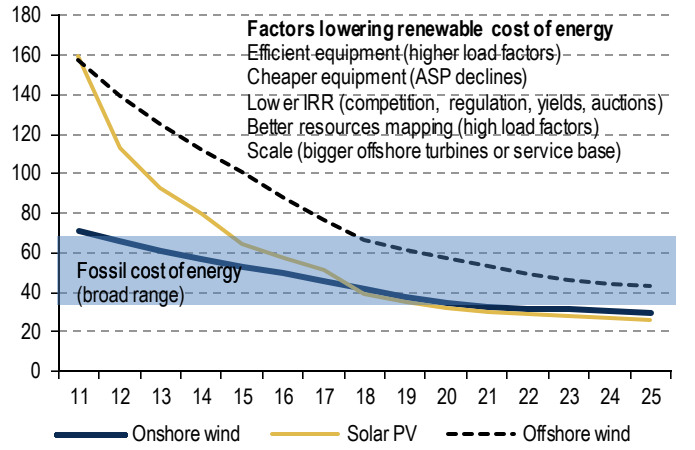
Renewables are now inexpensive but can be unreliable

After dramatic cost reductions in the last decade, new renewable energy is now at parity with, or cheaper than, fossil fuels in most global regions and costs are expected to fall further. The key renewable energy options are onshore wind, solar PV and offshore wind globally, but all have problems such as intermittency (not always available), lack of dispatchability (cannot be called upon on demand) and excesses (producing too much during times of low demand).

Energy storage makes renewables more reliable

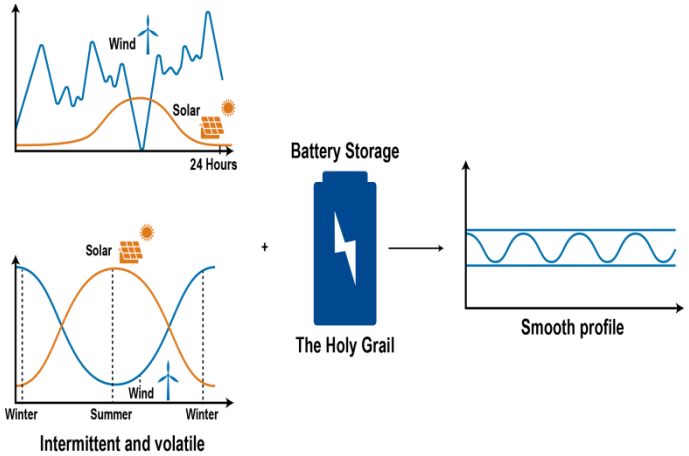
Despite progress, the share of wind and solar in total electricity generation is still low (c10% globally, 20-25% in some leading regions). To date, old fossil plants have been relied upon for back-up. But as the share of renewables rises significantly over the next decade (up to 30 percentage points in some regions) and older fossil plants are simultaneously shut down, energy storage will be needed to handle the variability of renewables. Battery energy storage cannot be used for seasonal variations (summer to winter) or for prolonged periods of imbalance (e.g. two weeks of no wind or extreme cold winters), so some fossil back-up will always be required, especially gas. However, energy storage in its various forms (Home ES, Grid ES, Renewables+ES etc.) can help smooth renewable generation and meet a significant portion of peak demand during a year, lessening the reliance on fossil fuel electricity.

Chart 5: Renewable costs falling rapidly & heading below fossil pre 2020



Source: BofAML Global Research, LCOE is levelised cost of energy

Exhibit 7: Battery storage smoothes the energy availability profile



Source: BofA Merrill Lynch Global Research

Harder to cut emissions without Energy Storage

Step changes in renewable generation are the only way to reduce annual carbon emissions, which have continued to rise in recent years. Some regions, like Germany and California, are targeting 60-65% renewable generation by 2030, up from c.35% today. In addition, electric vehicles are expected to increase demand for electricity longer term. We believe that without energy storage, materially increasing the share of renewable energy in electricity generation would not be feasible unless there were significant investment in new back-up fossil generation, which would be counterproductive for emissions. Gas would still have a role to play, however, even with energy storage.

ES technology/costs coming together, helped by EVs

The electric vehicle (EV) revolution has helped bring down the costs of lithium batteries dramatically: average prices have fallen 80% since 2010. This is also helping energy storage, as the EV batteries can be used for ES and big battery suppliers now also offer energy storage products. After some early successes (e.g. Australia 100MW battery), we think ES technology is ready to be scaled up, which should bring down costs. Global battery supply capacity is key to ES being adopted more widely, in our view, and there could be further technology breakthroughs even if Lithium batteries are the mainstay for now (e.g. graphene-based ultra-capacitors, flow batteries or hydrogen).

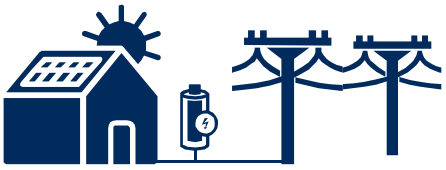
Many different forms of Energy Storage

We believe there will be multiple types of energy storage systems and solutions in future. Some of these are already available or being piloted today (e.g. Home ES, Grid ES and Renewables + ES) while others are likely evolve over the mid-term (e.g. V2G or V2H). Many use-cases for ES mean a bigger overall market, in turn enabling greater scale and cost reduction, and even more adoption.

Exhibit 8: MULTIPLE TYPES OF ENERGY STORAGE

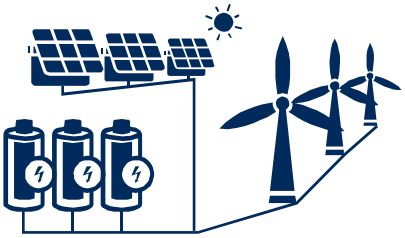
1 HOME ES

Easy to deploy & predictable patterns. Helps increase self-generation with solar. Economics make sense with high power prices & good solar but cost improvement to open new markets.



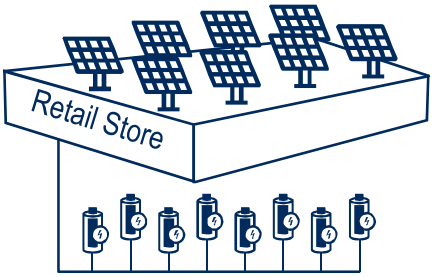
2 GRID RENEWABLES + ES

Smooth energy flows from wind/solar, can meet some peak demand. Economics work if ES cost 20-40% lower, pilot & big projects starting



3 ES FOR BUSINESSES

Helps enhance the solar self-generation model for businesses. Also provide back-up and price certainty as well as help meet climate goals.

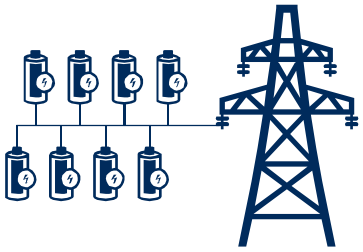


4 VEHICLE TO GRID & HOME

Electric vehicles connected to grid to can provide grid services, needs aggregation of thousands of EVs but some challenges (warranty, incentive)

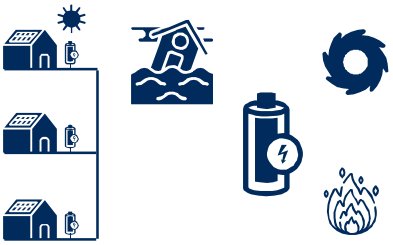
5 GRID ES (SERVICES, PEAKERS)

Batteries good at grid services like short duration frequency management vs. fossil. Ability to absorb excess renewables to meet peak demand.



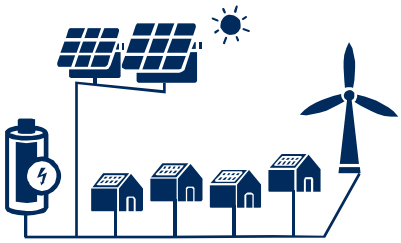
6 DISTRIBUTED ES, BACK-UP

Thousands of distributed batteries could act as a giant centrally controlled battery and provide flexibility as well as back-up during natural disasters



7 ES IN MICRO GRIDS

ES can help create micro grids with solar and wind, providing energy to remote areas or specific sites.

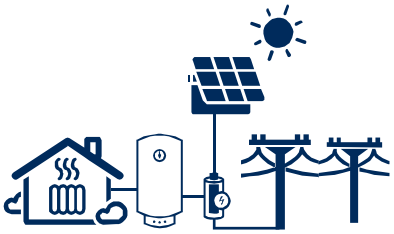


8 ES FOR EV CHARGING

ES can be used to charge EVs with solar self-generation and expand charging infrastructure at lower costs

9 ES IN ELECTRIC HEATING

ES could be used for heating in the future, either combined with self-generation or off-peak power



Source: BofA Merrill Lynch Global Research

10 Implications from Energy Storage

1. Much higher share of wind and solar with energy storage (vs. without ES)
Pace of wind and solar installations can be higher with energy storage vs. without, due to reduced intermittency and dispatchable clean power at economical rates vs. fossil.

2. Quicker reduction in fossil generation, especially coal
ES in combination with renewables will enable a quicker pace of fossil shutdown or usage reduction, much more than would have been possible with renewables alone. Gas would still be needed in specific situations (Germany, China, US) and be a bridge fuel for the next decade before ES becomes mainstream. Coal more at risk from ES, we believe.

3. Some countries & regions reaching 80%+ renewables as early as 2030
Some of the leading regions could see very high penetration of renewables by 2030 (>80%) enabled by ES and falling costs for both, for e.g. some US states & EU countries.

4. 10% boost to battery demand from ES (on top of ramp up from EVs)
Energy storage could add 10% to global EV battery demand, providing more scale and cost reduction opportunity. The ES market could have >$30bn pa revenues by 2030.

5. Economic decline in regions with coal mining & gas exploration
Regions heavily reliant on coal mining and gas exploration are likely to see secular decline in economic growth, unless they diversify into other activities.

6. Need for software and platforms to manage complex power arbitrage
The integration of ES with grids, homes, vehicles and renewables would be complex and will require advanced software to manage power arbitrage and enable smart solutions.

7. Shift in energy intensive operations to regions with renewable power
Energy intensive industries could shift to regions with high renewable resources, with intermittency taken care of by ES (e.g. data centres are in such regions already).

8. Heating starting to be converted to electric helped by excess renewables
With ES enabling greater renewable generation, the possibility of electrifying heating to some extent also opens up (heat water during times of excess renewables).

9. Development of ES value chain to tap into large market potential
ES value chain develops to tap into a large and growing global market, ranging from batteries, systems and construction to software, energy supply solutions and services.

10. Global geo-politics shift due to changing energy landscape
Global and local geo-politics could start to change as regions become more energy self-reliant helped by Renewables+ES and rely less on fossil energy flows.

The Clean Energy Decades: 2020-30 Clean Energy Part Deux

This first major phase in clean energy was the rise of wind and solar. We think the next phase for clean energy would be the rise of energy storage and electric vehicles.

1990-2000: First real awareness about Climate Change with world leaders acknowledging problem in the 1992 Kyoto Protocol agreement. Policy still weak and only some countries invest in renewables by end of decade (e.g. Germany, Spain).

2000-2010 Many countries initiate renewable subsidies which kick starts the wind and solar industry worldwide. Scale keeps improving and important milestones like the EU's flagship carbon trading scheme but 2008 financial crisis a setback.

2010-2020 Scale, competition, investments, innovation and maturing supply chain lead to dramatic reduction of wind/solar cost of energy, falling below fossil pre-2020.

2020-2030 With wind/solar already cheaper than fossil, the next leg in clean energy is rise of energy storage and electric vehicles in 2020-30 (EVs help reduce ES costs).

2030-2040 Decade that may see clean energy boom with major replacements of fossil fuels due to trifecta impact from renewables, energy storage and electric vehicles.

2040-2050 Humans activities (including transport) potentially powered >60% by wind & solar and >75% including all renewables (e.g. hydro, waste to energy).

Table 1: CLEAN ENERGY THROUGH THE DECADES

	1990-2000	2000-2010	2010-2020	2020-2030	2030-2040	2040-2050
ERA	**CLIMATE AWARENESS**	**RENEWABLE SUBSIDIES**	**RENEWABLE COST PARITY**	**RISE OF ENERGY STORAGE & ELECTRIC VEHICLES**	**CLEAN ENERGY BOOM**	**HUMAN ACTIVITY FUELLED MAJORITY BY CLEAN ENERGY**
Key Event	Kyoto Protocol international agreement on Climate Change in 1992	EU ETS (emission trading system) starts on 1 January 2005	Paris Agreement in late 2015 to limit greenhouse emissions	Much higher targets for clean energy?	Fossil electricity bans?	ICE bans?
Technology	Wind	Wind, Solar	Wind, Solar	Energy Storage, Electric Vehicles	Vehicle to Grid?	Hydrogen?
Highlights	Acknowledging climate change	Government support to reduce costs for clean energy technologies	Renewable costs fall significantly but early days for energy storage and electric vehicles	Renewables boom given cheapest electricity source. Energy storage and electric vehicles gain share.	Further cost reductions pushing strong adoption of renewables, energy storage and EVs	>60% electricity from wind & solar by 2050, vehicle fleet almost fully electric worldwide ?
Global Temperature Anomalies (Degree Celsius)*	1999-00 average 0.41 2000 average 0.42	2000-10 average 0.58 2010 average 0.70	2011-19 average 0.78 2018/19 average 0.87	2020-30 average 1.25 ? 2030 average 1.50 ?	2030-40 average >1.50 ? 2040 average >1.50 ?	2040-50 average 2.0 ? 2050 average >2.0 ?

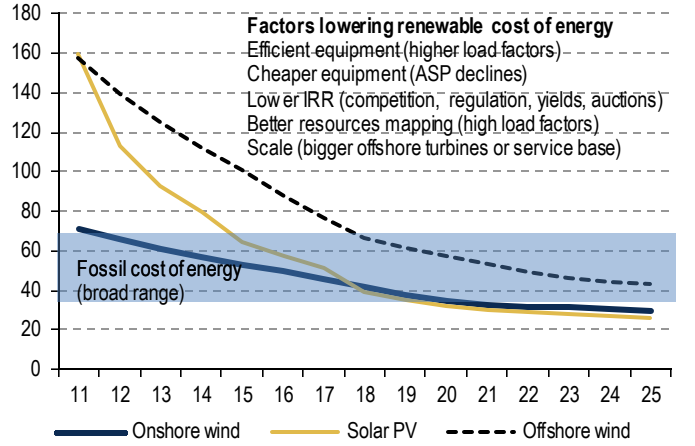
Source: BofA Merrill Lynch Global Research, * Global land and ocean temperature anomalies vs. 20th century average as per data from the NAOO (National Oceanic and Atmospheric Administration, USA)

The unstoppable rise of Energy Storage

As renewable share rises, storage is unavoidable

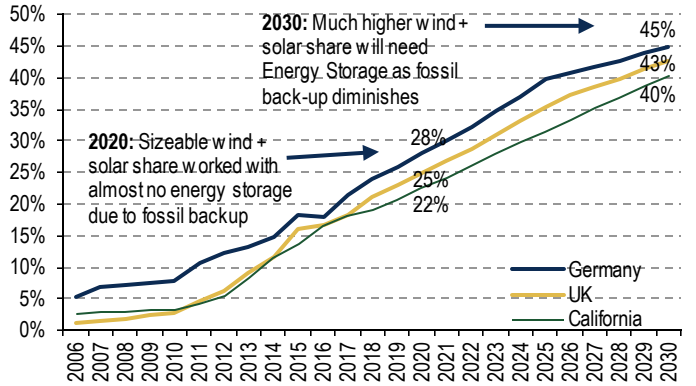
Energy storage will have to be deployed due to increasing share of renewable energy. Regions with already high renewable penetration like Germany, the UK and California could see their share of wind+solar jump from c.20-25% towards higher 2030 targets of 40-50% (ex hydro or other renewables). The share of wind+solar could be even more during certain hours, even exceeding demand. At such levels, grids may not cope with intermittency, making the installation of energy storage unavoidable within 5-10 years.

Chart 6: Renewable costs falling rapidly & heading below fossil pre 2020



Source: BofAML Global Research, LCOE is levelised cost of energy

Chart 7: Wind + Solar share likely to rise to very high levels in some regions, making Energy Storage unavoidable

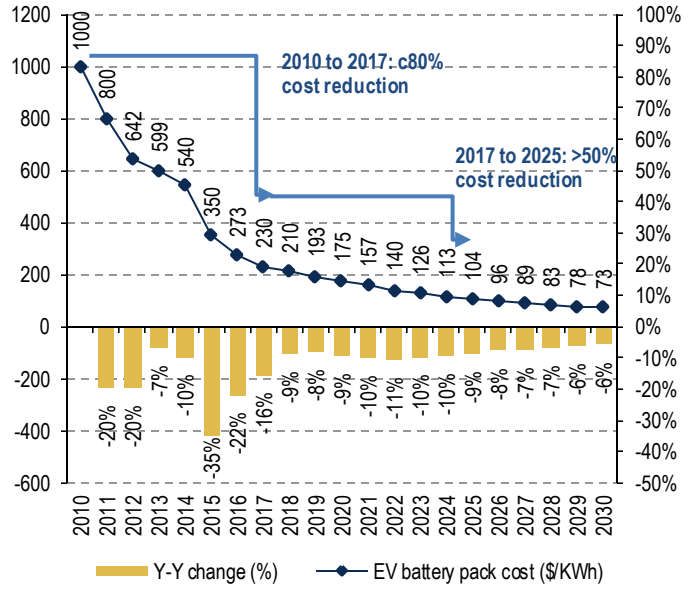


Source: BofA Merrill Lynch Global Research

Falling battery cost & improving economics drive adoption

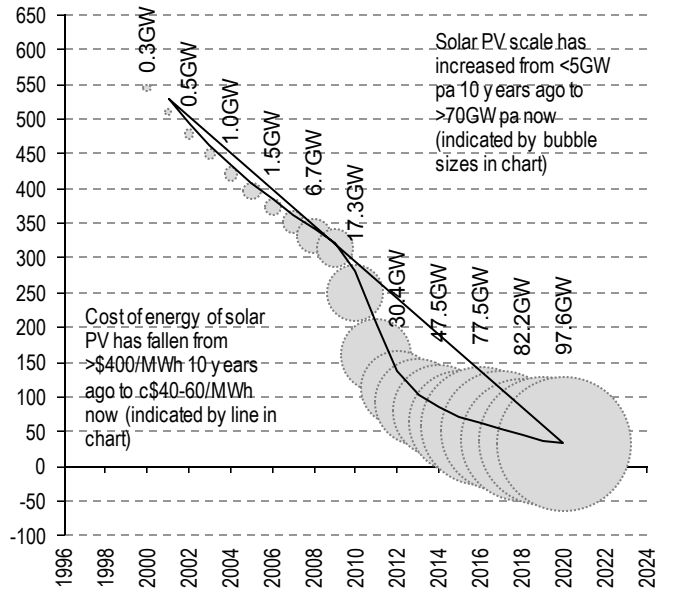
Battery costs are falling rapidly due to the electric vehicle revolution. Thus, the cost of energy storage, including other non-battery equipment, is set to fall, too. The pattern could be similar to cost trends for wind/solar over the last decade. As ES costs fall, the economics of energy storage + renewables start to look attractive vs. fossil generation.

Chart 8: Falling EV battery costs to help Energy Storage cost reduction



Source: BNEF, BofAML Global Research

Chart 9: Solar PV example: Increasing scale vs. reducing cost of energy



Source: BofAML Global Research, NB: BofAML cost of energy approximations for locations with good resources

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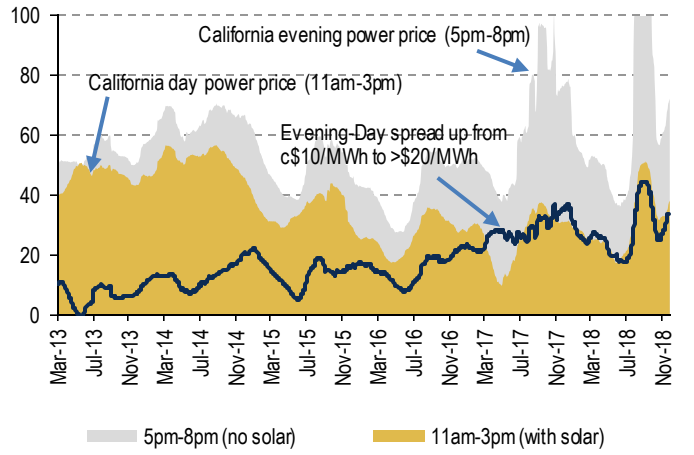
Power price spreads to compel renewables to add storage

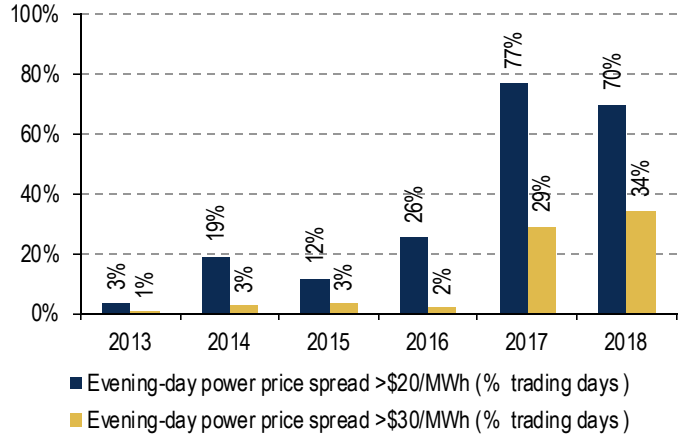
As renewable share rises, particularly in high penetration regions like Germany and California, the power price spread between off-peak (low demand) and peak (high demand) periods is widening. The situation will get worse as renewable share is set to rise in many power systems worldwide. This peak-base spread provides an opportunity for energy storage to arbitrage prices while the same ES systems can provide essential services such as absorbing excess renewables and grid frequency management.

Chart 10: In California, power price spreads for evening (no solar) and day (with solar) widened from c$10/MWh in 2013 to >$20/MWh in 2018



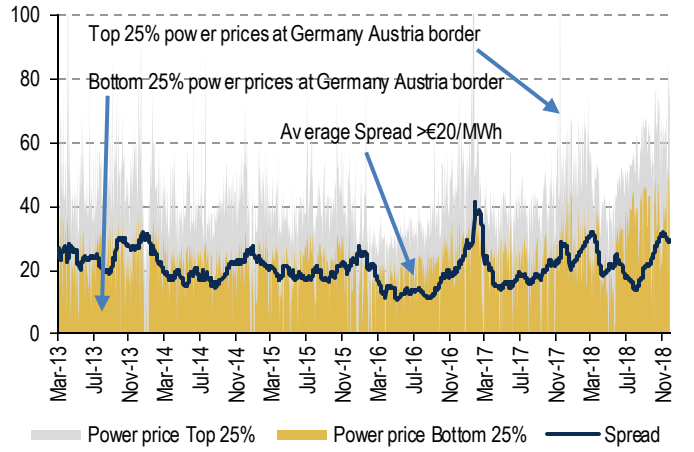
Source: Bloomberg Data, BofAML Global Research analysis, NB: 60-day moving averages shown for smoother trend, evening-day spread data filtered to leave out extremes (>+$75/MWh or <-$20/MWh)

Chart 11: Sizeable share of trading days have >$20/MWh power price spreads between evenings and days in key California power zones



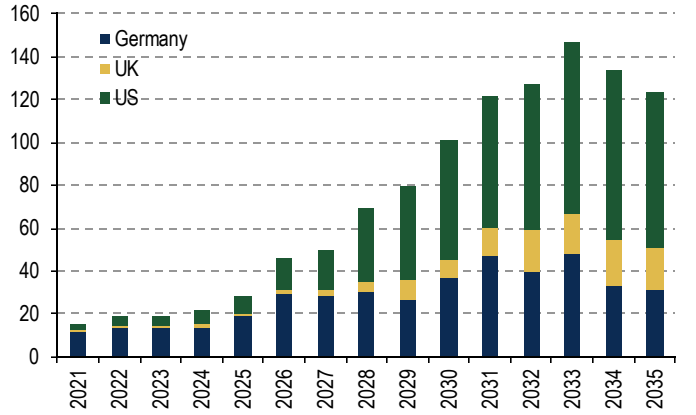
Source: CAISO data from Bloomberg, analysis & graphic from BofAML Merrill Lynch Global Research

Chart 12: >€20/MWh spread between Top & Bottom 25% power prices at Germany-Austria border suggests opportunities to use Energy Storage



Source: Data from Bloomberg, analysis & chart from BofAML Global Research

Chart 13: Daily renewable output (GWh) coming off fixed contracts in key renewable markets represents a big market for Energy Storage



Source: BofA Merrill Lynch Global Research

Older renewables coming off subsidies need storage

A sizeable proportion of older renewables are coming off subsidies or fixed price contractual periods already from 2021 – such projects in Germany, the UK and California alone could amount to 20GWh energy storage by 2021 (relative to the 2-3GWh energy storage market in 2018) and demand could be >7x greater by 2033 (see Chart 13). These older projects not only face a step down from fixed tariffs but also risk achieving below-average prices as typically more renewable generation depresses spot prices (i.e. generating during excesses). To limit the impact from poor pricing, older renewable

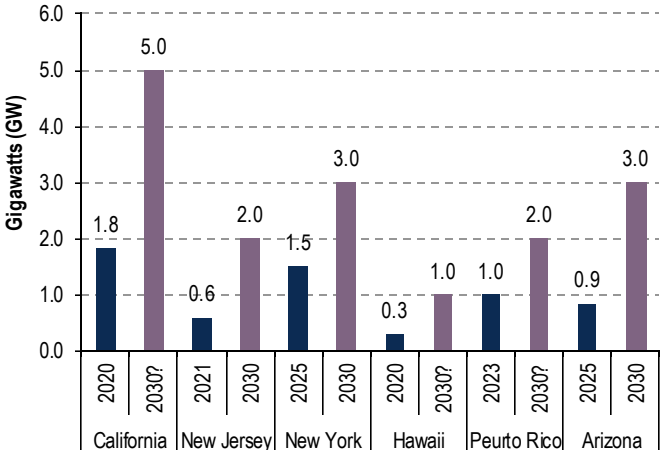
projects will try to sign new corporate agreements but, importantly, we think such projects are more likely to embrace ES quickly (ahead other types such as Home ES).

Policy & utility strategy moving towards energy storage

Policy is starting to shift towards supporting energy storage in some locations. US states are leading the efforts, with at least c.10GW of energy storage projects expected by 2030 as of today (e.g. California, New Jersey, New York, Arizona). But we think the targets and actual ES volumes by 2030 in US states will be much higher as costs come down for both renewables & battery systems, as excess renewable generation increases and clean energy targets are implemented. Australia (grid issues), Germany/UK (high renewable share) and Asian countries (China/Korea, local battery suppliers) will also look at installing ES. Utilities and renewable developers are investing in ES projects – some are large (100Mw+) while others are pilots (20-50MW). We expect more regions and energy companies to focus on energy storage policies, targets, strategies and plans.

Chart 14: US states are starting to announce Energy Storage targets

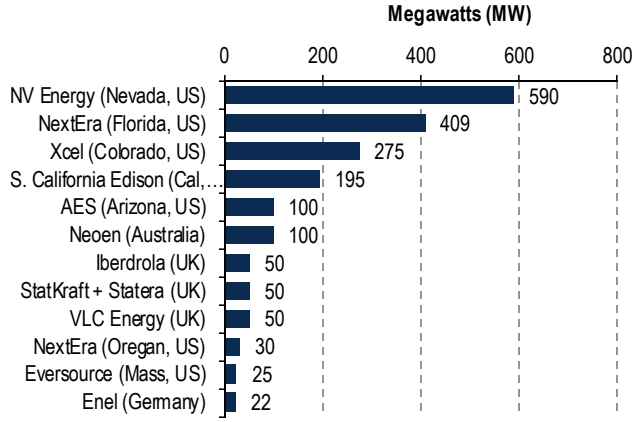
Targets vary by year and state while not many have long term 2030 targets yet



Source: BofA Merrill Lynch Global Research

Chart 15: Utilities looking to build energy storage projects

Announced or completed energy storage projects vary from large to pilots

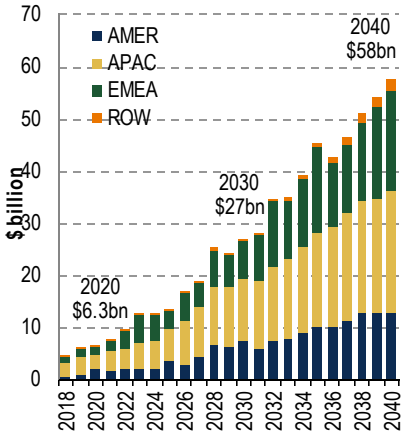


Source: BofA Merrill Lynch Global Research

Market: $2.5bn 2017 to 27bn 2030, 50% cost reduction

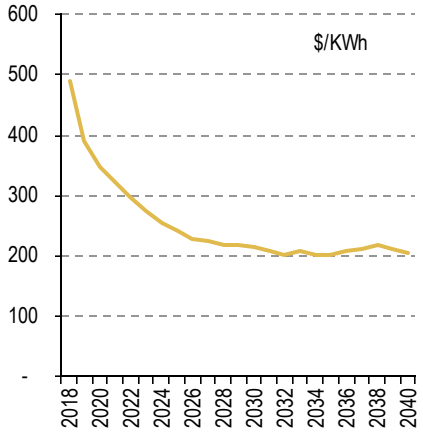
BNEF forecasts the ES market to grow to $27bn pa by 2030 from c$2.5bn in 2017, a 10x increase over the period. As per BNEF's data, average price of ES falls from c$500/KWh in 2018 to <$250/KWh by 2025, i.e. 50% cost improvement. We see huge potential for investments and new business models in ES, including services & software. The winners in ES could have multi-billion dollar businesses already before 2030.

Chart 16: ES market size $bn pa



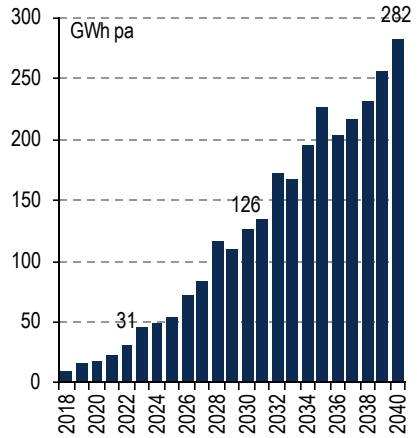
Source: BNEF 2018 data, Chart by BofAML Global Research

Chart 17: ES average implied $ price per KWh



Source: BNEF 2018 data, Chart by BofAML Global Research

Chart 18: ES market size in GWh volumes



Source: BNEF 2018 data, Chart by BofAML Global Research

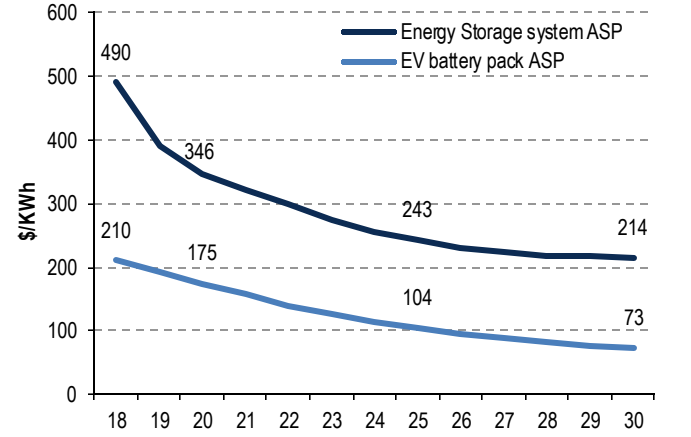
Significant increase in renewables as battery costs fall

Falling EV battery prices should bring down the cost of energy storage systems, while at the same time the cost of solar and wind keeps falling well below that of fossil fuels. As a result, we see a significant opportunity to increase renewable penetration worldwide, well beyond levels currently considered plausible.

Consultant forecasts for wind and solar penetration by 2050 vary (BNEF forecasts c.50%, IEA c30%) but we think most long-term renewable forecasts are still too low considering the potential boost that energy storage can provide to solar and wind. As a simple example, four hours of battery with solar can increase the potential hours of solar generation usability by 50% (12 hours instead of 8 hours).

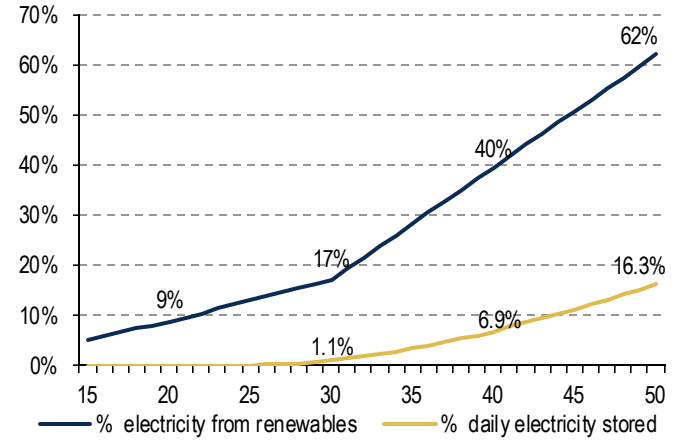
We think it is quite plausible that wind and solar's share of total generation (output, not capacity) could rise above 60% by 2050 relative to the 30-50% currently predicted. In some regions, the share of renewables could be >80% by 2050 helped mainly by different types of energy storage (such as Home ES, Grid ES, Renewables + ES, V2G, V2H etc).

Chart 19: ASP of Energy Storage (ES) in $/KWh set to fall dramatically similar to Solar PV (50% reduction by 2025 vs. 2018)



Source: BNEF, BofAML Global Research, ASP is Average Selling Price

Chart 20: Illustrative example - share of daily electricity demand could rise for both renewables & energy storage in the long term



Source: BofA Merrill Lynch Global Research

Economics of energy storage improving

Economics of energy storage vary widely by type/location

The economics of energy storage can vary widely depending on the type of deployment and location of installation. There is no one size fits all when it comes to ES.

Home ES economics vary by size/energy use at homes, retail power price levels, peak off-peak power price spreads and solar self-generation.

Grid ES economics depend on factors such as peak off-peak spreads, the cost of a new gas power plant, costs/options for storing excess renewables, need for grid services (e.g. frequency management), urgency of balancing grid (gas plants take years to be built).

Renewables + ES economics depend on factors such as the cost of the underlying renewable assets, level of system peak power prices, transmission limitations and structure of pricing contracts for renewables + ES.

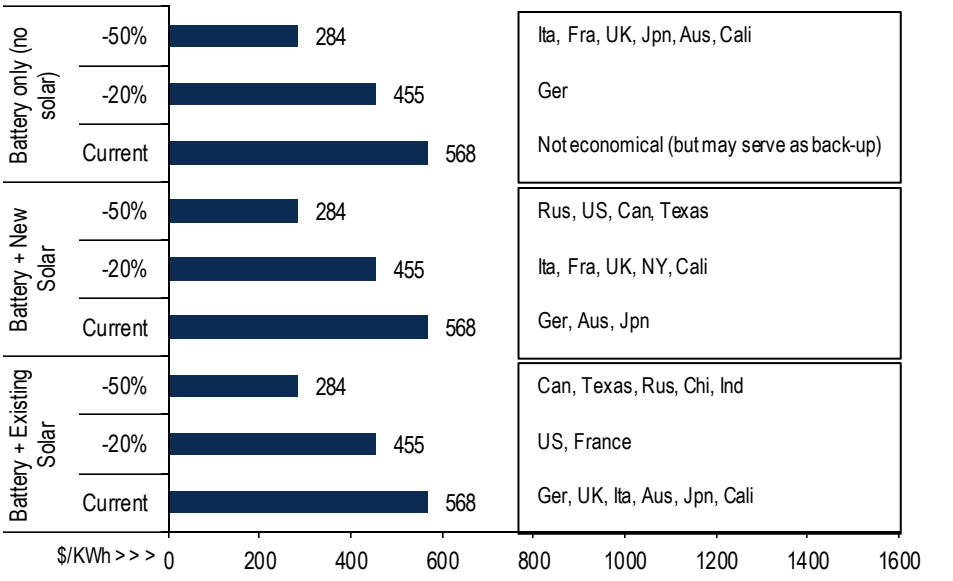
ES for businesses economics depend on factors such as power price levels, scope for self-generation (solar), peak off-peak spreads and power costs for an enterprise.

Simplifying the costs of ES

Estimating the cost of energy storage can be complex and influenced by multiple factors applicable to each individual situation, so we attempt to simplify it.

Home ES costs about $550-600/KWh. At locations with high power prices and existing old rooftop solar, Home ES would already lower monthly electricity bills. As Home ES costs fall 20% to $450-500/KWh, many more locations will find Home ES economical. Home ES would be too expensive in locations with low electricity prices and high usage, but there could be other considerations (like back-up power).

Chart 21: Regions where Home ES starts to be economic at different cost levels ($/KWh, illustrative)



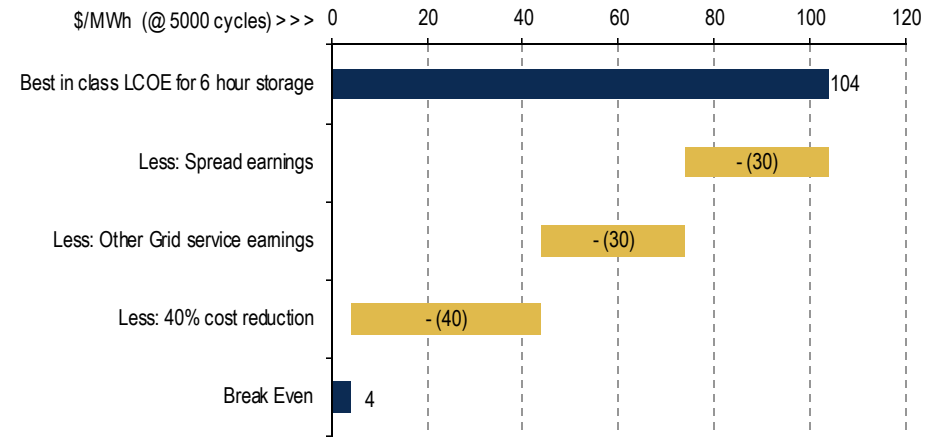
Source: BofAML Global Research, NB: Home ES costs in $/KWh (e.g. current $568/KWh)

Grid ES economics have to be compared with gas plants, the primary alternative for grid services (frequency management, quick response). Tesla's 100MW/129MWh battery in Australia cost c$67m in 2017/18 ($670/KW or $520/KWh, source: Neoen) vs. new gas plants $700/KW+ (source: US Department of Energy). Gas plants last longer (25 years) than batteries (10 years) but also have fuel/running costs, which increase per unit as utilisation reduces. Batteries are starting to be considered as alternatives for gas plants in some US states, partly also to provide the functionality of absorbing excess

renewable energy (which gas plants cannot do) and to meet climate goals. As battery costs fall, Grid ES can become competitive against gas plants in many regions.

System costs for current best-in-class ES (c.$520/KWh) can be much lower than other pilot projects (>$1000/KWh). Grid ES costs have to be considered in terms of cost per cycle (e.g. $520/KWh over 5000 cycles is equivalent to $104/MWh). This can be offset by revenues from peak off-peak spreads ($20-30/MWh), grid services ($-20-30/MWh) and, in future, cost reductions for ES (40% savings = $40/MWh). The combination of revenue streams or capacity payments is key and, in some regions, Grid ES can be adopted. For wider adoption, though, we think 30-40% cost reduction is required.

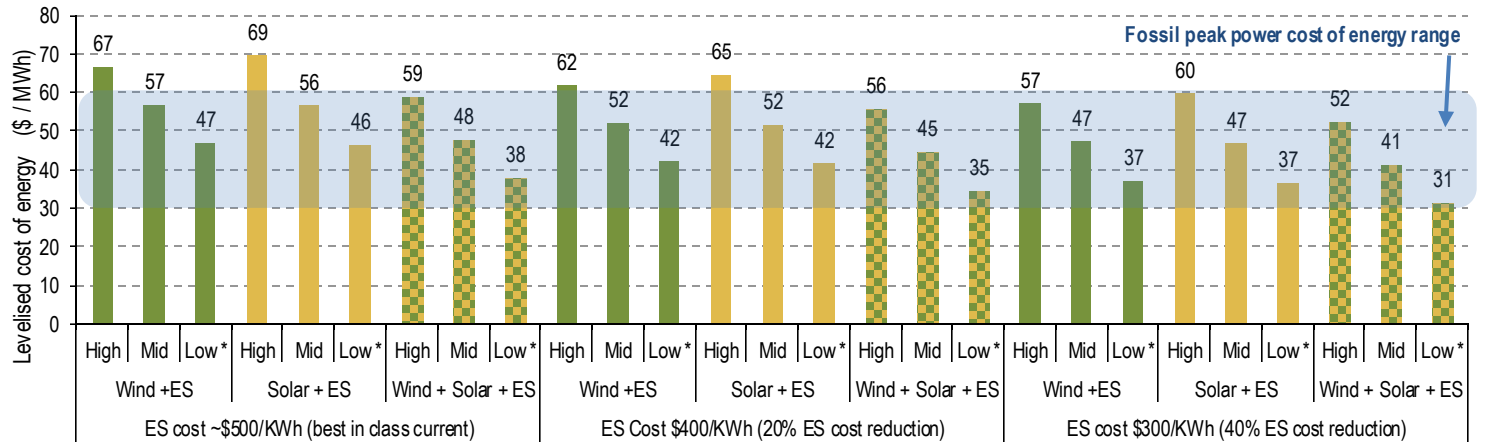
Chart 22: Grid ES could become competitive in a wider context depending on power price spreads, revenues from grid services and future cost reductions (Illustrative example)



Source: BofA Merrill Lynch Global Research

Renewables + ES economics are easier to compare with fossil than Home ES and Grid ES. At current best-in-class cost for ES ($520/KWh), adding three hours of ES to renewable projects costs about £27/MWh extra on top of LCOE of renewables. However, if ES costs fall to $400/KWh and then to $300/KWh in the next 3-5 years, renewable ES add-on costs could fall to $21/MWh and $16/MWh. Already some auctions show $15-20/MWh ES add-on costs for projects expected to be completed in 2-3 years. By comparing LCOE of renewables + ES against peak power prices, we can see that renewables + ES are already economical in locations with higher power prices ($50-60/MWh). As ES economics improve, even regions with low power prices ($30-40/MWh) could consider renewables + ES. We think Wind + Solar + ES would be more economical than just Wind + ES or just Solar +ES, mainly due to fewer hours of storage required.

Chart 23: Renewables + energy storage already comparable vs. peak fossil power in some areas but costs to come down (Illustrative example)



Source: BNEF data, BofAML Global Research, * Low scenario includes $10/MWh earnings from grid services

Energy Storage market size scenario

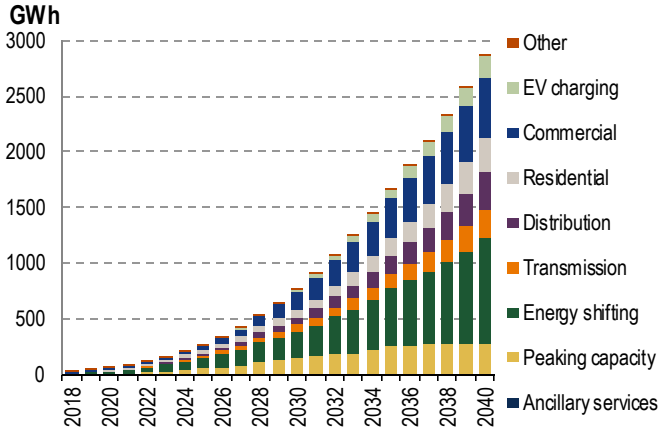
Energy Storage market could be grow significantly next decade

The Energy Storage market could grow significantly in the 2020s as economics, product availability, demand and policy support the market. From <$5bn pa revenues pre 2020, the ES market size could be as big as c.$27bn pa by 2030 (16% 2020-30 CAGR) according to the 2018 Energy Storage Outlook from Bloomberg New Energy Finance (BNEF). Growth can continue into 2040s and 2050s as ES and renewables become more established vs. fossil fuel generation.

Market split between various segments

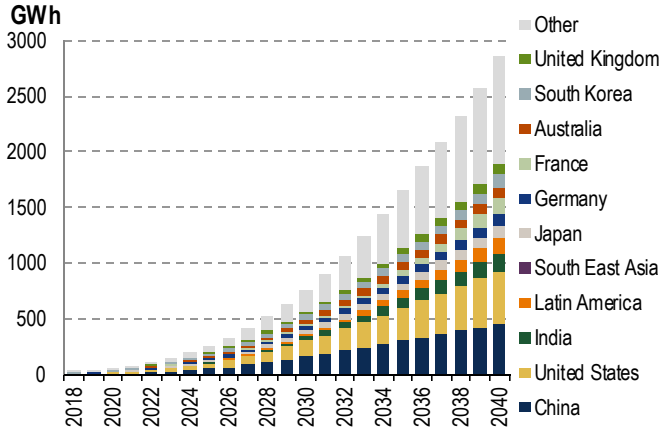
The ES market may be split between four major categories – Home ES (residential), Grid ES (peaking, ancillary services), Renewables + ES (energy shifting) and EV charging such as V2G (Vehicle to Grid) or V2H (Vehicle to Home). There would be some other applications such as Commercial ES (businesses installing ES), ES in micro grids and ES in remote areas. There could also be overlap between some categories however.

Chart 24: Cumulative Energy Storage Capacity by type (GWh)



Source: BNEF data 2018, BofAML Global Research graphic

Chart 25: Cumulative Energy Storage Capacity by region (GWh)

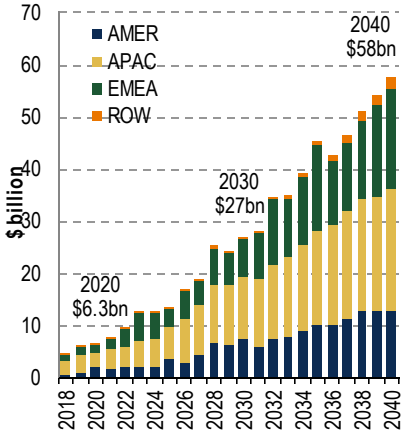


Source: BNEF data 2018, BofAML Global Research graphic

From $2.5bn in 2017 to 27bn by 2030 (10x), helped by 50% cost reduction

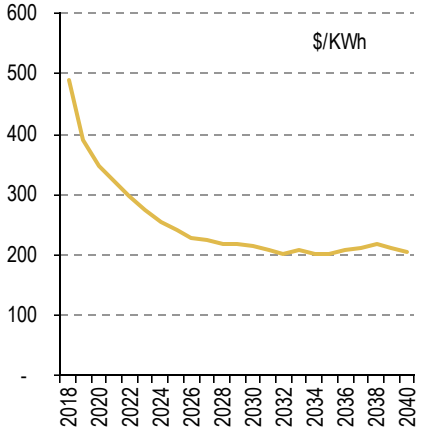
BNEF forecasts that the ES market grows to $27bn pa by 2030 from c$2.5bn in 2017, a 10x increase over the period. As per BNEF's data, average price of energy storage falls from c$500/KWh in 2018 to <$250/KWh by 2025, a 50% improvement in economics.

Chart 26: ES market size $bn pa



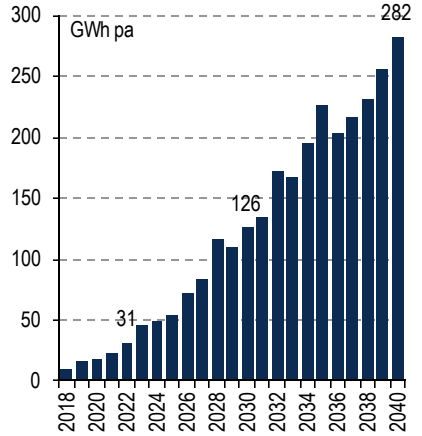
Source: BNEF 2018 data, Chart by BofAML Global Research

Chart 27: ES average implied $ price per KWh



Source: BNEF 2018 data, Chart by BofAML Global Research

Chart 28: ES market size in GWh volumes



Source: BNEF 2018 data, Chart by BofAML Global Research

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ES capacity could be 6% of power capacity by 2040, likely higher by 2050

BNEF highlights that cumulative ES capacity could reach 943GW by 2040 which would be 6% of global power installed capacity as of 2040 (15.5TW, BNEF NEO 2019) and almost 13% relative to 2020 global power capacity (7.5TW, BNEF NEO 2019).

How much ES would represent in terms of % of daily demand would depend on how many times the batteries are cycled daily – c2.6% of daily demand covered by ES if batteries cycled once, c.5% if cycled twice and c.8% if cycled thrice daily, as implied by BNEF's data.

BNEF forecasts are not available for 2050 but we think 2050 cumulative capacity would be much higher considering the rising annual installations run-rate. We believe ES could go a long way in meeting evening peak demand from 6-10pm by 2040-50. BNEF published its Long Term Energy Storage outlook in 2018 but provided some updated numbers in 2019 (see Table 2)

Table 2: Energy Storage Market Outlook from BNEF (Bloomberg New Energy Finance) - Key Data

		2020	2030	2040	Source	2020-30 CAGR	2030-40 CAGR
Energy storage additions – annual	GW	8	50	131	BNEF 2019	20%	10%
Energy storage additions – annual	**GWh**	**18**	**137**	**396**	**BNEF 2019**	**22%**	**11%**
Cumulative energy storage capacity	GW	25	284	943	BNEF 2019		
Cumulative energy storage capacity	GWh	53	767	2857	BNEF 2019		
Global electricity installed capacity	GW	7529	11027	15485	BNEF 2019	3.9%	3.5%
Global electricity generation - annual	TWh	27382	34132	39678	BNEF 2019	2.2%	1.5%
Energy storage additions – annual	GWh	18	126	282	BNEF 2018	21.3%	8.4%
$bn annual market size	**$bn**	**6**	**27**	**58**	**BNEF 2018**	**15.6%**	**7.9%**

Source: BNEF, BofAML Global Research Summary

Challenges for ES & role of fossil (gas)

ES can increase reliance on renewables but fossil still has a role (esp. gas)

We believe ES will help smooth renewable energy generation materially and allow it to take more share from fossil over time. Even now, some renewable production has to be curtailed due to excess production or grid bottlenecks, which can easily be avoided with ES. Nevertheless, ES cannot completely solve all situations and fossil back-up would still be required. There is also the issue of timing – in the long term, we believe ES will be instrumental and mainstream in the energy system, but over the next 5-10 years fossil fuels still have a role to play, especially gas-fired plants in some locations or situations.

Gas plants will be key in some regions (Germany, China) and as an interim fix

We think there will be certain times and locations where new gas plants will be required in the next 5-10 years. For example, Germany is planning to shut all of its nuclear generation within the next five years, and while wind (onshore/offshore) capacity is increasing fast, Germany is likely to require a fleet of new gas plants as an interim fix and considering some of the most polluting (but reliable) lignite and coal plants will be shut down in 2025-35. There will also be a need for fossil back-up during the winter months. Similarly, China might have to rely on new gas plants if it wants to shift away from coal (currently c.70% of the mix) even if renewables grow fast.

Gas plant growth may be lower in regions like the US and Middle East

Gas plant additions in the US have been strong in the last decade helped by low shale gas prices, although we believe the pace of gas additions could slow down as some states start to consider renewables + ES seriously as an alternative to gas (economics for ES improving, tougher state climate goals). In the Middle East, solar PV + ES should become a viable alternative to gas given abundant solar resources (the region has already seen some ultra-low-priced mega solar projects in recent years). ES may not become a substitute for baseload electricity until after 2030 but it could start to meet peak demand more often already in the next 5-10 years.

Coal more at risk than gas

We think the rise of renewables and energy storage would put coal plants more at risk than gas plants. Coal retirements are already happening worldwide (except in some EM countries like China and India) but this trend could be accelerated with ES.

Battery capacity could be a bottleneck for ES

Battery manufacturing capacity could be a bottleneck for ES, especially as battery demand is primarily driven by EVs (and the EV market is growing fast too). Planned annual global battery production capacity by 2023 stood at almost 1000GWh as of mid-2019 vs. c200-250GWh current capacity (source: Cleantechnica / Benchmark Minerals). The battery production capacity ramp-up compares favourably against 3-5GW current ES demand and even c56GWh pa 2025 scenario (source: BNEF). If battery production capacity additions lag expectations though, ES will compete with EVs for supply. ES demand for batteries could rise to 137GWh by 2030 and c.400GWh by 2040 (source: BNEF), while demand from EVs keep rising. Thus, battery production needs to keep pace. Longer-term, recycling of old batteries would have to be considered as well.

ES costs need to come down and systems need to be simplified/improved

ES system costs need to come down from >$500/KWh today (source: BNEF) towards $300/KWh for wider adoption, we believe. Economics will be vital if demand is to pick up. In addition, functionality, financing (leasing), ease of use/installation and policy will be necessary for wider adoption of ES, especially for home batteries where customers want less hassle. In emerging markets, system costs would have to be reduced by probably 50%+ and system size would have to be smaller vs. developed markets, considering the lower energy use and affordability issues in EM.

Sub segment exposure to energy storage

Businesses that may benefit from ES

- **ES system suppliers (beyond batteries):** Suppliers of ES could buy batteries from suppliers and focus on overall ES systems. Consumers ultimately want a product that is plug-and-play and with multi-functionality, not just the battery pack.
- **Balance of plant and electronics:** ES would require balance of plant components such as inverters and control equipment, i.e. more electronic components.
- **New energy suppliers:** New energy suppliers or utilities at the forefront of the transition to clean energy can use batteries to lower customer bills using power price arbitrage and grid service revenues. We are likely to see the emergence of virtual power plants, aggregating thousands of small batteries.
- **Software for complexities:** Power arbitrage, self-generation input, grid services and battery management to require sophisticated software for ES.
- **Demand response & grid services:** Some businesses will focus on using ES for grid services (frequency) and demand response.
- **Service businesses:** Emergence of service businesses to maintain and repair ES systems, either as independent players or as part of bigger ES solution providers
- **Recycling & disposal:** Exponential growth of battery systems (EV+ES) would require recycling (esp. for valuable materials) but also appropriate disposal.
- **Infrastructure investments:** A new style of infrastructure investments might emerge which focuses on ES financing and owning ES assets in the long term.

Businesses facing headwinds from ES

- **Utilities with merchant fossil plants:** utilities that still have sizeable fossil fuel in their generation or profit mix may see headwinds, particularly if exposed to merchant markets (regulated assets ought to be safer). The impact would depend on individual circumstances, e.g. some utilities may already be planning to phase out old fossil fuels and replace them with new renewables + ES, perhaps as part of regulated assets.
- **Fossil plant equipment suppliers:** suppliers of fossil plants would see reduced demand for new gas or coal plants – already impacted by renewables but more pressure from ES. They may also see reduced demand for spare parts and services, either due to lower utilisation or closure of older plants due to ES.
- **Industrial suppliers to fossil plants:** suppliers of valves, compressors, pumps, etc, to fossil plants should see a gradual decline in demand in the long term.
- **Coal mining & gas exploration:** as energy storage enables renewables to take a greater share from fossil fuels, coal mining could decline and even gas exploration activities may stagnate in the long term.
- **Equipment for coal mining, gas exploration:** equipment suppliers to the coal mining and gas exploration industries could see reduced long-term demand.
- **Shipping/trading of coal & LNG:** shipping and trading activities for coal and LNG could face headwinds if end demand for fossil generation diminishes due to ES. However, there could be other drivers that influence these activities (e.g. what if China starts importing much more LNG?).

Regions: US ahead of EU & APAC

Energy Storage in Europe

Europe well placed to embrace energy storage but behind US for now

Europe is at the forefront of renewable energy but is behind the US on energy storage at the moment judging from the size of ES projects. Still, Europe has huge potential and need for ES, especially as the share of renewables is expected to rise significantly and older renewables are coming off fixed tariff periods, which suits the addition of ES. The share of fossil electricity in Europe could fall be much lower by 2030, implying >1% share loss every year as per BNEF data (decline more in coal).

Europe's utilities and energy companies are stepping into energy storage

Many EU utilities have already planned for a transition to clean energy and those investing early in energy storage could benefit from this long-term transition. Still, there could be some market share losses in terms of retail energy supply if energy storage enables more decentralised generation. For oil & gas, the main exposure is stagnating growth in gas demand as batteries start to take share from gas electricity. That said, some oil majors have acquired or invested in energy storage companies or projects.

Energy Storage in the US

US is at the forefront of embracing energy storage

US regions are at the forefront of energy storage, with utilities in many states announcing large ES projects as part of regulator-approved plans, typically in combination with new renewables. Some large states have also announced long-term goals for energy storage (e.g. California, NY, NJ). Large ES plans include NV Energy's 590MW in Nevada, FPL's 409MW in Florida, Xcel's 275MW in Colorado and SCE's 195MW in California. There are smaller projects in other states like Wyoming, Hawaii and Puerto Rico. In some cases, the new ES projects are aimed at shutting down old coal (Colorado) or gas plants (Florida). In others, grid batteries are being planned as alternatives to new gas plants, to even out renewable generation or to meet peak demand with renewables.

US has many advantages that support energy storage

State renewable/climate targets, excess renewables (thus need to store), economics and regulatory/utility strategy are helping drive adoption of energy storage faster in the US than in the rest of the world. The US is also in an advantageous position with solid renewable resources and some tax breaks (for the time being) that make renewables + energy storage projects relatively competitive vs. new/existing gas plants (and coal plants).

Coal decline may be quicker with ES

There is little debate that coal generation will decline but quicker closure of coal plants is possible as energy storage helps integrate more renewables and can act as an alternative supply of peak power to an extent.

Gas demand growth from power sector could slow but complex drivers

Even gas plants, whether new or old, are not completely safe from ES (for example, Florida's FPL is planning to replace two old gas plants with a huge 400MW+ battery). Share loss to ES in the gas power segment could impact gas exploration in the long term and, as a result, equipment & service providers for the gas value chain. Still, the overall gas demand impact from ES is less straightforward to predict as power plants are not the only end-users of gas (space heating, industry and exports are important segments). US gas demand rose 30% in 2008-18, partly helped by demand from power plants, as cheap shale gas enabled the replacement of coal generation with gas. The pace of gas demand growth due to new gas power plants could slow down in the next decade as energy storage (in its multiple forms) replaces older gas plants and becomes an alternative to new gas plants in more and more locations.

US utilities can include energy storage in rate bases

US utilities benefit from being able to include energy storage investments as part of their regulatory asset bases. State regulators also seem more willing to embrace ES compared to the rest of the world, judging from approved projects or proposals so far in the US. However, there could be some market share losses in terms of retail energy supply if energy storage enables more decentralised generation (esp. rooftop solar + Home ES which works well in sunny US locations). For oil & gas, the main exposure is stagnating growth in gas demand as batteries start to take share from gas electricity.

Energy Storage in APAC

Slow start for Asia in energy storage but Australia at forefront

The Asia Pacific (APAC) region has been slow to embrace energy storage, although it is still early days in this long-term transition. That said, Australia has been at the forefront of energy storage with the "100 days or no charge" 100MW Tesla battery in South Australia a famous example. Due to unreliable grid power supply, some Australian states (e.g. South Australia) have embarked on further energy storage projects such as plans to install home batteries in 50,000 homes to create a virtual power plant. One of the largest energy storage systems to be installed in Asia seems to be the 7MWh Tesla battery for Japan Railways (source: GTM), but this is much smaller than US projects.

Asia has the big battery suppliers (and thus energy storage system suppliers)

Asia is still home to the largest global battery suppliers from South Korea, Japan and China. Most of these battery suppliers also manufacture energy storage systems for homes and grid scale applications. We think it is likely that Asia's battery and energy storage suppliers will work towards developing the ES market in APAC.

Asia has big plans for renewables, so energy storage should follow

Asia has big plans for renewables as well. China is already the #1 global market for wind and solar, while India has already stepped up its renewable investments in recent years (the recently re-elected government in India even talked about 500GW of renewables in India, well ahead of the c200GW current plan by 2022). Other smaller countries in Asia are also embracing renewables given economics and local resources (e.g. offshore wind in Taiwan). As the share of renewables grows and given Asia does not have as much spare fossil underutilised capacity as in EU/US, energy storage will have to be considered seriously in Asia, in our view.

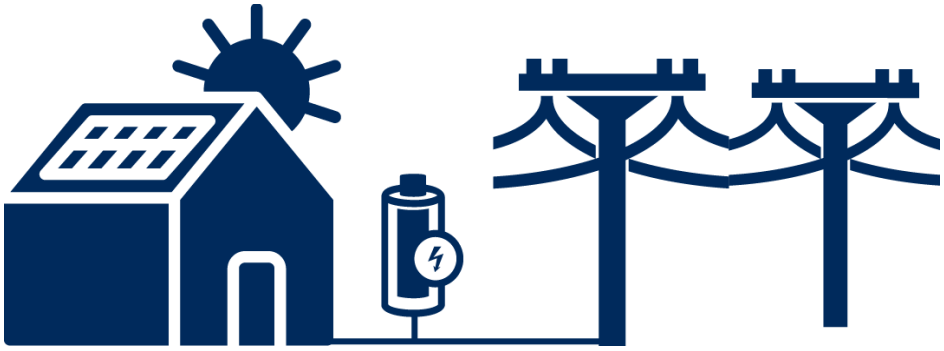
Cost of ES systems still an issue for APAC overall, Renewables + ES well placed

The cost of energy storage is likely still too high for Asia. For example, a typical home energy storage battery could cost $5,000-8,000, which would be a significant cost for households in Asia. Similarly grid batteries are expensive currently and, with regions used to power outages, grid batteries could be too expensive to fully curtail outages. Battery costs need to come down significantly (>50% ?) and systems need to be designed specifically for the diverse Asian market for energy storage to pick up in Asia. We think renewables + ES is probably the most obvious segment where ES can pick up in APAC given economics of this ES segment.

Home ES: After all, you're my power wall

SUMMARY
Home energy storage, sometimes known as behind-the-meter (BTM) storage, could be the most easily deployable and scalable option to ramp up battery ES. Home ES is becoming economical in some sunnier locations but even elsewhere, Home ES can offer peak shaving, excess renewable energy storage, back-up power and grid services via aggregation.

Exhibit 9: Home Energy Storage



Source: BofA Merrill Lynch Global Research

Examples of Products in Home ES

Tesla battery in Australian homes: Home battery (13.5 KWh) + solar (5KW) in 50k Australian homes by 2022, creating a virtual power plant.
Sonnen battery offer in Australia: Sonnen offers batteries via monthly instalments in Australia and plans to build a factory in Australia.
Sunrun home battery aggregator: Sunrun won a capacity auction (Feb-2019) in New England (US) for 20MW aggregated storage at 5000 homes.

Relevant Conditions

Sun resources: Home battery storage to work better with rooftop solar
Roof Area: Need roof area, batteries less impactful in flats/apartments
Power prices: High power prices better (EU, Australia) vs. low prices (US)
Peak-base balance: High peak-base spread better vs. steady prices
Economics/affordability: Electricity bills vs. income, financing, payback
Grid reliability: More attractive if grid prone to outages, natural disasters
Existing solar PV: Ready market available in existing solar PV adopters

Why is Home Energy Storage so appealing?

Easy to deploy and scalable

Home ES is very easy to deploy as the batteries are relatively small (wall-mounted) and price points are not too high ($2500-10000), especially in combination with monthly instalment schemes. Roll-out can start from low levels and be scaled up over a period of time as experience builds up, costs fall and awareness increases.

Solar + storage utopian dream – independence from utilities and fossil fuels

Home ES offers households the possibility of becoming energy-independent from centralised utilities via the solar + battery storage model. It also allows the possibility of fixing long-term bills, i.e. independence from annual bill increases. Solar + battery solutions additionally allow consumers to become fossil fuel-independent, which is a relevant driver as awareness about climate change is increasing worldwide.

Solution to home evening-peak and solar-duck-curve problem

Home ES solves the famous "duck curve" problem seen in California, whereby solar generation peaks during the day but residential demand peaks in the evening as people come back home. Excess solar during the day but tight capacity during peaks has been a problem but home battery storage can solve both these problems in one go.

Works best in sunny locations but has appeal even in non-sunny locations

Home energy storage works best in sunny locations due to the obvious mismatch between solar generation peak and evening usage peak. Solar PV systems are starting to offer battery storage options to maximise self-usage and limit grid reliance. But Home ES also has appeal in non-sunny locations depending on conditions such as peak-base spread, back-up needs and incentives from grid operators to limit evening peak demand.

Home ES cheap vs. grid batteries option given limited set-up cost & easy fitting

Home ES system set-up costs are modest – home batteries can cost $2,500-$10,000 depending on capacity and installation $1,000-2,000. Unlike grid batteries, where balance of plant and site preparation are expensive and time-consuming, wall-mounted or floor-standing Home ES systems can be set up easily in 1-2 days.

Ready market of solar PV adopters

Home ES's biggest advantage is a ready market of households that already have rooftop solar PV. Such households (above-average incomes, green-minded) could be the ideal demographic for home ES in the early days when costs are still high. In addition, some early solar PV adopters will see their solar generation incentives coming to an end in the next 5-10 years, incentivising Home ES even more. Retail prices for energy bought from utilities are typically much higher than potential wholesale prices achieved on the sale of excess solar generation, which should encourage self-usage of solar generation in combination with batteries.

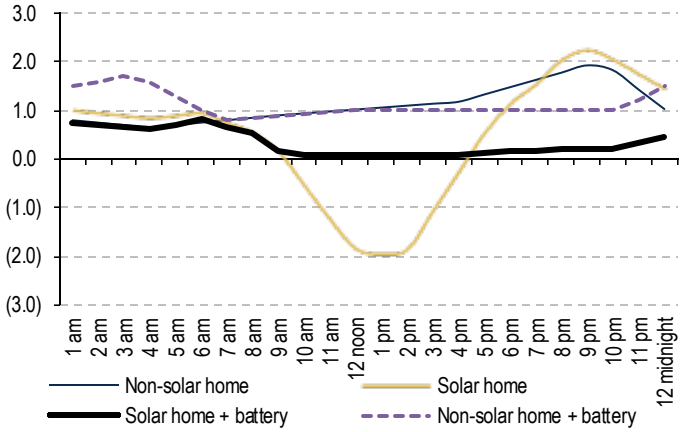
Home ES fits well with evening peak & eases grid load

Household electricity demand during evening peaks is typically double or even more than double off-peak times. While households represent about 35-40% of electricity demand in developed countries, a sizeable proportion of this is skewed towards the evening peak and therefore the proportion in household demand is likely to be higher in the evening. Home ES can flatten evening peaks from a grid perspective through a combination of soaking up excess renewable generation (solar during the day, wind during the night), reducing evening peak demand and releasing energy during day peaks.

Home ES fits with distributed energy, cloud services & electric vehicles

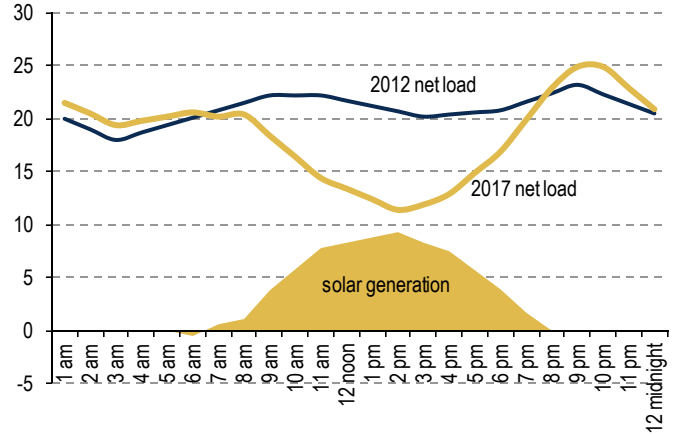
Home ES fits well with the concept of distributed energy and "cloud" services (for e.g. a large number of home batteries aggregated into a "virtual" power plant managed remotely with software). Home batteries would also work with electric vehicle charging at home using either rooftop solar, excess grid renewables or just off-peak power.

Chart 29: Home batteries can change profile of household net load (KW)



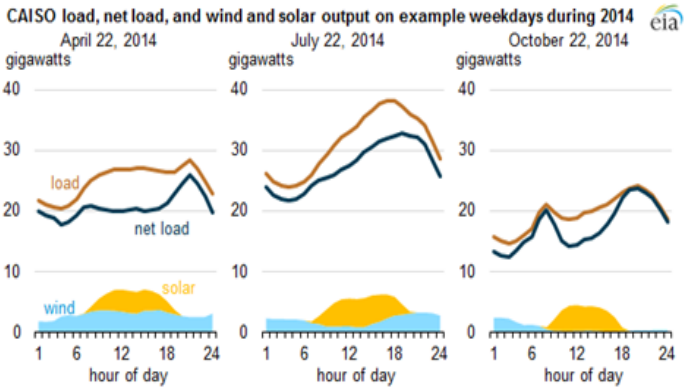
Source: BofAML Global Research: Illustrative example for western US

Chart 30: California's famous duck curve problem



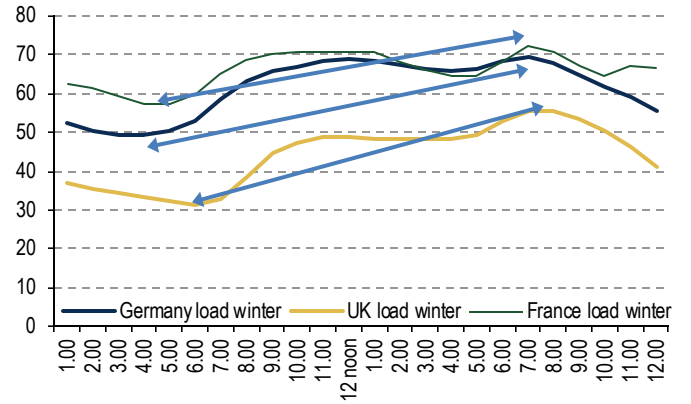
Source: CAISO data, BofAML Global Research, NB: Illustrative example

Chart 31: California's duck curve varies at different times during the year



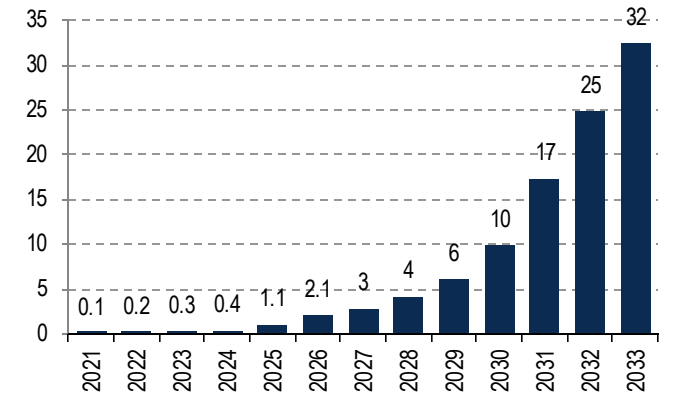
Source: CAISO & EIA, BofAML Global Research

Chart 32: Battery storage can help in Europe during winter even without solar due to gap in daily peak and off-peak demand



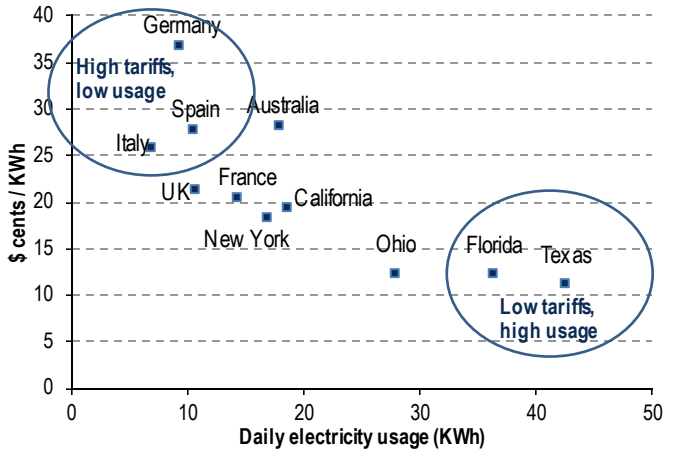
Source: ENTSOE load data, BofAML Global Research, NB: average hourly loads during Nov-Mar

Chart 33: Solar PV capacity exiting Germany's 20-year Feed-in tariff presents a lucrative potential market for battery ES (GW)



Source: BNEF data, BofAML Global Research

Chart 34: Energy storage likely more effective in high-tariff low-usage regions (& vice versa)



Source: BofA Merrill Lynch Global Research

Relevant considerations for Home ES

Sun resources

Available sun-hours in a particular location are a key driver for Home ES as solar+battery storage systems make for better economics via increased self-consumption.

Roof characteristics (houses vs. flats/apartments)

Detached or semi-detached houses would have enough roof area to put solar and add batteries. Flats or apartments would not have sufficient roof area for solar panels, so Home ES would only be applicable for other uses like peak-base spread optimisation or back-up power. Smaller flats might have space limitations for wall-mounted batteries.

Power price levels

Power prices influence economics as well. A house facing high unit electricity tariffs will find solar+battery solutions more appealing given the possibility of cheaper self-generation.

Amount of electricity used

For a house using limited amounts of electricity, a big Home ES system may not make sense. A medium-usage household may find the economics easier to digest. A house that uses a lot of electricity would need much bigger, costlier storage systems.

Peak-base power price spreads

For non-solar homes (and even some solar homes), Home ES would mainly allow for optimisation of electricity costs by storing cheaper off-peak electricity at night and using it during day-evening peaks when electricity unit prices are high.

Economics and affordability

For mass adoption of Home ES, the overall economics would have to work and these differ widely by region and conditions such as solar generation, power price levels, total bills, peak base spread, total usage and any additional income streams (subsidies, capacity payments).

Grid reliability

The propensity for power outages is also starting to become a factor for home ES adoption as the frequency and intensity of storms or other climate events increases (especially in the US in recent years). Solar+battery provides some power back-up even if grid power is impacted and this could be a deciding factor for some households. For some emerging markets, grid power is already unreliable (e.g. India), so having good battery storage would be attractive for many households to avoid power outages.

Customer retention

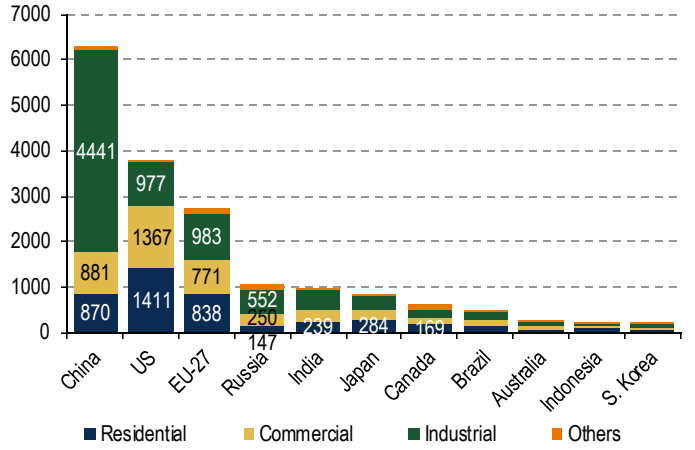
For traditional utilities, offering solar+battery or just battery schemes could be attractive as these may help customers better in the face of increased switching (esp. in some European countries). Utilities also hope to up-sell other services like maintenance contracts and energy management services in the process.

Solar feed-in-tariffs or net-metering schemes ending

Most existing solar capacity enjoys some form of fixed tariff or net-metering schemes for generation sold to the grid during the day. These tariffs are typically generous but such schemes are usually available for only limited years (10-15 years). Once they end, households would have to sell energy to the grid at much lower wholesale prices. Thus, once a rooftop solar house comes out of the high-tariff period, it would make more sense to maximise self-usage versus buying more expensive grid power for evening/peak usage.

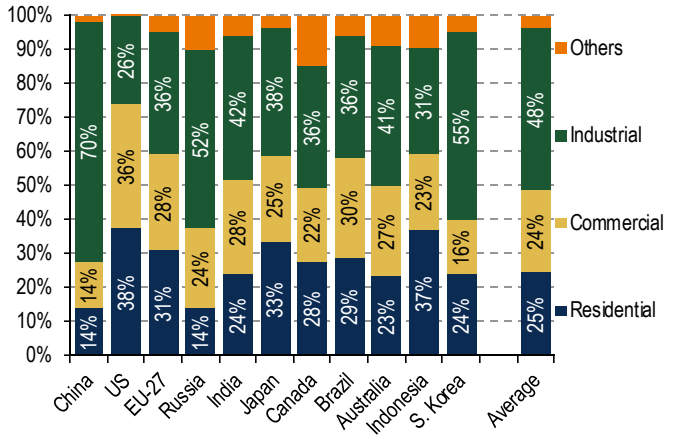
No such thing as an average household

Chart 35: Electricity demand by sectors (residential vs. rest, TWh)



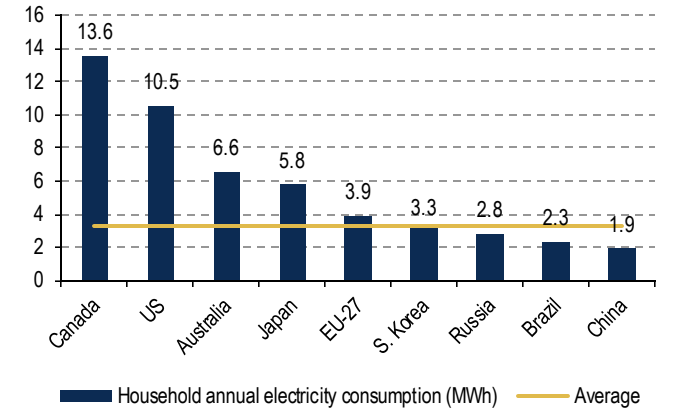
Source: Country TSOs, BofAML Global Research

Chart 36: Share of electricity demand by sectors (residential vs. rest, %)



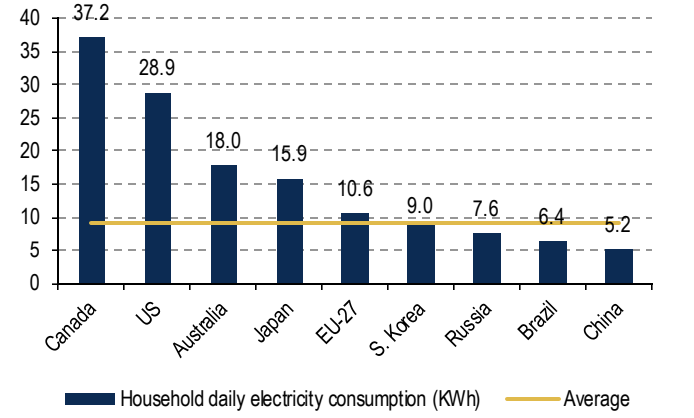
Source: Country TSOs, BofAML Global Research

Chart 37: Annual household electricity demand by key countries / regions



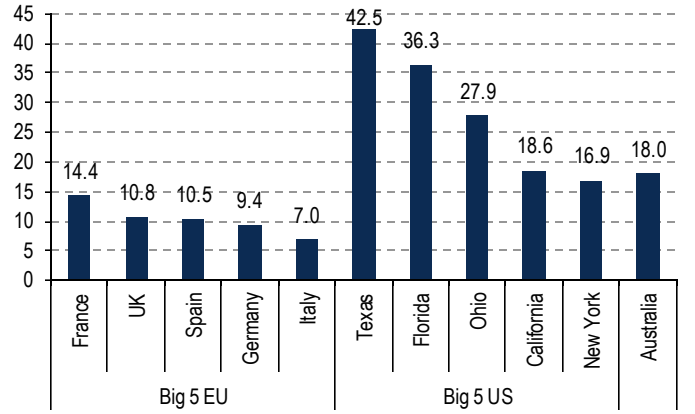
Source: Country TSOs, Bloomberg, Worldbank, IEA, BofAML Global Research

Chart 38: Daily household electricity demand by key countries / regions



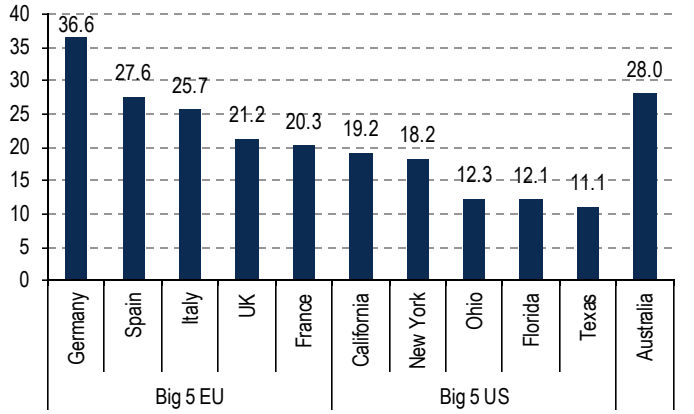
Source: Country TSOs, Bloomberg, Worldbank, IEA, BofAML Global Research

Chart 39: Daily residential electricity demand (KWh)



Source: Country TSO, EIA, IEA, BofAML Global Research

Chart 40: Residential electricity tariffs per unit ($c / KWh)



Source: Country TSO, EIA, IEA, Press reports, BofAML Global Research

How big do Home ES batteries need to be?

Battery size depends on home usage patterns

The amount of energy capacity (i.e. KWh) in a home battery depends on how much electricity a house uses. As daily home use varies widely between countries and even within each country due to home size and weather conditions, battery sizes would have to be different in different locations (Chart 38 and Chart 39).

Battery size also depends on number of target hours or storage

Battery capacity would also vary depending on how many hours of storage are needed. To store enough solar energy for evening-night usage, home batteries may need 10-15 hours or more of storage. But if the purpose of the battery was only to help shave off peak energy consumption in the evening (either to exploit peak-base spread or due to incentives from grid operators), then 5-hour storage could be enough. If households want multi-day storage and to go completely off-grid, then battery sizes would have to be significantly higher. The number of hours of storage would then have to be weighed up against daily usage to assess the appropriate Home ES battery size (Chart 41). Note that the countries and regions shown in Chart 41 represent c.75% of world electricity demand, thereby covering many of the key markets worldwide.

Battery costs by key regions/countries

Home ES sizes will vary widely within each country given differences in house sizes and usage. Even for the same country, there would be regional differences – e.g. urban electricity usage in India and China would be much higher than in rural areas, so national averages are likely too low relative to the addressable urban market (where Home ES batteries are more likely to be deployed). Chart 41 shows battery sizes by country/region depending on number of storage hours.

Europe: 5-hour storage would need a 2.2KWh battery, 10-hour 4.4KWh battery
US: 5-hour storage 6.0KWh battery, 10-hour 12.0KWh, 15-hour 18.0KWh
Australia: 5-hour storage 3.7KWh battery, 10-hour 7.5KWh, 15-hour 11.2KWh
Canada: 5-hour storage 7.8KWh battery, 10-hour 15.5KWh, 15-hour 23.3KWh
India: 5-hour storage 0.5KWh battery, 10-hour 1.1KWh, 15-hour 1.6KWh
China: 5-hour storage 1.1KWh battery, 10-hour 2.2KWh, 15-hour 3.3KWh

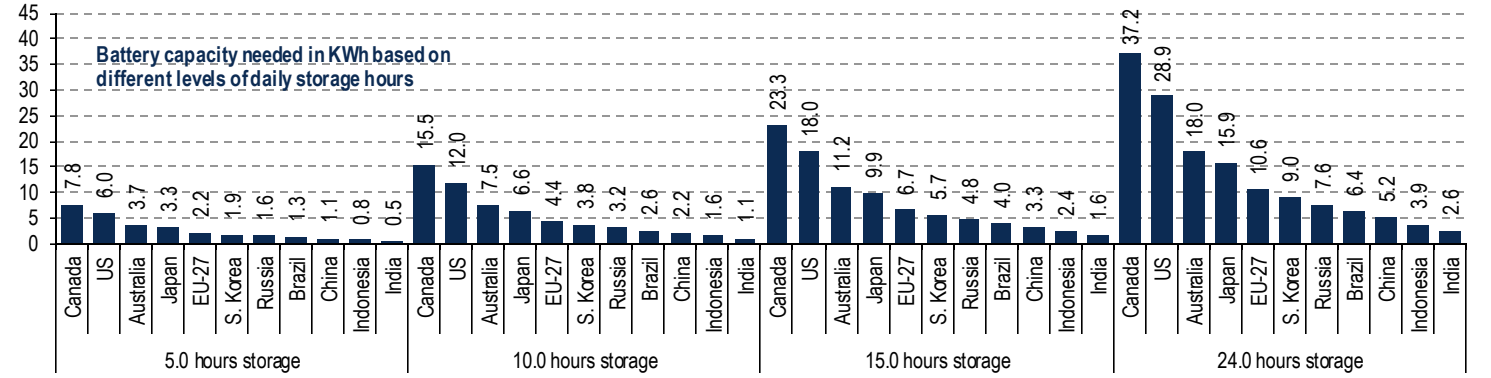
Batteries costs by key region / countries - current

The cost of Home ES system for each country shown below assumes $7500 installed cost per KWh (based on the publicly known market price for Tesla's 13.5KWh home battery). Chart 42 shows cost per household using current battery prices while Chart 43 shows a scenario assuming battery costs fell 50% longer term.

Europe: 5-hour storage would cost $1500 per battery, 10-hours $2600
US: 5-hour storage $4200 per battery, 10-hour $6900, 15-hour $9400
Australia: 5-hour storage $2600 per battery, 10-hour $4300, 15-hour $5800
Canada: 5-hour storage $5400 per battery, 10-hour $8900, 15-hour $12100
India: 5-hour storage $400 per battery, 10-hour $600, 15-hour $900
China: 5-hour storage $800 per battery, 10-hour $1300, 15-hour $1700

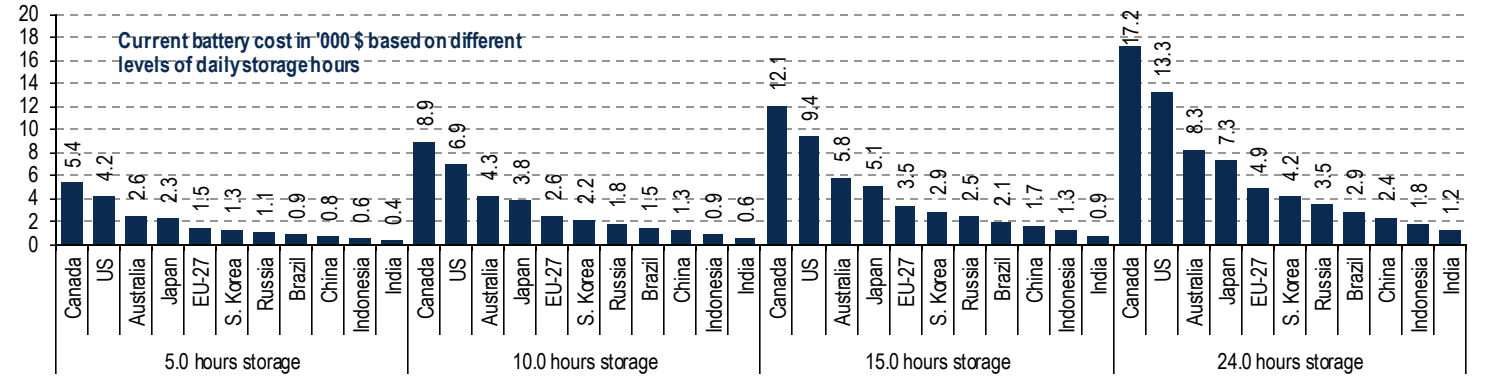
Battery size & costs in different markets

Chart 41: How big do batteries need to be to provide certain hours of storage in different locations?



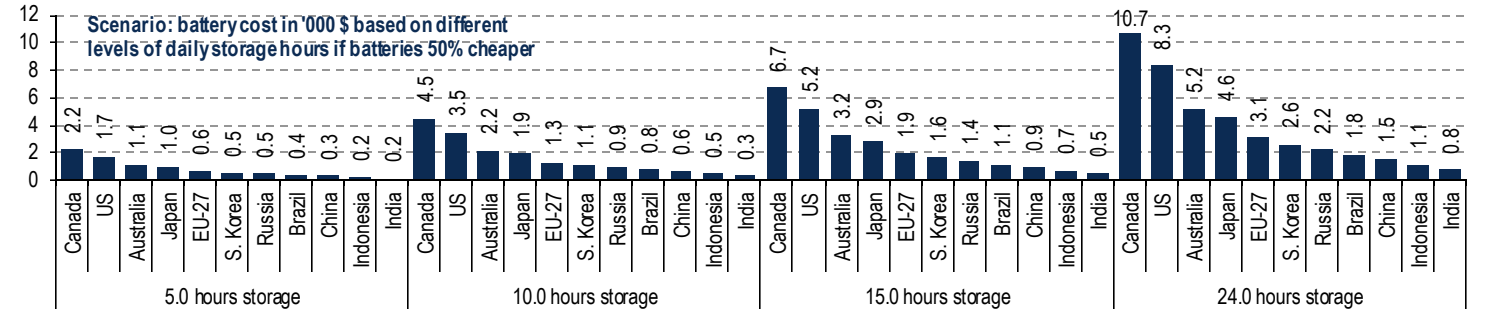
Source: BofA Merrill Lynch Global Research

Chart 42: Upfront cost of providing 5-10 hours of storage likely to be modest relative to annual bills if spread over 10 years of asset life



Source: BofA Merrill Lynch Global Research

Chart 43: 50% reduction in battery costs longer term would make Home ES very attractive globally



Source: BofA Merrill Lynch Global Research

Bank of America Merrill Lynch

Home energy storage products

Some prominent home battery offerings

- **Tesla:** Tesla's home battery is among the first commercially available home batteries in the market. It is also one of the cheapest (on a $/KWh basis).
- **Sonnen:** Based out of Germany, Sonnen operates in home energy storage with presence worldwide, especially in the US and Australia. It uses Lithium Iron Phosphate technology rather than Lithium Ion.
- **LG Chem:** LG Chem's home battery offering is from one of the largest global battery manufacturers. It has various capacity configurations and is one of the three products usually compared on internet forums vs. Tesla and Sonnen.

Table 3: Comparison of some leading home battery offerings

Product	Energy Capacity	Power Capacity	Price per KWh	Price assumptions	Technology	Round trip efficiency	Depth of discharge	Temperature range (Celsius)	Warranty Years	Warranty Cycles	Warranty Degradation	Total KWh
Tesla Powerwall 2	13.2 KWh	5-7 KW (steady-peak)	US$ 568 /KWh	$7500 with installation for 13.2 KWh	Lithium Ion	90%	100%	-20C to +50C	10 year	10000	Unlimited cycles for 10 years, 70% capacity	37800
Sonnen Batterie	4-16 KWh		US$ 786 /KWh	$11000 with installation for 14 KWh	Lithium Iron Phosphate	98%	100%	+5C to +40C	10 year	10000	70% capacity for 10000 cycles or 10 years	
LG Chem RESU	3.3-9.8 KWh	5-7 KW (steady-peak)	US$ 806 /KWh	$7500 with installation for 9.3 KWh	Lithium Ion	95%	95%	-10C to +45C	10 year	>6000	60% capacity at year 10	30000

Source: Various press reports & web articles, company data, BofAML Global Research

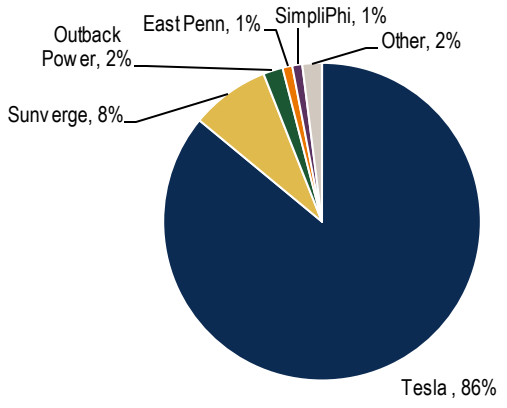
Many other players also offer home batteries

While Tesla, Sonnen and LG Chem are probably the most prominent players in the home battery market currently, many others offer home battery products. These include companies involved in solar PV (like GCL, Enphase) and other fields (E3DC, Pika) but also the large battery suppliers (CATL, BYD, Samsung SDI). Some auto OEMs are also offering Home ES products, either using new batteries or recycling electric car batteries.

Comparing product offerings is difficult currently as market still evolving

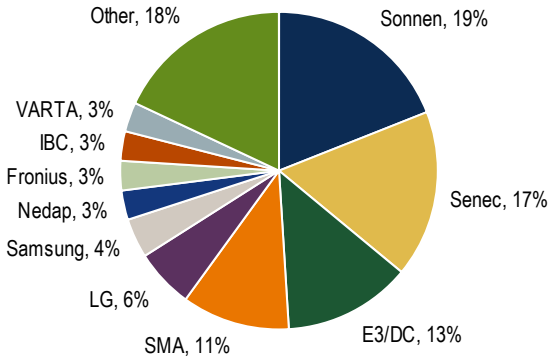
Home battery products are not yet homogenous, making them difficult to compare. In our view, only Tesla, Sonnen and LG Chem seem to be matching offerings to an extent when it comes to specifications and warranties. The comparison items include easily understandable specifications (such as battery capacity, loads, warranty life, cycles), more technical aspects (trip efficiency, degradation, inverter, DC/AC conversion, compatibility with solar, grid interface units) and management (energy management systems, digital interface, seamless switching between solar and grid).

Chart 44: Home ES market share in California (2017)



Source: California Public Utilities Commission, Bloomberg New Energy Finance (BNEF)

Chart 45: Market share of Energy Storage suppliers in Germany (2017)



Source: Registered under the KfW subsidy program 2013-17, BNEF, GTAI, KfW bank

Is Home Energy Storage economically viable?

Factors to consider: huge variation in inputs

Key inputs vary a lot by region (daily demand, solar vs. non-solar usage, peak base spread, winter-summer, retail electricity tariffs and cost of solar PV), making it hard to figure out the economic viability of a home battery. There is no average household, so tailor-made calculations would be required for each home within the same country or even the region within a country.

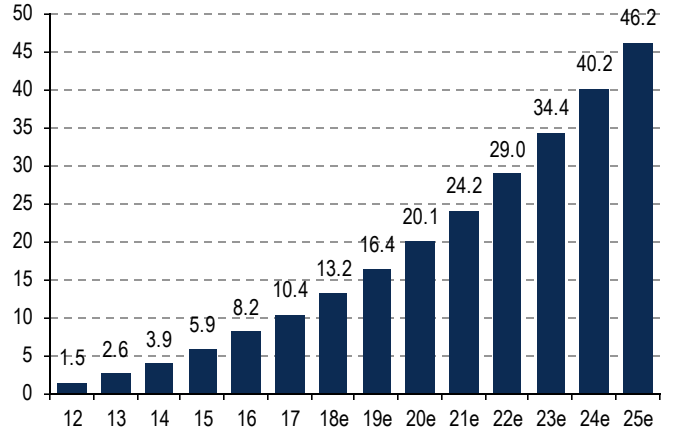
Effective in some situations now but 20-30% cost reduction to open big market

Battery storage would be effective today in certain situations where retail household tariffs are high (Germany, California, Australia), older solar PV systems are reaching the end of their incentive periods (Germany) or solar is very efficient (Australia, California). Rooftop solar PV installed around 2008 may start to see high tariffs ending around 2023 and would be suitable for adding battery storage (selling excess solar at low wholesale prices and buying expensive retail power later would not be efficient). Modest reduction in battery+solar system costs would open up many markets (EU-27, some US states) while bigger cost reduction would make batteries efficient in most locations. Costs would have to fall significantly in some locations like India/China and Canada/Texas where either tariffs are low, energy consumption is high or affordability is an issue.

Ready customer base in rooftop solar PV adopters

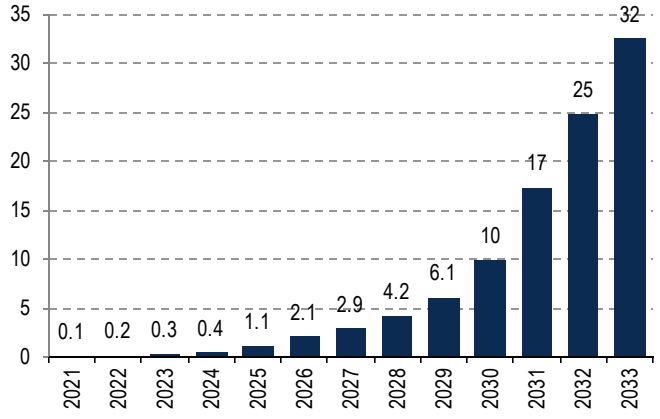
One of the main supports for Home ES is that a lot of homes already have rooftop solar PV, which could benefit from the addition of battery storage. The situation will vary by individual circumstances though. For example, a house with rooftop solar exiting a fixed tariff revenue stream and moving to lower market power prices benefit by adding batteries. This market will be huge in Germany, where already has a sizeable volume of homes are moving from lucrative tariffs to market prices, around 1GW by 2025 and >30GW by 2033. In the US, too, residential rooftop solar is growing rapidly. Although the US ramp up was later than in Germany, the total installed base in the US could be larger over time given the differences between the countries in terms of both scale (# of households) and conditions (bigger houses and more sun-hours in the US).

Chart 46: Rising US residential solar capacity (GW, cumulative) offers scope for Home ES to be deployed in existing or new solar homes



Source: BNEF historical data & forecasts for cumulative US residential solar PV, BofAML Global Research

Chart 47: Solar PV capacity exiting Germany's 20-year Feed-in tariff present a lucrative potential market for battery ES (GW)

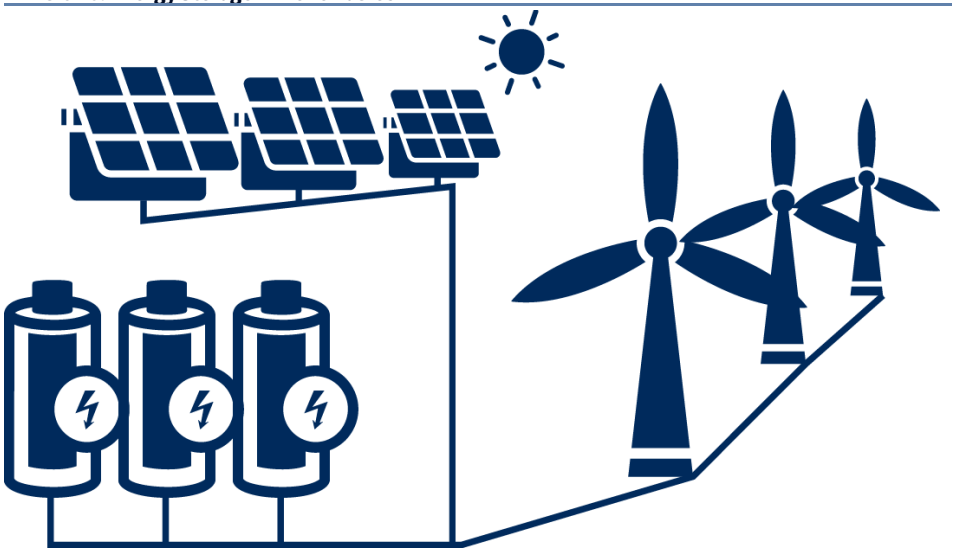


Source: BNEF data, BofA Merrill Lynch Global Research

ES in Renewables: reliable clean energy

SUMMARY
Renewable developers and equipment suppliers are starting hybrid projects, combining renewables (wind/solar/both) with some battery storage, typically 2-4 hours. Such projects can reduce problems such as intermittency, curtailment, low pricing and grid overload. These projects cannot move grid power to 100% renewable or provide long-duration/seasonal storage (summer-to-winter). However, by serving as quasi-baseload, they can help raise renewable penetration overall. Long term, we think renewable auctions may consider including energy storage.

Exhibit 10: Energy Storage in Renewables



Source: BofA Merrill Lynch Global Research

Examples of Hybrid projects

Vestas & Tesla 60MW Australia hybrid renewable: 43MW wind & 15MW solar PV combined with 4MWh Tesla battery to provide grid energy.
Siemens Gamesa 194MW Australia hybrid wind: Siemens Gamesa & Neoen to build 194MW wind park with 20MW/34MWh Li-ion battery.
NextEra Florida 75MW hybrid solar: Largest US renewable developer NextEra building 75MW solar + 10MW/40MWh battery project in Florida.
NextEra Arizona 100MW hybrid solar: NextEra building 100MW solar + 30MW/120MWh battery project in Arizona.
NV Energy Nevada 1.2GW Solar + 0.6GW storage: Nevada utility NV announced plans for 1.2Gw new solar PV and 590MW of battery storage.

Relevant Conditions

Economics: Cheap renewables + some ES to become competitive
Regulation: Government programmes for ES (California, NY, Australia)
Grid condition: Hybrid projects may work well where grids are weak
Renewable penetration: High renewable share to encourage storage
Private demand: Private demand for hybrid projects (e.g. data centers)
Renewable subsidy end: ES enhances value for old off-subsidy projects
Balancing market: Renewables can tap into grid balancing markets
Curtailment: Hybrid ES can help utilise curtailed renewable energy
Better pricing: Store renewables during low prices and sell at highs

Renewables + Energy Storage hybrid projects coming up

Renewables + ES hybrid projects are easy to deploy and scalable

Incorporating some battery energy storage into new renewable projects is relatively straightforward as scalable battery systems can be attached to the electrical systems built for renewables (i.e. balance of plant). There would be some additional civil works required to house the battery systems and some extra service needs. Many utilities, renewable developers and equipment suppliers (both wind and solar) are already collaborating on the first batch of hybrid projects that will come online in 2019-22. ES system sizes can be increased later if needed or retrofitted with existing renewables.

Financial incentive key for developers to install ES with renewables

Renewable developers would consider the financial aspects of adding some battery storage to their projects, assessing drivers such as curtailment reduction, grid capacity optimisation, peak vs. off-peak power price spreads, grid services revenue opportunity and regulatory incentives (such as premiums over auction-based tariffs). In some projects, the economics of putting in energy storage could be favourable. For example, if putting in higher capacity transmission is a bottleneck or where the regulation allows for some ES-related revenues. In other cases, ES may be too expensive, at least for now.

Ability to combine wind, solar & ES to make renewables quasi-baseload

Hybrid renewable + ES projects would allow wind and solar to work better in combination and utilise less battery storage than would have been required for a standalone wind+ES or solar+ES project. This is because solar and wind are complementary (solar in day/summer, wind at night/winter) and hybrid projects are likely to have a more balanced output profile, making it easier and cheaper to incorporate energy storage. Hybrid solar+wind+ES projects would work best in regions which enjoy good resources for both wind and solar (i.e. both windy and sunny). Such hybrid projects could act as quasi-baseload plants with solar strong in the day, wind output intermittent through the day but with higher load factors and ES smoothing out the overall output profile. Such projects are already successfully bidding against new gas plants in some regions, even in the US where gas is cheap due to the shale revolution.

ES with renewables helps with grid issues (congestion, utilisation, curtailment)

One of the main bottlenecks for greater renewable deployment is the slow expansion of electric grid infrastructure, which could be due to either sub-optimal long-distance transmission networks, local/regional distribution grids or bottlenecks at different points/nodes in the grid. In addition, the planning, approval and construction of grids typically take many years. Grid issues can lead to problems such as curtailment (forcing renewables to stop production), limitations on total renewable capacity expansion, grid system bottlenecks during certain times and increased system balancing costs for the system operators due to intermittency. ES deployed with renewable capacity can help

reduce many of these problems by smoothing the output/flow profile. This means more renewables can be deployed for the same grid infrastructure.

Retrofitting ES is attractive for older renewables which are going off subsidies
Older renewable capacities will start to go off subsidies or fixed tariffs period (typically 15-20 years) from 2020 onwards. Post end of fixed tariffs, any renewable output will likely have to be sold at market prices, increasing revenue volatility and reducing realised prices. Typically, power prices are low during times of excess renewable energy, resulting in renewable energy achieved prices being below the average baseload price (e.g., in Spain, c.10-15% discount assumed by regulator). As renewable penetration increases, this problem will become exaggerated. By adding battery ES to renewable projects, especially in older projects rolling over to market prices, achieved prices can be increased by storing during times of low prices and selling during peak prices. Such ES could also earn revenues for grid balancing services. We believe retrofitting ES into older renewable capacity coming off subsidies could be a big theme post-2020.

More auctions or mandates will include ES as a standard element of renewables
We believe more and more renewable auctions worldwide will start to require some ES capacity as standard. This will be driven by multiple factors such as the falling costs of plain-vanilla renewables, declining battery ES costs, increasing renewable penetration, greater intermittency, grid bottlenecks and system balancing costs. Currently, only a handful of hybrid projects include battery storage, but over time we think a sizeable proportion of renewable auctions (perhaps 25-50%) run by governmental bodies will require some as standard. In addition, private procurement of renewable energy via bilateral contracts or Power Purchase Agreements (PPAs) by corporates or industries should start to consider ES an integral part of overall renewable energy procurement.

Energy storage aggregation and part of the future ES virtual power plant
ES with new or existing renewables will be geographically distributed and typically away from demand centers (cities/towns), given wind and solar parks are in more rural areas. The size of such ES system "add-ons" to renewable projects will vary greatly depending on the size of the renewable project itself. As a result, a wide range of ES system sizes is likely to be deployed across regional renewable capacities.

We think new software (including AI-based solutions) and new/existing companies will start to offer "energy storage aggregator" services similar to today's "demand response aggregators" but on a much bigger scale. Demand response aggregators currently have the one-way ability to switch off usage at multiple users to help provide grid balancing services such as load management. ES aggregators would have the two-way ability to generate energy (release from battery) for the grid and consume energy (store in battery) from the grid, which would be significantly more useful than just plain demand response aggregation. ES deployed with renewables will likely form part of a wider "energy storage virtual power plant" in combination with other forms of ES.

Bottlenecks are around suitability of sites & availability of incentives
While it would be nice to add battery ES to all renewable projects, this may not be practically possible for many reasons. There could be issues around servicing and maintenance of batteries if service professionals for wind and solar are not able to service batteries (batteries are more complex, esp. vs. solar). Some sites may be too far away to ensure the physical safety of battery units. There could also be weather issues (too cold or hot) making batteries unsuitable. There might be restrictions around land use due to existing agreements or regulation. Some regions may provide incentives to add ES but others may not, while the economics of adding ES may not be attractive enough. Therefore, ultimately, we think ES in renewables will represent a modest share of total renewable output, but that can still be enough to smooth energy flows.

Relevant conditions to consider for renewables + ES

Economics of renewables vs. peak power prices & other competing technology
If renewables are very cheap relative to prevailing power prices or the cost of energy of new build fossil plants, then adding some battery ES to such renewable projects would make economic sense. Even with the extra costs of the batteries, hybrid renewable+ES projects could compete vs. fossil plants as quasi-baseload clean energy alternatives.

Renewable penetration in the region & resultant excess at certain times
If a certain region has high renewable penetration, the case for adding some battery ES to renewable capacity or to the grid becomes important to balance the system. If renewable penetration is low, then existing fossil fuel plants can play the balancing role, but with a high share of renewables, older less-efficient fossil fuel plants are likely to shut down and then some battery ES would be needed.

Condition of grids
The condition of the grids in a particular region could also make ES with renewables an attractive option. For example, if transmission capacity has bottlenecks, then using ES to store some energy could help build more renewable capacity for the same transmission capacity by smoothing out energy flows. If grids are weak or not interconnected enough, or if available fossil fuel back up is unreliable, then adding some battery ES to renewables might also be a good option both for project owners and the grid system operator.

On-peak vs. off-peak power price variation for market priced renewables
As some older renewable generation capacity comes off subsidies or fixed-tariff periods, output will have to be sold on the power market at prevailing prices. Thus achieved power prices would be low during off-peak periods and high during peak periods. Unfortunately, renewables themselves dampen power prices, for example solar in California or summer in Germany and wind at night. Thus it is quite likely that such market-priced or merchant renewables could end up achieving very low power prices, partly due to their own generation. The problem will become more acute as more renewables are added and the newer ones do not have to worry about prices due to initial fixed tariff periods. We think older renewables will have to consider installing 2-4 hours of storage to optimise achieved power prices, avoid lows and sell at the peaks.

Ability to utilise complementarity of wind and solar
Hybrid wind+solar+battery ES projects would work well in some locations, especially those that enjoy good conditions for both wind and solar. Solar would work during the day, while wind would be more spread out, though typically wind generation is higher at night. By adding some battery storage to combined solar and wind projects, energy output would become smoother and could be considered almost quasi-baseload. Such projects would also require less battery storage per unit of renewable capacity due to the naturally smoother profile arising from the combination of solar and wind, leading to lower costs and better economic rationale.

Suitability of site in terms of service, safety, space & temperature range
Factors such as temperature, site location, safety at site, availability of skilled service technicians and contractual agreements with land owners/authorities could also play an important role in determining whether any particular site is suitable for installing ES. These factors would ultimately affect the economics of investments.

Mandates from regulators to include ES with new renewables

Whether ES is added to new renewables would partly depend on whether the regulation allows for certain revenues for any ES included in the projects. Now, developers could add ES on their own after weighing up factors such as curtailment risks, price arbitrage, grid bottlenecks or balancing revenues. But it would clearly be easier if the regulators were to allow a steady revenue stream for projects with ES as opposed to ES systems being solely dependent on market revenues, especially at this nascent stage.

Better ability to sign PPAs as a quasi-baseload clean energy source

In the private market for clean energy power purchase agreements (PPA), having some ES embedded in hybrid solar + wind projects could allow the developers to offer almost baseload-like clean energy. This could be valuable for power offtakers, such as tech companies building data centers, as they get access to reliable clean energy rather than being dependent on both grid power and renewables.

Economics of ES + Renewables

ES with new renewables – $10-20/MWh for 2-4 hour storage by 2023-25

Once ES system costs come down to $250-300/KWh (vs. >c$500/KWh now), adding 2-3 hours of storage to new renewables could cost as little as additional $10-15/MWh while 4 hours storage may cost additional c.$20/MWh. The cost of add-on ES would be more for those renewable projects which are themselves less competitive, for example in areas with lower resources or higher costs. We think that for the next 5 years or so, until ES costs come down, renewables + add-on ES would be skewed towards the most efficient projects and then later widen out to more projects.

Wind+Solar+ES ought to be cheaper than either Wind+ES or Solar+ES

Costs could be even lower for wind + solar + ES projects as the generation profile would be smoother in hybrid projects and the amount of storage required ought to be less (2 hours instead of 3 hours, for example). We think such economics could push more projects to consider using wind and solar together to complement each other, mainly due to the benefits of having to spend less on ES.

ES with older renewables: peak/off-peak gap & grid service revenues key – not adding ES may not be an option in some projects

Older renewable projects that are coming off subsidies or their legacy fixed tariffs/PPAs ought to be well suited to add-on ES. This is mainly because such projects may still have 5-10 years of life remaining (or even longer) but will have to accept lower market power prices, often skewed towards lower prices.

In many cases, periods of high renewable generation may coincide with low wholesale power prices. This problem will be exacerbated as the share of renewables grows further, to the point that selling non-tariff renewable power on the wholesale market may fetch very little. A famous example is California's duck curve, whereby solar generation is too high during the day and pushes down power prices (sometimes into negative territory).

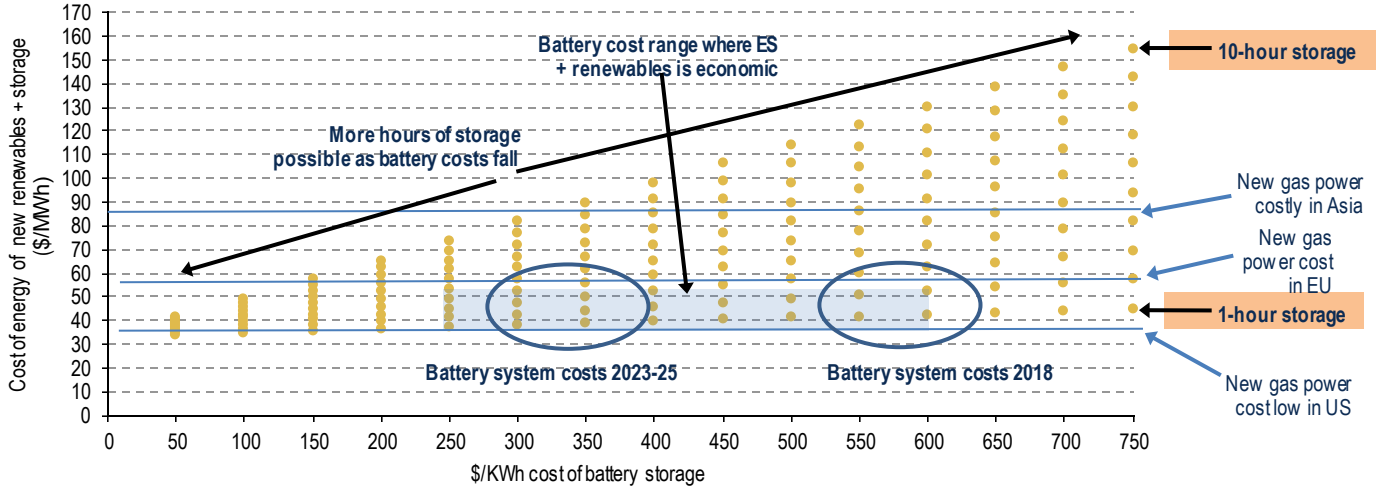
Eventually, we believe owners/operators of older renewable generation capacities might be left with no option but to retrofit some energy storage into their projects. Others may try to terminate their contracts, but in a competitive market for PPAs, installing ES might be a better option as it provides more optionality to sell when power prices are high and also to provide ancillary grid services (frequency response, load management).

More hours of storage would be possible as battery system costs fall

As battery system costs fall, more hours of storage can be installed with renewables as the economics would get better.

- At the current $500-600/KWh ES system costs, 2 hours of battery storage can be added to renewables while still keeping the total cost of energy comparable to grid power.
- Adding more hours of storage, for example 8-10 hours, would push cost of renewables + ES much higher and well above current power prices.
- As battery system costs fall to $300-400/KWh, adding 3-4 hours storage would be feasible for most renewable projects with levelised cost of energy (LCOE) competitive against current power prices.
- If battery costs fall much more, e.g. to $100-150/KWh, then adding more storage hours would be possible.

Chart 48: Number of hours storage that would be possible to add economically would increase substantially as battery costs fall



Source: BofA Merrill Lynch Global Research

"ES in renewables" market potential depends on renewable market growth

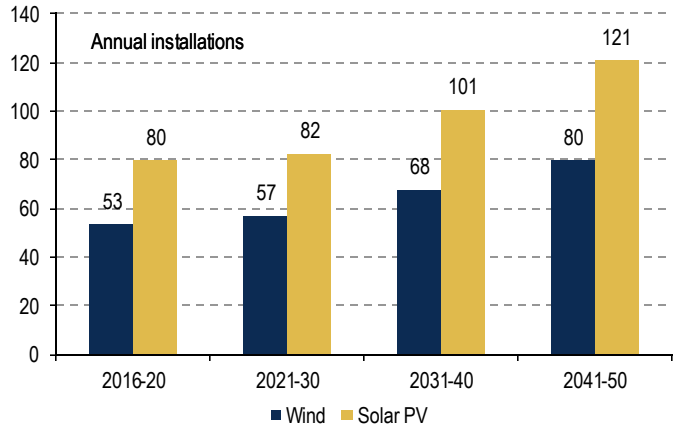
Wind +solar growth: The potential size of the "ES in renewables" market will depend on how big the renewables market will be (annual installations, installed base and total generation).

Proportion of daily renewable output stored: The next step is assessing how much of daily renewable output could be stored.

GWh market: Using daily renewable generation and # of hours stored, it is possible to figure out the market size of "ES in renewables".

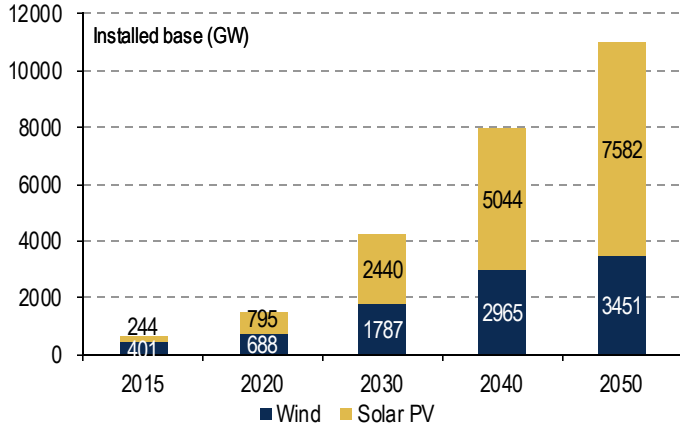
ASP of battery systems: For $bn market size, one has to look at $/KWh system costs.

Chart 49: Global wind/solar installations grow on low-costs & policy



Source: BNEF data, BofAML Global Research

Chart 50: Cumulative global installed capacity of wind/solar to multiply

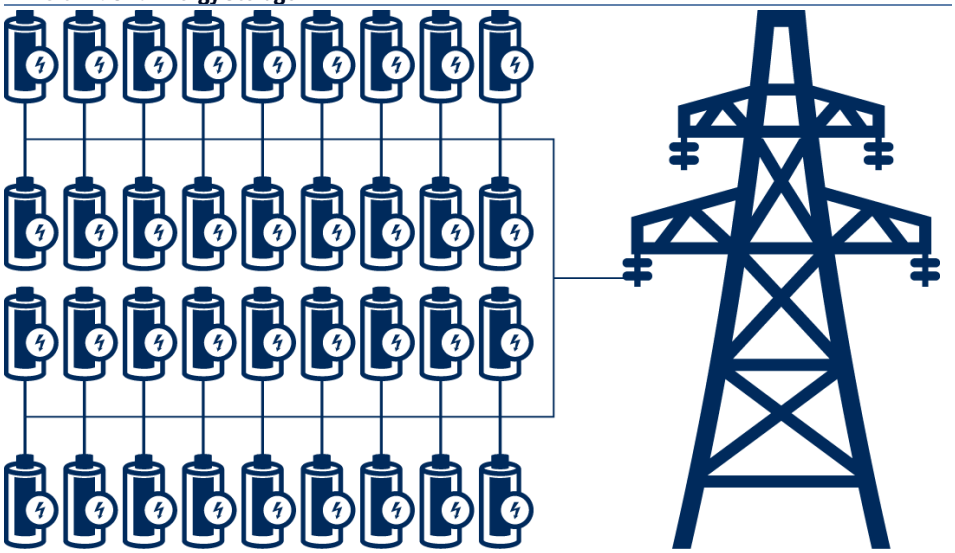


Source: BNEF data, BofAML Global Research

Grid ES: Grid services & peak shaving

SUMMARY
Grid ES are large battery systems connected to the electricity grid to provide important value-added services to the grid. Most electric grids tend to spend large sums on maintaining frequency, meeting peak demand and balancing (plant outages, renewable intermittency). Batteries are well suited to some of these applications as they can respond faster than flexible gas plants or other measures such as demand response. Grid batteries can be expensive since balance of plant (land, civil works, control systems) add to pure battery costs. Revenue models are still evolving but grid batteries have a major role to play in energy storage due to their varied services. Grid batteries are relevant even in less sunny regions, especially where renewable generation is high and/or grids are weak.

Exhibit 11: Grid Energy Storage



Source: BofA Merrill Lynch Global Research

Examples of Grid ES

Tesla 100MW in South Australia: Installed in Dec-17in <100 days as promised by Tesla CEO Elon Musk, this 100MW battery cut grid costs.
55MW in State of Victoria, Australia: Two separate projects of 20MW/30MWh and Tesla 25MW/50MWh + 60Mw solar.
48MW/50MWh in Germany: Eneco, Mitsubishi and NEC built this grid battery in 8 months to store excess wind energy and provide grid services
50MW in Hertfordshire, UK: Housed in seven custom-built 'E-houses', the facility includes 27 inverters and 150,000 lithium-ion battery cells.
200MW/800MWh vanadium flow battery, Dalian China (2020): The largest planned battery system with longer expected life than lithium ion.

Bank of America Merrill Lynch

Relevant Conditions
Grid strength: ES attractive where grids weak (outages, frequency issues)
Peak gap to off-peak: Bigger peak vs. off-peak gap offers opportunities
Renewable resources: More renewables means more ES is preferable
Market structure: LT revenue models can be attractive (esp. regulated)
Economics: Cost of running with and without grid ES key for adoption
Regulation: Mandates to include ES into the electricity system (CA, NY)

Services that can be provided by Grid ES

Grid ES can provide many of the services that grid operators currently get from traditional sources such as fast-response gas plants or even demand response. In many use cases, batteries are a better option – for example they can respond faster and also provide new functionality such as storing excess renewable energy to smooth loads, which is not possible with traditional gas plants.

- **Frequency regulation (10 seconds)** helps balance momentary differences between demand and supply, responding within 10 seconds to maintain system frequency, for example, during an unexpected outage.
- **Spinning reserve (10 minutes)** is capacity that can respond within 10 minutes to compensate for generation or transmission outages.
- **Voltage or reactive power support** ensures the quality of power delivered by maintaining local voltage within specified limits.
- **Load balancing and load management services** – supplies (discharges) or absorbs (charges) power to compensate for load variations.
- **System peak shaving** reduces or defers the need to build new generation capacity or purchase capacity in the market, often during high (peak) demand.
- **Storing excess wind and solar generation** helps smooth intermittency as well as reduce curtailment, shift output from low price times or avoid overproduction penalties. Adding ES can make renewables "quasi" base-load.
- **Arbitrage power prices** – some grid batteries charge when electricity prices are low and discharge when prices are high.
- **Backup power** – for during major natural disasters or grid failures.
- **Limit grid upgrade costs** – adding grid ES can help utilise existing electric grids better given the services batteries provide, especially load shifting.

Grid battery systems more complex than most other ES

Grid batteries can be more complex than other forms of battery storage due to their bigger sizes, the need to interact with the higher voltage grids and more complex management / use cases (frequency response, for example). Apart from the battery modules, grid batteries need to have sizeable temperature management systems, interfaces with the grid, management software/controls compatible with grids and also civil works at the site.

Cost structure of grid batteries

Grid batteries have sizeable balance of plant including wires, management systems (including control centers and software), cooling systems, housing and other site civil work. These add up, taking total system costs to US$500-1000/KWh (early pilots were even more expensive) relative to pure EV battery pack costs of <US$200/KWh and home batteries costing $500-700/KWh. Balance of plant in grid batteries substantially increases the costs, but as the technology and scale improve, we believe total system costs should decrease fast.

Grid batteries are part of the bigger ES ecosystem

Grid batteries would be part of a bigger Energy Storage (ES) ecosystem rather than standalone units. Electric grids would look at all the different ES sources linked to the grid, utilising software to optimise the use of different ES and generating sources (like gas). Grid batteries would be used more for frequency response and load management.

Effective where grids weak or renewable penetration high

Grid batteries would be particularly effective where electric grid systems are relatively old and weak. Installing a large battery on the grid might be a much quicker solution than trying to rebuild or strengthen the grids (takes longer, potentially costs more). In South Australia, where the grid system was weak for various reasons, Tesla's battery helped reduce the balancing costs of the system by some 80% within a year (although this might be an extreme example or an outlier, we feel).

In areas with high renewable penetration, evacuation of renewable power can be a problem when production is very high and transmission capacity is at its limits. Installing grid batteries at such transmission bottlenecks might allow for smoothing the flows and allowing more renewable energy to be utilised (instead of being curtailed). Installing batteries may also help to defer or reduce investments in the grid which would otherwise have been required. Finally, there could also be price arbitrage opportunities.

Pros & Cons of Grid ES vs. other ES

Grid batteries would be better at demanding fast-response tasks like frequency management or load shifting from the grid. They would be more closely connected with the grid system than other types of ES (home, commercial, V2G), enabling grid operators to have remote access via their command centres. Grid batteries would also be well suited to handling bottlenecks in the transmission and distribution networks, for example at pinch points or where there is limited capacity in the grids to evacuate renewable energy at peak times.

That said, grid batteries would likely be more expensive due to complexities and site / balance of plant costs. Home batteries can be almost plug and play (even if they require professional installation) with no major additional balance of plant or management systems. Distributed batteries at home or commercial enterprises may allow for individual demand units (i.e. the household) to be unplugged from the grid, allowing for better load management. This would be especially useful under the aggregation model, where one demand response manager controlling thousands of distributed batteries could provide significantly more flexibility to the grid than a centralised grid battery.

Costs could come down with scale & experience

Given balance of plant is a major cost for grid batteries, this sub-segment of ES should benefit if the value chain can standardise equipment, improve cooling, make units more "plug and play" and reduce the overall costs of deploying systems. These cost reductions ought to be in addition to the cost reductions in pure battery units – the latter are driven more by the expansion and improvement in electric vehicle battery technology and production.

Recycled EV batteries could be a major cost leg down

When substantial annual volumes of electric vehicles start to reach their battery replacement thresholds, there should be recycled batteries available for deployment into stationary energy storage. Electric cars themselves could be used for longer than the battery life (typically 8-year guarantees), so replacing the batteries after 6-8 years could be a logical option. Such older batteries may not remain suitable for transport but could still be useful for less demanding stationary storage..

If the electric vehicle industry finds a cost-effective way of re-using the vehicle battery modules or cells for stationary storage (the cars would be refitted with new batteries), then the cost of stationary storage could be a fraction vs. using new batteries. The challenge is recycling, which would require (1) current EV and ES designs to already anticipate battery re-use in the future, and (2) building out recycling / refitting capacity.

Grid ES a separate sub-market within ES

Grid ES is likely to be a separate sub-market for ES, and it differs slightly from other ES applications such as Home ES or ES with Renewables. This is mainly because the loads and functionality are quite different. For example, Grid ES would be used more for frequency and load balancing in contrast to the higher share of pure energy storage in the case of Home ES and ES for Renewables. The underlying battery chemistries could also be different, as Grid ES is likely to be able to combine a mix of technologies in the same project. For example, Lithium Ion can be used for fast response applications, while other chemistries (Vanadium Redox/Flow), Sodium Sulphur, Advance Lead Acid or Lithium Iron) could be used for long duration storage within the same project.

Grid ES market size variables

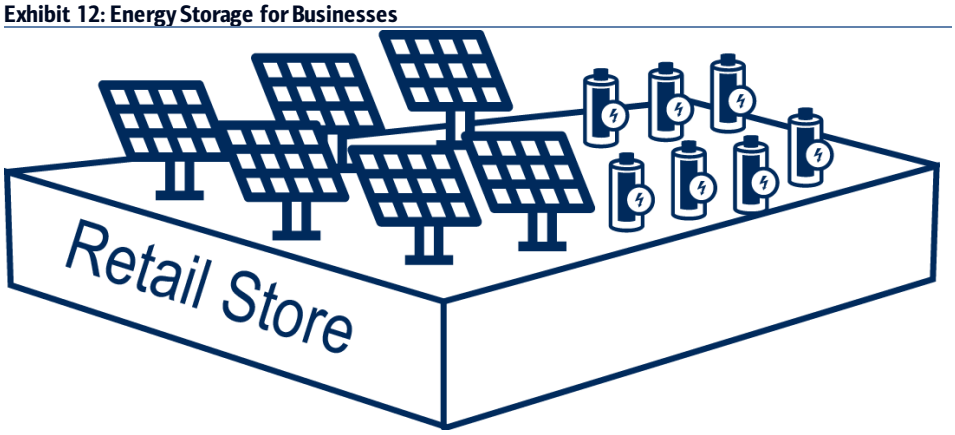
Proportion of daily peak demand key assumption: Typically, peak demand can be around 15-20% of the total hourly demand. Eventually, installed battery capacity would have to cover all of the peak demand in a given country, region or power system.

Grid ES part of broader ES ecosystem: Grid ES will be a part of the overall ES ecosystem which would include other types of ES such as Home ES, Renewables+ES, Commercial ES and other applications (Vehicle to Grid or V2G, ES in micro grids). Depending on how these other ES sub-segments develop, Grid ES needs may vary.

ES for businesses: Economic$

SUMMARY
Energy storage is likely to form an integral part of industrial power procurement as more commercial and industrial premises move to the self-generation + energy storage model. This model however would be more applicable to those factories and commercial complexes with certain attributes such as rooftop space, high power prices, peak-base spreads, corporate renewable goals, security of supply risks and a high share of power in total costs. Corporates have an advantage in terms of being able to make decisions based on a payback period and NPV analysis, while also being able to secure cheap financing amid low bond yields.

Exhibit 12: Energy Storage for Businesses



Source: BofAML

Relevant Conditions
Sun resources: Areas with high solar resources suited to self-generation
Roof Area: premises with more roof area better suited for solar+storage
Power prices: High power prices incentive to move to self-generation
Peak-base balance: High peak-base spread better for storage
Economics/affordability: Electricity costs, payback, NPV analysis
Grid reliability: More attractive if grid prone to outages, natural disasters
Financing: Cheap financing could support self-generation + storage

Businesses may use energy storage for multiple reasons

Many businesses could embrace energy storage due to its multiple benefits, such as maximising self-generation, the ability to arbitrage power price spreads and as back-up power during outages (risks increasing on this front due to climate change). We believe the economics will start to make sense for industrial and commercial customers, albeit depending on their specific situations and ES cost reductions. Businesses that already have rooftop solar in sunny regions could easily install some energy storage to maximise self-generation and enjoy a more stable power profile. Similarly, businesses in areas with high peak-base spreads could use energy storage to optimise their power costs.

However, many businesses may not have rooftop solar or power prices/spreads could be low in some regions, so energy storage would be too expensive there.

Back-up power may be key if climate events increases

Back-up power is set to become an important use case for energy storage with businesses. It will be particularly important if climate change leads to more climate events such as storms, floods, heatwaves and fires, among others. Most businesses consider business continuity important even if it means slightly higher costs vs. grid energy. Some businesses have self-generation and that can be enhanced with energy storage. On-site generators can also provide back-up, but these are typically too expensive for regular use (vs. grid power). Energy storage, on the other hand, can serve the dual purpose of regular use (especially with self-generation) as well as back-up.

Batteries serve many purposes, reducing back up costs

For businesses, batteries can serve many purposes, which can help reduce the costs of the overall system. Apart from maximising self-generation while concurrently providing back-up and reliable power supply, batteries may also be able to earn extra revenues by providing services to the grid that would reduce the cost of ownership for businesses.

Having access to power more important than costs

For some industries, having access to reliable power is more important than just the cost of electricity. Manufacturing has gradually been moving to lower labour cost regions, e.g. first to China but then to Vietnam and Bangladesh. Often, some such locations do not have reliable power supply and, at the same time, power may be a less important input than labour and throughput. It may make sense for such industries to install energy storage to ensure continuous production, especially as this is likely to become a cheaper alternative to on-site generators while grid power may remain unreliable. Even for highly automated industries, having reliable power is key, as disruption can be much more expensive than the extra costs for energy storage.

Vehicle to Grid (V2G): Free fuel?

SUMMARY
Vehicle to Grid (V2G) generates a lot of hype even if there are few practical examples. V2G is a utopian concept whereby most vehicles are electric and enough are plugged into the grid to make the fleet act as a giant battery. The best part is that earnings from using EV batteries for grid services and power arbitrage could offset charging costs, allowing for "free" driving. However, there are also challenges for V2G, such as the value of driving range vs. the value of energy stored for the grid, availability of bi-directional chargers and risks of battery / EV resale value degradation. If all passenger vehicles were electric, cumulative battery capacity could in theory store almost all of global daily electricity demand (even more coverage if commercial/freight were also EVs).

Exhibit 13: Vehicle to Grid

Source: BofA Merrill Lynch Global Research

Examples of Vehicle to Grid (V2G)
Nissan UK pilot: Nissan (using Leaf EV) and Enel started a UK V2G pilot
Renault Zoe Dutch pilot: Netherlands Renault pilot using its Zoe EV
OVO UK trial: 1000 V2G customers with Nissan leaf and warranty for battery, potential to earn by selling power to the grid and drive for "free"
EDF Energy UK Trial: Plan to install 1500 V2G chargers on the premises

Relevant Conditions
Power price spreads: High peak base power spreads good for economics

Parking: Ability to park EV in driveway or connect with grid at work key
EV battery capacity: Higher EV battery capacity more conducive to V2G
Driving range: Remaining driving range could be a factor for V2G take-up
Warranty/Insurance: Impact on EV warranty & insurance due to V2G
EV resale value impact: EV resale value impact a deciding factor for V2G
Bi-directional chargers: Charge points need to allow 2-way power flow
Control software: Specialist control software to manage battery flows
Grid ES schemes: Regulatory schemes to allow & compensate V2G
Ride hailing: EVs used in ride hailing likely not ideal choice for V2G

EV fleet to have immense spare storage capacity for V2G

If all passenger vehicles became electric globally, cumulative battery capacity in the EV fleet could reach c.65TWh – assuming 1.3bn vehicles-in-use globally (source: OICA) were electric and each were to have 50KWh battery capacity. In theory, such a fully electric vehicle fleet would be able to store almost all of global daily electricity demand (c.68TWh). This coverage would be even higher if all commercial and freight road transport vehicles were to also become electric. Road transport battery capacity would be bigger per unit vs. passenger vehicles. Together, the commercial and passenger vehicle fleet could potentially store all of global daily electricity demand, in theory.

V2G has many complexities however

That said, most transport fleet batteries may not be available to use as grid batteries. Among the simpler reasons for this are that only a portion of the vehicles could be on the grid at any time, or the vehicles could be on the road during times of peak electricity demand, only freeing up later in the evening. More complicated reasons could relate to the value of primary use cases vs. energy storage (for example, in ride hailing or taxis, range could be valued more than grid energy storage value) or issues regarding battery or EV resale value degradation. Even the insurance of cars could be affected if used for V2G instead of just for transport, due to the different risks. In addition, infrastructure would have to be upgraded, especially installing bi-directional chargers, which are more complicated (although this should not be a major hurdle in the very long term as charging infrastructure is only expected to be rolled out in numbers over time).

Pros vs. Cons: spare capacity vs. value of driving range

Typical passenger vehicles are likely to have some spare capacity to help provide capacity for energy storage via the V2G model. As an example, if a mass market EV with 200 miles of range, a 60KWh battery pack and <50 mile daily commute wanted to adopt V2G while retaining 50% range for emergencies, then only 25% of the vehicle battery capacity would theoretically be available for V2G (up to 25% used daily, 50% for emergency range and 25% spare capacity for V2G). Of course, not all cars would be connected to the grid at the same time, so the available spare capacity for V2G would be even lower. As for commercial vehicles, whether ride-hailing, taxis, fleet vehicles or vans/light trucks, primary use case and range would be far more important than energy storage use via V2G. Thus, we think that less than 10% of the total EV battery fleet capacity could in practice be available for V2G. This is still substantial, though.

Potential to get "electron" fuel for free?

The potential to get "free fuel" is an exciting concept and could potentially tip the balance in favour of V2G. EV batteries could absorb cheap excess energy at night (off-peak) and release some of it during peak times to earn some extra revenues. OVO Energy, a UK supplier, showed that an EV under V2G could earn c.£300 pa from power arbitrage, fully offsetting the cost of EV charging. There could be even more opportunities as a large aggregated V2G fleet could earn extra revenues from other grid services, not just power price arbitrage.

Regulation and grid policies also need to change

For V2G to pick up, grid operators need to update their rules and regulations to allow such distributed energy storage to interact with and earn from the energy grids. Without the proper protocols, it would be challenging to scale up V2G as interaction with the grid can be a complex matter. However, small-scale wind and solar installations have shown that grid operators would be able to gradually cope with the phasing in of V2G.

Auto OEMs need to take the lead due to warranty issues

We think Auto OEMs could end up taking a leading role in V2G. This is partly due to battery warranty and EV resale value considerations. If Auto OEMs did not provide assurances around battery degradation and resale values, energy suppliers would find it hard to convince EV customers to sign up for V2G, as the value of EVs far exceeds any V2G earnings. Auto OEMs may actually be willing to expand their markets into energy, which they have not been able to do so far with oil (unlike in financing, which Auto OEMs have entered).

Auto OEMs may link up with utilities or energy companies

Auto OEMs could link up with utility or energy companies on integrated energy contracts. Ultimately, the whole energy landscape could be quite complex due to abundant renewables, huge EV fleets and variable pricing. So it might make more sense to partner with energy companies than to go it alone.

"V2G" could boost EV ownership economics

Analysis by our European utilities team suggests that "Vehicle-to-grid" is economically viable at scale and could have major implications across multiple industry sectors, 1) potentially allowing electricity suppliers to offer charging for free ("fuel zero"), thus lowering total cost of EV ownership by up to €300/pa, 2) providing up to €10bn annual margin opportunities for European utilities, 3) hastening the strategic shift of Big Oil towards "new energies" i.e. renewables and electricity retail, and 4) driving increased demand for power semiconductors and inverters.

Energy storage could help expand charging at lower costs

Electric Vehicle charging infrastructure is expected to expand materially in the coming decades as the number of electric vehicles increase. However, such an expansion in electric vehicle charging infrastructure is also expected to increase costs to make the electricity grids more resilient, mainly as EVs require much higher energy flows and especially for fast charging. Investments in sub-stations and other grid assets are expected to be required due to EV charging. However, energy storage could help reduce the need for such grid spend – commercial scale batteries could charge a number of EVs without the need for upgrades to the sub-stations in some locations. Energy storage could help expand EV charging at lower costs and faster compared to upgrades to the grid (which take longer for planning permission and deployment by grid operators). Tesla has already used batteries in such fashion in its supercharger network.

Vehicle to Home (V2H): Drive Plug Power

SUMMARY
Vehicle to Home (V2H) could be one of the most exciting use-cases of energy storage using electric vehicles. Mass-market EVs with ranges of >200 miles are expected to have around 50-60KWh batteries. Daily electricity demand at homes ranges from 10KWh (EU) to 29KWh (US). Once EVs are back at home and plugged in, spare battery capacity could easily power a home for more than a day (up to 5 days in the EU). EVs can then be charged overnight at low off-peak electricity rates, powering both transport and the home with cheap electricity. V2G could be extended to heating as well. It could significantly reduce energy bills and emissions, although battery warranty and EV resale value issues (thus Auto OEMs) would be key

Exhibit 14: Vehicle to Home

Source: BofA Merrill Lynch Global Research

Relevant Conditions
Low off-peak rates: Off-peak electricity would have to be cheap
Driveway: Ability to park EV in driveway and connect to home
EV battery capacity: High capacity EV battery useful to power home
Excess driving range: Smaller commutes would leave spare capacity
Battery warranty: Auto OEMs have to assure on battery warranty
EV resale value impact: EV resale values could be impacted, OEMs key
Home size: Powering small homes with EV would be easier vs. large ones

EVs would have enough spare capacity to power homes

Typical mass-market EVs are expected to have around a 200 mile range and a 50-60KWh battery. Given average daily drives are typically <50 miles per day, there ought to be >35-40 KWh spare capacity in an EV for the vast majority of days in a year even after the daily commute. On the other hand, daily electricity usage in a typical home can range from 10KWh/d (EU) to 29KWh/d (US), although these are averages and there would be regional differences even within the same country/region. Thus, we think a typical mass-market EV could easily power a home for more than a day in more energy-intense regions like the US and up to 5 days in less energy-intense regions like the EU.

EVs can also charge at inexpensive off-peak rates

EVs can be set up to charge at off-peak electricity rates, typically late at night (but possibly in the day in areas with too much solar, e.g. California). Some off-peak electricity rates (5 GBp/KWh) in the UK, for example, can be a third of average rates (15 GBp/KWh) for households. Off-peak rates are not available everywhere but many locations (esp. the US) do offer off-peak rates. As the energy system evolves (more renewables, smart meters, smart appliances), we think time-of-use-tariffs will become common. Thus, EVs would be able to charge at the lowest electricity rates and provide the added benefit of soaking up excess renewable energy from the grid. In future, smart systems could allow EVs to charge dynamically through the day/night at low rates.

Potential to cut energy bills (transport + home) with V2H

Energy bills for households fall into three categories – electricity (lighting, cooking, appliances, air-conditioning), heating (typically gas in developed markets) and transport (for vehicles). We take the UK as an example, even if bills will vary by region. A typical UK household with one car spends >£2700 per annum on energy (£650 on electricity, £650 on gas and £1435 on vehicle fuel). With V2H, households may be able to reduce their electricity bills by a third, from £650 to £427, as per our analysis. The savings in transport fuel expenses would be significant: £1453 with petrol/diesel compared with only c.£160 with an EV using off-peak electricity. It would be more difficult to switch from gas heating due to low gas prices. Still, there may be opportunities for electric heating due to the scope for efficiency (less energy loss, pinpoint heating using smart systems), dynamic pricing (benefit from ultra-low prices during times of renewable excess) and energy storage (incentive from grids to use electricity for heating during certain hours).

Table 4: UK household annual energy bills could look like with V2G vs. now (£ pa)

Type	Status Quo	Using off-peak electricity with V2G	Savings from V2G
Electricity	650	427	223
Gas	650	650	0
Transport (1 Vehicle)	1435	159	1276
Total energy bill of a household	**2735**	**1236**	**1499**

Source: BofA Merrill Lynch Global Research

Need Auto OEMs to facilitate V2H (warranty & resale)

The two big issues for V2H are the warranty of EV batteries and resale value of the EV itself, if used for V2G. Auto OEMs need to provide some assurances on warranties and resale values for EVs used for V2H, otherwise consumers may shy away from using their vehicles to power the home. The annual energy savings from V2H in terms of home electricity may be small relative to the loss of value or risk to battery warranty.

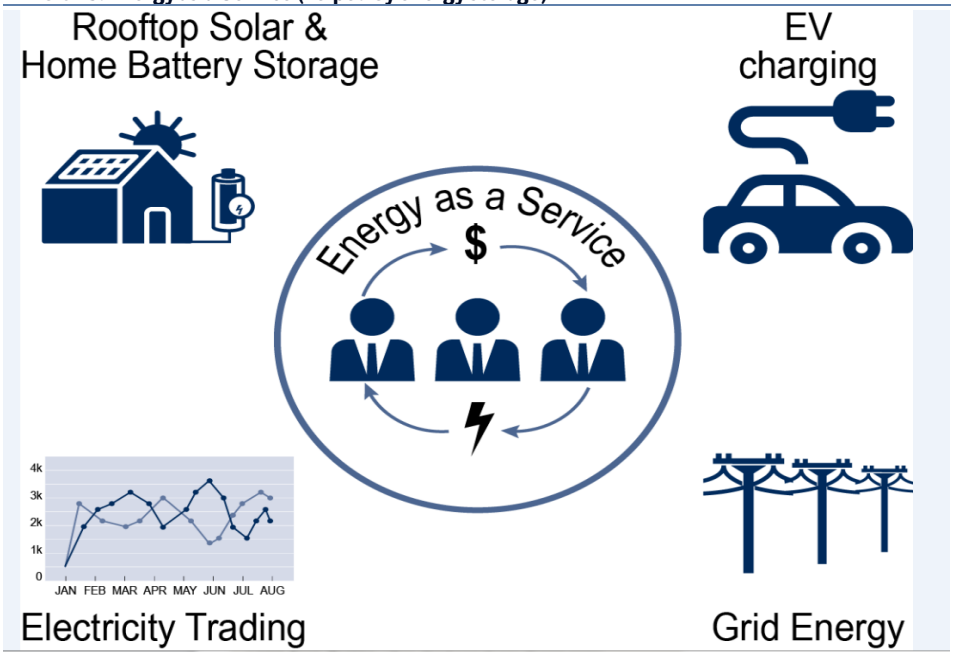
Auto OEMs could tie up with energy companies

Auto OEMs could also tie up with energy companies (utilities, oil companies, smaller companies involved in supply/trading) to help provide the overall ecosystem for charging at off-peak rates. Without an adequate trading set-up, it may not be possible to charge at off-peak rates or benefit from dynamic pricing during times of excess renewables. Furthermore, energy companies may have their own charging networks for times that customers are not at home but need charging. For Auto OEMs, tie-ups with energy companies can help to access power markets and their charging infrastructure.

Energy as a Service (EaaS): Subscription

SUMMARY
Helped by a combination of factors like home energy storage, self-generation, more grid renewables, rise of demand response, smart meters, electric vehicles and smart appliances, energy supply in the future is likely to become an integrated service contract including hardware, energy trading, remote/automated management and maintenance. This will be very different from current plain vanilla gas/electricity supply or transport fuel sales, evolving into a much more technology- and software-driven activity. This will favour those at the forefront of this change.

Exhibit 15: Energy as a Service (helped by energy storage)



Source: BofAML

Examples of Energy as a Services/Products

OVO Energy EV plan: OVO, a UK energy supplier, launched a new energy plan which incorporates EV charging into the contract.
Tonik Energy EV credit: Tonik, another UK energy supplier, offers 2500 free EV miles pa as a credit plus 100% renewables in its energy plan.
Ecotricity half-price highway charging: UK renewable energy supplier Ecoticitry offers half-price highway EV charging in its energy plan.

Relevant Conditions

Rooftop solar: Having rooftop solar would be an advantage in EaaS
Power price spreads: Higher spot power prices spreads better

Renewable share: Rising renewable share to up price volatility & excess
Home battery costs: Lower home battery costs would help adoption
Retail tariffs: High home electricity bills means more room to save
Electric vehicles: Charging EVs provides more room for optimisation
Smart meters: Ability to use time-of-use tariffs would help reduce costs
Electric heating: Ability to heat water during low prices would help

Energy transition could kick-start Energy-as-a-Service

We see the concept of "Energy-as-a-Service" or EaaS potentially starting to pick in the next five years driven by a combination of the following factors.

1) More decentralised energy (esp. rooftop solar)
2) Rising abundance of renewable energy, with more times of surplus
3) Cheaper home battery storage products
4) Leasing model for home batteries, just like rooftop solar
5) Demand response aggregators combining thousands of home ES customers
6) Need to factor electric vehicle charging and vehicle to grid (V2G) into equation
7) Integrated solutions combining self-generation, energy trading, demand response, smart appliances, price arbitrage EV charging and V2G
8) Smarts meters starting to enable time-of-use tariffs which can be used by tech- savvy energy suppliers to manage costs

Traditional energy supply losing its edge

In electricity markets where supply is deregulated and more competitive (e.g. in the UK), such activities are becoming less attractive due to market share losses (to new entrants, esp. online-only) and poor supply margins (competition, regulation, etc). Even in markets where competition is not yet as intense (e.g. continental Europe), new entrant activity is on the rise due to private sector investments via replicating online-only models. With multiple technologies set to transform the energy market in the coming years and decades, we think the electricity supply market could face even more challenges unless it adopts a more nimble approach and starts providing more value-added services such as energy storage and EV charging, i.e. branch out into Energy-as-a-Service.

New-age energy supplier needs to be quite tech savvy

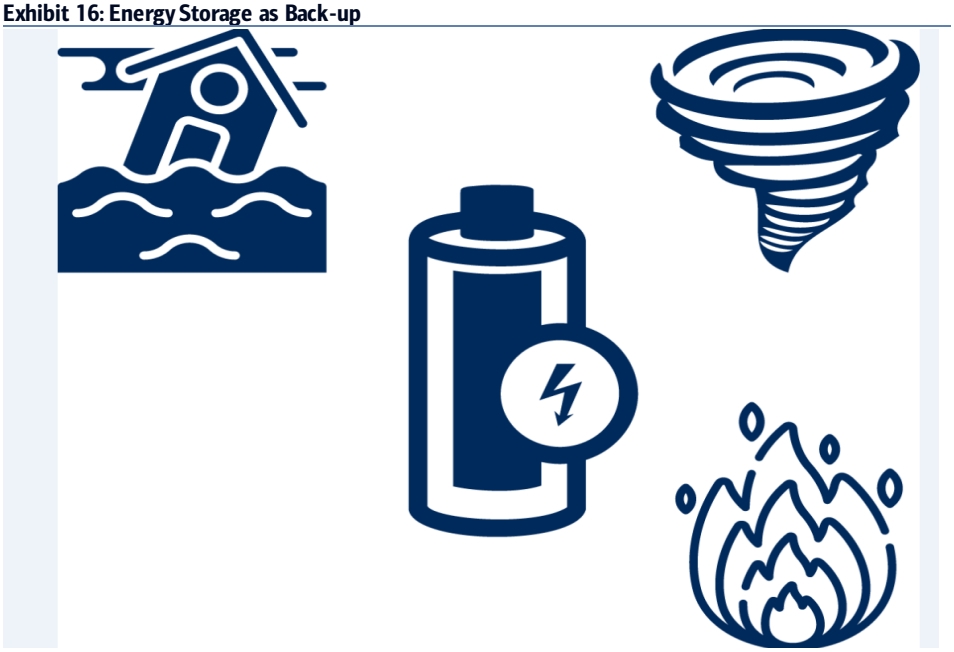
Imagine a future residence at the cutting edge of the transition to clean energy: such a household will likely have rooftop solar, home energy storage, electric vehicle(s), smart meters (with time-of-use-tariff optionality), smart appliances and possibly some supplementary electric heating (in addition to gas boilers). Managing such a complex new system would quickly become difficult for a resident who was only interested in aspects such as ease of use, lower bills and cleaner energy.

Specialist tech-savvy suppliers who can combine all these systems at residences to work harmoniously while also providing additional services such as trading (to buy cheap electricity), aggregation (demand response with batteries & smart appliances) and EV charging (two-way for V2G) would be well placed to capture value. Such savvy suppliers can also provide long-term service offerings to maintain these systems and benefit from recurring business. It would be easy for a specialist supplier to store cheap energy procured via centralised trading in multiple decentralised batteries or to heat up water with electric boilers when power prices are low.

Energy storage as backup: Safety net

SUMMARY
In many locations, back-up electricity is becoming more important due to drivers such as natural disasters (e.g. US storms, wildfires), weak grids (e.g. parts of Australia) and unreliable supply (e.g. emerging markets). These locations are well placed to embrace home energy storage from a back-up perspective, rather than due to pure economics, as the inconvenience of not having electricity is a much bigger issue and the extra cost of the back-up element (net of energy savings) would be small. In fact, homeowners who already have solar could continue to function almost as normal during disasters if they have some energy storage.

Exhibit 16: Energy Storage as Back-up



Source: BofAML

Relevant Conditions
Rooftop solar: Having rooftop solar an advantage for (longer) back-up
Natural disaster: Regions prone to natural disasters more likely to adopt
Weak grids: Weak grids (load shedding) support case for home back-up
Supply deficit: Supply deficits (in EM) support case for home batteries
Income levels: High income regions more likely to adopt home batteries

Back-up power may be key if climate events increases

Climate events, i.e. natural disasters, are becoming more frequent, expensive and disruptive across the world and take many forms (hurricanes, storms, floods and wildfires). In many cases, these can leave households and enterprises with no access to electricity. If the severity and frequency of such disruptions keep increasing due to

climate change, there would be greater need and demand for back-up power, from both households and enterprises.

Batteries serve many purposes, reducing back-up costs

Batteries are the obvious choice for back-up power for most households and enterprises. While end-users could install batteries for the primary purpose of back-up power, batteries could also be used for other operations at different times including storing self-generated renewable power for use during peak hours to save costs and for extra earnings from demand response services. These additional revenue sources would ultimately reduce the cost of back-up power. Another way to look at this is that batteries help provide cheap power through self-generation, power price arbitrage and demand response earnings. Furthermore, they would provide back-up power with limited additional costs.

Having access to power more important than costs

Some enterprises with mission-critical operations or limited tolerance for disruptions (e.g. data centers) would value uninterrupted electricity supply over pure economics. Self or distributed generation coupled with energy storage could make operations more resilient in the face of disruptions in the grid due to natural disasters or other causes. But, at the same time, energy storage could also reduce costs for such enterprises, especially due to the avoidance of transmission/distribution costs as well as government taxes on electricity. Such enterprises could also limit spend on back-up generators.

Higher-income regions would likely value back-up more

Households and enterprises in higher-income developed regions would be willing to put a premium on uninterrupted power supply as opposed to countries used to power outages (e.g. in developing countries). Up until now, grid power has been very reliable in developed countries but risks around reliable power supply are rising due to drivers like ageing infrastructure and higher incidence/severity of natural disasters.

But back-up power can also work in developing regions

While we think back-up power would be valued more in developed regions more used to uninterrupted power, even developing regions with unreliable grid power could be adopters of back-up energy storage. Still, costs would have to fall much further due to affordability issues in developing regions, while the average size of energy storage systems could be much smaller due to lower energy usage there.

Policy should aggressively incentivise back-up batteries

We believe regulators and policy makers should aggressively incentivise back-up power due to the multiple benefits that battery energy storage provides, not just back-up. As the share of renewables in the generation mix increases, having a big base of back-up batteries would make it easier to absorb excess renewable production and balance the grids. Back-up batteries are likely to increase resilience, in our opinion.

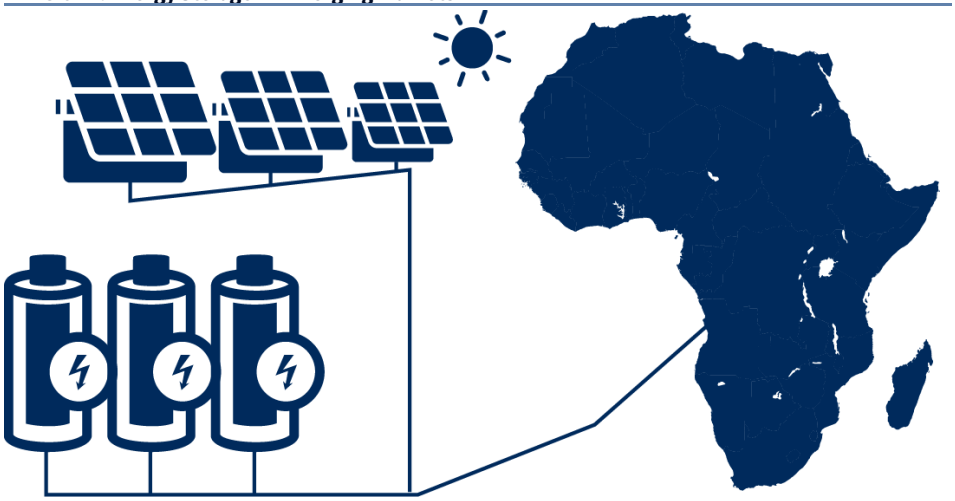
Batteries means less spend on fossil back-up generators

Enterprises looking for uninterrupted power supply invest in back-up generators to protect against unreliable grid power or unexpected outages. With battery energy storage, however, there would be less need to invest in fossil back-up generators. Typically, back-up fossil generators are utilised only occasionally during a year, leading to high fixed costs, while running costs can be high (due to less efficiency vs. grid power). Batteries can be used daily though the year, either with renewable self-generation or arbitraging power prices, meaning system amortisation costs are much lower for batteries vs. generators. In addition, batteries don't use any fuel, so there are no major running costs (except some maintenance), unlike fossil generators.

Energy storage in EM: Power leapfrogging

SUMMARY
Emerging markets are embracing renewable energy at a fast pace and this trend supports the addition of energy storage. Renewables in EM benefit from solid economics, scalability (small to large projects), quick lead times, less reliance on fossil imports, funding availability for green projects and solid sun/wind resources. But EMs also suffer from weak grids amid growing demand, so energy storage could become unavoidable. Micro grids enabled by energy storage and renewables may work well in EM given the difficulty in providing reliable grid power everywhere.

Exhibit 17: Energy Storage in Emerging Markets



Source: BofA Merrill Lynch Global Research

Relevant Conditions
Growing demand: Demand growth supportive of renewables + storage
Unreliable grid power: Unreliable grid power supports energy storage
Solar resources: Good solar resources enable shift to self-generation
Active NGOs: Good network of NGOs and start-ups to enable change
Cheap solutions: Appropriate & inexpensive solutions key for adoption
Financing models: Micro credit/payments & loans key for adoption

Growing energy demand means more power capacity

Electricity demand is expected to increase in most major emerging markets due to factors like population growth and rising per capita consumption from low levels. This means growing demand for new power capacity, increasingly met by new renewables due to better economics and ease of installation.

EMs have good renewable resources

EM countries also have good renewable resources, for example solar in India/Africa and wind in LatAm or other coastal areas. This good resource availability means the cost of renewable energy is now lower than fossil alternatives.

Renewables + ES provides a fast, cheap, scalable option

Cheap renewables coupled with some energy storage can provide cheap dispatchable power in EM. The projects can be small to start with but scaled up as costs come down and expertise improves from experience. Renewables and ES can also be deployed quickly compared with fossil plants, which can take years of planning and construction.

Less need for big fossil projects requiring infrastructure

Fossil generation plants are usually planned to be large in order to benefit from economies of scale. However, this also means the need for good electricity and gas grids as well as other infrastructure such as ports (for coal imports) and landing facilities (for LNG gas). Without the whole ecosystem and a planned large scale, the costs would be too high. Renewable + ES projects do not need to be planned as big and do not require as much infrastructure apart from the grid connection (and even a lower-capacity grid connection may work vs. a big fossil plant). So it would be much easier to build distributed renewables + ES projects than big centralised fossil plants.

EMs lack spare fossil back-up or strong grids, so ES useful

EMs generally lack the spare fossil capacity (old plants) that are currently being used as back-up to manage intermittency in developed markets like Europe and the US. This means building a lot of intermittent renewables in EM without back-up power or energy storage would not be appropriate. We think ES would provide more flexibility (ability to absorb, distributed) than fossil back-up in EM.

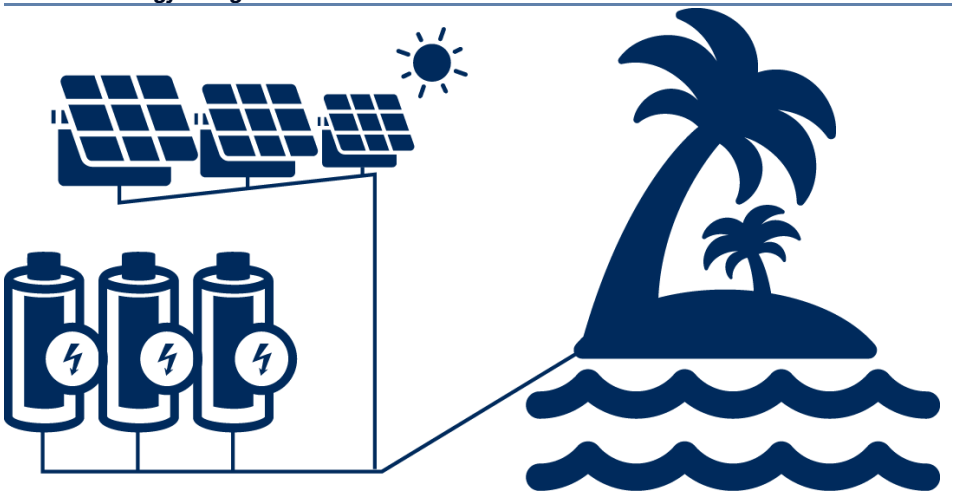
EM already big player in renewables; can be in ES too

EM regions are already big players in renewables. Even excluding China, EM demand for wind and solar could exceed that in the US and EU, mainly due to economics, ease of deployment and leap frogging. We think ES could also become very big in EM due to multiple problems that ES can tackle – lack of fossil back-up, expanding intermittent renewable capacity and lack of overall infrastructure for fossil plants.

Energy storage in remote areas: #1 option

SUMMARY
Regions lacking reliable power supply could benefit immensely from energy storage combined with solar, allowing such regions to leapfrog grid power and go straight to a self-generation model. The market size would be much smaller than the energy-intense developed markets, though, and products/solutions would be very different (small-scale solar + battery lamps or small-scale rooftop + battery solutions). Some islands may be economically well off but still see ES as the way forward (e.g. Hawaii).

Exhibit 18: Energy Storage in remote areas



Source: BofA Merrill Lynch Global Research

Examples of ES in remote areas

Hawaii: First US state with 100% renewables targets (by 2045) and looking at 1.4GWh energy storage by 2022. Utility KIUC to pay $0.11/kWh for power from solar+ES on Kauai, below grid fossil power ($0.15/KWh)
Puerto Rico: After the island's power was disrupted by Hurricane Maria in 2017, the authorities opted for renewables and energy storage. A proposal in 2019 by the power authority calls for 1.1GW energy storage (+ solar).
Thailand: Remote mountain village Ban Pha Dan uses solar + energy storage (lithium, zinc bromide flow) for power vs. candles and oil lamps.

Relevant Conditions

Remoteness: Remote areas most suited to small-scale solar + batteries
Lack of grid power: Limited access to grid power supportive
Solar resources: Good solar resources enable shift to self-generation

Active NGOs: Good network of NGOs and start-ups to enable change
Economics: Appropriate & inexpensive solutions key for adoption
Financing models: Micro credit/payments & loans key for adoption

Remote areas most suitable for solar + batteries

Remote areas, e.g. islands, are well placed to use distributed renewable energy combined with energy storage systems. Hawaii (remote island with high fossil energy costs) and Puerto Rico (the island's power supply was disrupted by a hurricane) are examples where renewables + ES are already starting to become mainstream.

Micro grids a leapfrog option for lagging regions

Small villages in remote areas are suitable for renewables + ES, as building electric transmission and distribution lines to such areas may be prohibitively expensive (which is why so many remote areas are not yet connected to the grid). Areas lacking in access to reliable power grids can adopt self-generation easily but would require ES for steady power flows, for example on cloudy days. Sunnier regions are better suited to this.

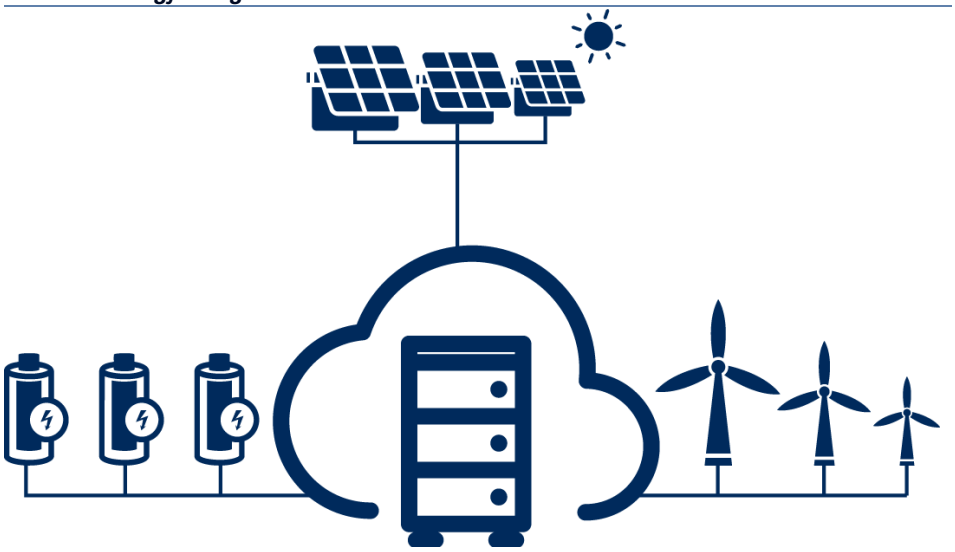
Appropriate financing models and products are key

For renewables + ES to pick up in remote areas, system size and costs would have to be appropriately low while financing solutions (micro finance, subsidies) could also help.

Energy storage: Cloud data opportunity

SUMMARY
Cloud computing and data storage are areas where energy storage has significant potential scope for deployment, in our view. Many data centers already procure renewable energy in bulk (sometimes 100%) partly because renewables can often be cheaper than grid energy (especially directly connected) and power is a key cost. But ES provides additional utility in terms of steady power during intermittency and mission-critical back-up power. As more data centers deploy energy storage, ES capacity can be used for other grid services like frequency management without affecting the data center operations materially and providing additional revenues.

Exhibit 19: Energy Storage for Data Centres



Source: BofAML

Examples of energy storage being considered for data centers

Google white paper on data centers energy use: Google's 2018 white paper on data energy usage suggested 65% of its data centers' demand in some regions could be matched with renewables, but to go higher than this, other solutions such as energy storage would be required.

Microsoft data center with storage: Microsoft's Boydton data center is equipped with extensive battery systems to back up in the event power goes out, but the system is being used for grid energy services, too.

Relevant Conditions

Renewable dependency: More reliance on renewables supports storage

Intermittency: Intermittency profile of solar/wind affects storage needs

Cost of grid power: Expensive (peak) grid power is incentive for storage

Uptime importance: Focus on reliable service supports energy storage
Disaster risks: Regions prone to natural disasters likely to adopt storage
Grid demand response: Use cases where grids allow services from ES

Cloud and data are power-hungry, needing renewables

Total power consumption by all data centers the world over was around 416TWh in 2016, 40% higher than electricity demand in the UK (source: Colocation America). Data centers are power-hungry due to the computing in vast server arrays as well as due to air conditioning needs. Power demand from data centers is growing strongly (18-24% y-y in some locations, as per US utility Dominion) given data volumes are also growing strongly y-y (doubling every 2-3 years), requiring more compute and storage capacity. Power is a key cost in data centers and as most technology companies which own data centers target 100% renewables, procuring clean energy is critical and even economical.

But intermittency requires expanded energy storage

But intermittency of renewables remains a problem for data centers. Some big US technology companies have already achieved their 100% renewables procurement goals as they have been some of the biggest purchasers of renewable energy, especially in the US. However, this does not mean that all their power demand is exactly matched with renewable energy on an hourly basis. Google highlighted in its 2018 White Paper on data center energy that their data centers in locations where they have procured renewable energy were able to match c.65% of energy demand with renewables, with daytime solar generation helping. However, to get much higher levels of direct matching of renewable energy generation vs. hourly data center power demand, other solutions such as large-scale economical energy storage would be critical. Energy storage may still not be able to ensure 100% matching (especially due to seasonal variations), but it can go some way towards higher matching

Disaster planning another reason for energy storage

Data centers require reliable power supply and while grid power has been reliable so far, potential increase in incidence and severity of natural disasters means adding energy storage to the power systems combined with local renewables would provide more resilience if grid power were to fail. Reliability can be a key reason to add ES even if ES itself does not fully solve the intermittency problem.

Grid services from ES could offer new revenues

If data centers add large-scale battery storage systems for their own use, the same batteries would also be able to provide grid services and earn extra revenues, which would help bring down the costs to the data center owners.

Big batteries in data centers means greater influence

Data centers are likely to have to install relatively large batteries if they target much higher levels of renewables and reliability. These large batteries would be easier to control centrally for the purpose of grid services compared with thousands of small distributed batteries (for e.g. Home ES). A collection of data centre batteries could be called upon to help balance the grid and provide services such as demand response.

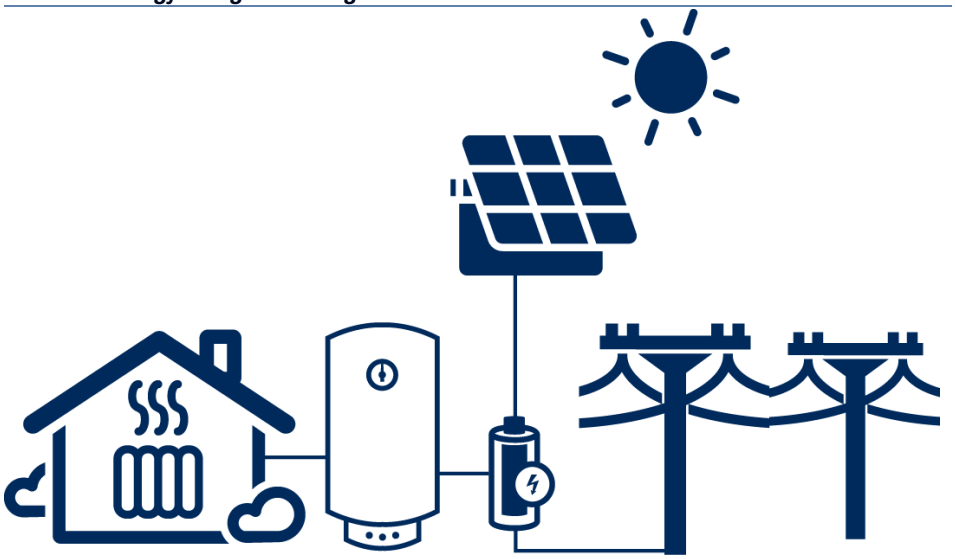
As data/cloud grows, so will renewables & energy storage

ES in data centers can grow strongly due to (1) data centers capacity grows due to rising data volumes and (2) existing data centers either shift more towards renewable energy or increase matching of renewable generation with demand with ES.

Energy storage in heating: Watt to Hot

SUMMARY
Energy storage, whether using batteries or not, could play an important role in heating. In colder climates, which span many energy-intense regions in the US and Europe, heating can be as big an energy expense as electricity. Gas has typically been inexpensive for heating vs. electricity but as excess renewable energy grows in certain hours, electric heating could be used to "store" clean energy, leading to less gas usage and less peak demand for electricity, although this option does not allow release of energy. Batteries could, however, use off-peak and excess renewable energy for either on-premises heating or district heating, increasing efficiency, lowering costs and reducing carbon intensity.

Exhibit 20: Energy Storage in Heating



Source: BofAML

Relevant Conditions
Excess renewables: More reliance on renewables supports storage
Cold climate: Intermittency profile of solar/wind affects storage needs
Heat storage: Expensive (peak) grid power is incentive for storage
Smart meters: Focus on reliable service supports energy storage
Time of use tariffs: Regions prone to natural disasters likely to adopt storage
Smart grids: Use cases where grids allow services from ES

Heating bills can be as big as electricity in some regions

Heating bills are typically as high as electricity bills in some of the colder regions in the world, which tend to be more developed and have high energy usage. Gas is the most widely used fuel for heating and is generally quite economical relative to electricity. However, if abundant renewables bring down the cost of electricity substantially, especially off-peak rates, then there is potential to switch some heating to electric.

Makes sense to store excess electricity in heat tanks

Storing excess renewable energy generation will become an increasingly bigger problem over the coming decades as renewable capacity is set to rise significantly. During times of abundant renewable generation, it would make sense to store the electricity in battery energy storage systems but also in heating (by using electricity to heat water and storing hot water for later use, either home heating or as hot water).

Heat stored in tanks or district heating is one-way flow

There is one major limitation of storing excess renewable electricity as heat given its only a one-way flow. The energy embedded in electricity once stored as heat cannot be converted back to electricity (unless in some special plants).

Batteries could be more flexible, two-way & used for heat

Battery energy storage has the big advantage of serving dual purposes, to store electricity during excess generation and to release electricity during hours of peak demand or low renewable generation. Heating does not provide this two-way flow.

Smart meters/controls, variable tariffs, smart grids key

To be able to use excess electricity in heating, smart meters, time of use tariffs and smart grids would be key. Smart meters enable measurement of electricity usage in small intervals (e.g. every 15 mins) while smart controls can help control heating systems. Variable tariffs (time-of-use tariffs) can allow usage of electricity during off-peaks but smart grids can take this one step further by relaying information about excess renewable generation to smart controls.

High renewables share would allow heating with storage

Very high renewable share in the generation mix would be required for heating to be converted from gas to electric. Without excess renewable energy, it would not be possible to electrify heat in a meaningful way.

Cheap gas, hardware and control systems key obstacles

Gas prices are still very low and therefore heating with gas is economical. This is a major bottleneck for shifting away from gas heating. Another important obstacle is that expensive control & heating systems would have to be installed, and there would also be costs for installing equipment, especially considering the safety risks involved.

Peak shaving means peak coal & gas use

SUMMARY
Energy storage can reduce peak demand which is currently being met with fossil plants. The installed base of energy storage is quite small now but as ES capacity increases every year, it will start to chip away at peak demand. In addition, some peak hours also happen to be the most profitable for peaker plants, so if ES takes share from these profitable hours, then the financial impact could be more than the volume impact. Auctions are already starting to reflect some renewable + ES projects, replacing either new or existing fossil fuel plants. Eventually, as renewable capacity grows and frequency of excess renewable generation increases, ES would be unavoidable and there would less peak demand as a result.

Examples of peak shaving with energy storage
Colorado: Auction for renewable + ES at $45/MWh, among the first
Arizona: Auction for renewable + ES at $30-35/MWh post subsidies but still relatively competitive against peak power and showing falling costs
California: The US state plans to install c.1.8GW of battery storage by 2020 which could satisfy c.4-5% of peak demand (c46GW)
New England: Sunrun won a capacity auction with a 20MW distributed home ES project covering c.5000 homes

Relevant Conditions
Installed energy storage: As installed storage grows, peaks to reduce
Excess renewables: Excess renewables means more storage & less fossil
Peak base spread: Whether peak-base gap can be filled by storage
Policy support: Support for energy storage and penalties for fossil
Utility strategy: How quickly utilities want to reduce fossil usage
Self-generation: More self-generation (solar) means more storage
Cost of maintaining fossil: Expensive to maintain old fossil

Fossil would remain key during tight demand supply

While we think energy storage can help increase the share of renewables substantially vs. a system without energy storage, we believe energy storage will still not mean the full phase-out of fossil electricity generation. Especially in areas with long harsh winters, fossil generation would need to be called upon for 2-3 months at least. Wind generation is typically high in winter months but sometimes there can be weeks without good wind resources and therefore fossil back-up would be required (solar does not work well during dark winter days anyway). Fossil generation may still maintain c.20-25% share in the generation mix (mainly winter) but it would be down significantly from a >60% share now.

But majority of peak demand can be reduced by storage

We believe there would be some need for fossil generation during winter months in the absence of credible seasonal storage. But normal peak demand (typically evenings) can be substantially reduced with the help of energy storage, in our view. 2-4 hours of energy storage would be enough to take out the bulk of the evening peak demand, although some studies show 6-8 hours would be more appropriate.

Batteries can absorb excess renewables, fossil cannot

Batteries can absorb excess renewable generation (e.g. solar during the day) but peaking fossil plants cannot perform this function. Therefore, we believe it would make more sense to use batteries to meet peak demand rather than peaking fossil plants given the multiple uses of batteries, especially absorption of excess renewables.

Batteries better at services like frequency management

Batteries are also better than fossil plants at providing some grid services, for e.g. frequency management and faster ramp-up than a gas plant. Batteries don't pollute, so they can be located nearer to dense load pockets vs. a new gas plant.

Auctions to start pitching energy storage against gas

Already in some regions, auctions for peak energy capacity have seen renewable+ES projects bid and win against peaker gas plants. There have already been some very competitive prices at reverse auctions in US states like Colorado, Arizona and Hawaii. In 2018, Colorado saw renewable + energy storage bids at $30-35/MWh, albeit this includes some tax subsidies (of c30-40%). Still, even excluding the subsidies, bids would have been around $50/MWh which is competitive relative to peak power, costs are expected to fall over time and such storage-enabled projects serve multiple purposes (peak shifting, storing excess renewables, etc).

Multiple types of energy storage to cut peak fossil use

As highlighted through this report, energy storage comes in many forms with the main segments being Grid ES, Home ES and Renewables+ES. Together, the growth of installed energy storage capacity is likely to gradually reduce peak demand in areas where these systems are deployed. Typically, the highest peak periods are also the most profitable for those who own flexible fossil generation assets, so the impact of energy storage systems on profits could be much more than the volume impact.

Excess renewables means energy storage the only option

Given renewables are expected to grow substantially over the coming years and decades, there is no option but to store the excess energy and use this energy during peaks and when renewables are not generating fully. We believe power system regulators will have no option but to focus on energy storage and this is already starting to happen in areas that are seeing very high levels of renewables (e.g. California, Mid-West US states with high wind generation).

Energy companies also considering ES

SUMMARY
Utilities, oil & gas majors and clean energy companies are starting to focus more on energy storage. Many have already started pilot projects or invested in joint projects. Even industrial and battery companies are doing joint pilot projects to learn in these early stages of energy storage. Energy companies that are more focused on the energy transition are more engaged with energy storage, probably because they also own renewables.

Examples of energy storage projects
NV Energy: Nevada utility plans 1.2GW new solar + 590MW battery ES
NextEra: Planned 409MW Florida ES project start by 2021
Xcel: Colorado plan 1.8GW renewables, 275MW ES to replace 660MW coal
AES: Broke ground on a 400MWh ES project in South California in Jun-19
AES: Awarded 100MW ES project in Arizona in Feb-19
Neoen: Owns "within 100-days" 100MW Tesla battery in Australia
Engie: 120MW Ireland ES projects, 90KWh Dutch ES (used EV batteries)
Shell - Sonnen: Shell acquired Germany's biggest ES player Sonnen
AES Siemens JV Fluence: JV has some big projects in the US
Iberdrola: 50MW Scottish lithium-ion ES project approved in 2019

Relevant Conditions
New energy focus: Those with new energy focus more likely to try ES
Regional targets/schemes: New build where there are targets/schemes
Stranded asset mitigation: Energy companies trying to diversify risk
Innovation & growth: Some trying to pilot new projects to learn storage

For energy companies, energy storage is a key future pillar

We believe that energy storage would be a key area of investment for most energy companies, whether utilities, oil & gas majors or clean energy companies. There is a significant amount of capital that needs to be deployed into energy storage, which would bring opportunities for those embracing and moving early.

Many utilities are investing in pilot projects to learn

There are a number of examples of utilities investing in energy storage projects. Most of the major European utilities (Iberdrola, Enel, Engie, EDF, Centrica) and some US utilities in states with high renewable focus (California, Colorado, Arizona, Hawaii, Puerto Rico) have projects already running or being developed.

Storage can reduce price volatility for renewable owners

Utilities that transitioned to renewables early will have some of their older renewable capacity coming off subsidy or fixed-price periods (ranges from 10-20 years) from 2020 onwards. As a result, their renewable output will be more exposed to merchant power

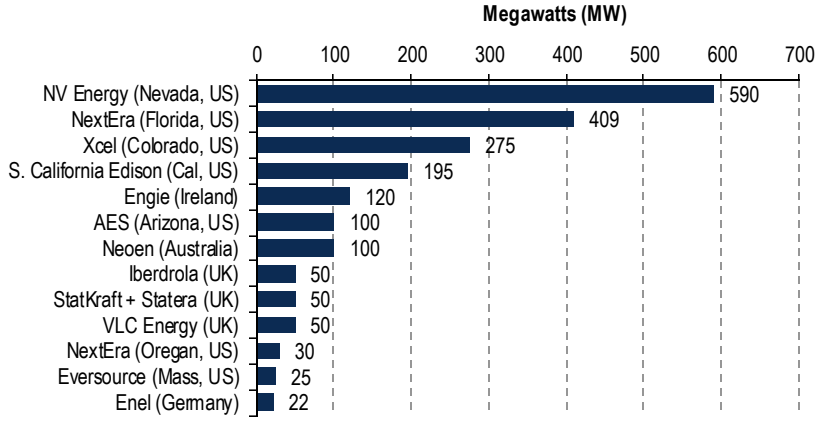
prices with the added disadvantage of potentially low power prices when (their) renewable output is high. We believe energy storage would be most beneficial for such older projects as it can stabilise pricing for renewable generation and potentially also allow the signing of new power purchase agreements helped by more stable output.

Energy storage starting to compete against gas

Some utilities are starting to invest in energy storage either as a replacement for older fossil plants or as an alternative to investing in new gas plants. There are examples in many US states such as California, Colorado and Arizona but also island regions like Hawaii and Puerto Rico. In some cases, like California, solar generation is already high and it makes more sense for regulators/utilities to invest in battery storage than gas as batteries can also absorb excess energy while gas plants cannot.

Chart 51: Utilities looking to build energy storage projects

Announced or completed energy storage projects vary from large to pilots



Source: Company press releases and media.

Oil majors have also shown interest in energy storage

Some oil majors have also shown an interest in energy storage. Shell bought out one of Germany's leading privately owned energy storage companies, Sonnen, in 2019, as the oil major is starting to focus on energy transition (Shell also bought First Utility, its investment in the utility area). BP also mentioned energy storage as one of the five key areas of its $500m pa low carbon investment pledge and, in 2018, announced plans to install a 212KW/840KWh Tesla battery in its Titan 1 wind farm in South Dakota.

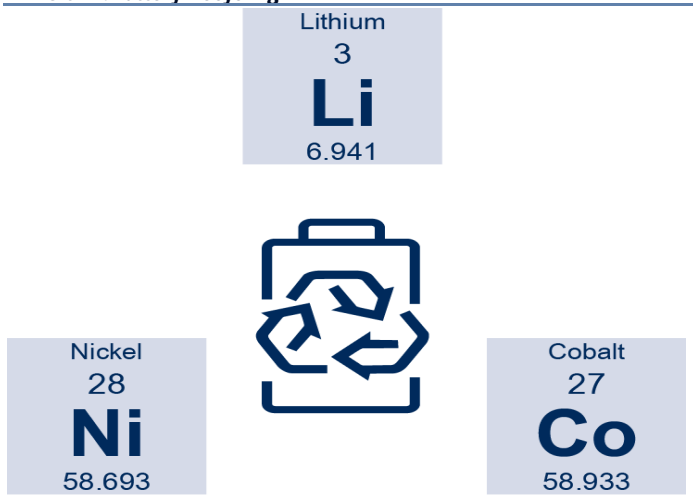
Auto OEMs may also be interested in energy storage

Tesla was one of the early movers in energy storage among automakers, selling home batteries and batteries for industrial/grid installations. However, other automakers also have expressed an interest in ES. Nissan, maker of the electric vehicle LEAF, has projects with used EV batteries (e.g. Amsterdam Arena) and is linking up with partners to sell energy storage products (e.g. with Eaton). Daimler announced its entry into energy storage a few years back but then withdrew some products. In our opinion, automakers could have some involvement in the energy storage market for multiple reasons: (1) greater scale for battery manufacturing, (2) potential second use for old EV batteries, and (3) potential integration of "solar + batteries + energy trading + EV charging" via a new integrated energy offering for home + transport.

Used batteries – Re-use vs. Recycling

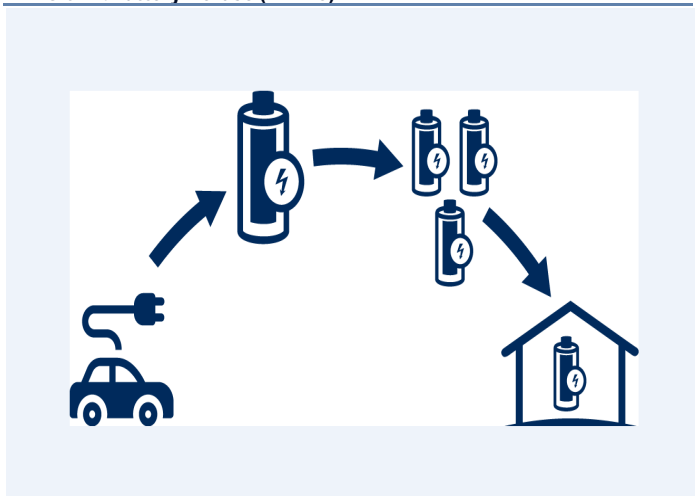
SUMMARY
Whether old EV batteries should be reused or recycled is an important current debate. In terms of re-use, even if EV batteries do not remain suitable for transport after some years of degradation, they can still be used for less demanding stationary storage. As for recycling, materials used for batteries could become quite scarce/valuable, tech improvements may mean multiple batteries can be produced from the same volume of material, and even stationary storage asset life needs to be long. The final outcome will depend on the scarcity of materials, technology and economics.

Exhibit 21: Battery Recycling



Source: BofA Merrill Lynch Global Research

Exhibit 22: Battery Re-use (2nd life)



Source: BofA Merrill Lynch Global Research

Examples of battery recycling and/or re-use

Tesla: Tesla reportedly developing battery recycling system to recover valuable materials for reuse in new battery production (source: Electrek)
Nissan: Nissan has been testing re-use of its used Nissan LEAF batteries for stationary storage (e.g. partnership with Eaton).

Relevant Conditions

Old battery value of material: If materials too valuable, recycling better
Degradation: If batteries degraded, might not be good for storage either
Economics: Cost of recycling vs. cost of reuse
Remaining life: Low remaining life might favour recycling

Battery tech: Fast innovation means more batteries with same material
Material scarcity: Mining & processing may influence reuse vs. recycling

Option 1- Reuse: Old EV batteries in stationary storage

One option is for older EV batteries (say after 6-8 years) to be used in less demanding stationary storage. This could mean a second life for the batteries with another 5-10 years of usage while it would also bring down the cost of energy storage. Nissan has been trialling this via its partnership with Eaton and also other projects (e.g. at the Amsterdam Arena). Engie has trialled an ES project using Renault Zoe's used batteries.

Option 2 - Recycle: extract materials from used batteries

The other option is to recycle the old batteries, extracting all the valuable materials and then disposing off any residual material responsibly. This approach has the benefit of access to scare raw materials while also being able to produce significantly higher volumes of batteries if material usage can be reduced per KWh. Another benefit would be that energy storage systems would get new batteries and therefore last longer vs. systems built with used batteries, although costs could be higher too.

Reuse or recycle will depend on scarcity of materials

We think reuse or recycling of batteries will mostly depend on scarcity and costs of key raw battery materials such as lithium, cobalt and nickel. If such materials become very expensive, it may make more sense to recycle and extract the raw materials for use in new batteries. If raw material scarcity and costs are not as much an issue, then reuse in stationary storage could be an easier second-life option.

Technology improvement will also be a key factor

Technology may also have a major role to play in the reuse vs. recycling debate. It is possible that innovations could lead to a significant reduction in the use of scarce raw materials. If cobalt use is reduced materially over time and cobalt remains scarce/expensive, then recycled cobalt from older batteries could be used to manufacture much higher battery volumes vs. the original battery capacity. For example, if one cell today has 20% cobalt and a new cell in 5 years has only 1% cobalt, then extracting the 20% cobalt from today's battery could help manufacture 20 batteries in 5 years. Furthermore, if battery life and degradation trends improve substantially in the future, the availability of old batteries could be reduced and consumers may prefer the newer battery technology over used ones.

Ultimately, recycling may have advantages over reuse

We think that ultimately recycling could be a more attractive option: (1) materials in high concentration in older generation batteries would be much more valuable for newer generation batteries in future which would use less scarce materials. (2) Consumers of stationary storage would prefer not to have used batteries in their systems over the latest batteries at the time. (3) Battery life and performance could improve so much that volumes of used batteries could be less than would otherwise have been the case. (4) Both recycling and reuse have some associated costs, so the final cost of a new battery with the latest technology and longer life could be actually cheaper than a used battery with limited residual life.

Key battery technologies

The main battery technologies for energy storage are either lithium-based or flow batteries. For now, lithium ion is dominating due to significant cost reductions helped by EVs but flow batteries can also provide attractive characteristics such as long duration energy storage and higher cycles.

Lithium – most common ES battery tech now (EV-led)

Lithium-based batteries continue to be the most commonly used in both EVs and for energy storage. That said, there are other options in energy storage (e.g. flow batteries) which are not applicable for EVs. Within the lithium battery family, NMC (Nickel Manganese Cobalt), NCA (Nickel Cobalt Aluminium) and LFP (Lithium Iron Phosphate) are more commonly used in energy storage. There are some other lithium-based configurations, but for now, those above are expected to dominate unless some other battery breakthrough is made.

Lithium ion NMC or Nickel Manganese Cobalt

NMC is a common battery technology for EV batteries and consequently, also for energy storage products from battery suppliers. Used by Samsung SDI, LG Chem, CATL.

Lithium ion NCA or Nickel Cobalt Aluminium

NCA is used by Tesla/Panasonic for its EVs and also for its energy storage products. For now, Tesla's home battery has among the lowest costs (c$568/KWh vs. peers >$700/KWh).

LFP or Lithium Iron (Ferrous) Phosphate

LFP technology is used by BYD, one of China's biggest suppliers of EVs, industrial forklifts and batteries. It is also used by Germany's leading home ES player, Sonnen (and also used by BYD).

Flow batteries – suitable for longer storage but small now

Flow batteries get their name from their liquid electrolyte which 'flows' through the battery system. Flow batteries could have some advantages vs. lithium batteries such as higher cycle/life and less degradation, but flow batteries have lower density and a larger footprint. In flow batteries, the energy-carrying electrolyte is physically separate from the power-producing stacks (like an engine and fuel tank in an automobile). For longer duration storage, one can have bigger storage containers (although in reality, flow battery systems likely come in standard sizes).

Vanadium Redox (VRB) Flow Batteries

Vanadium redox batteries (VRB) are the most common flow batteries. According to the US Department of Energy, as of June 2018, 856MWh of vanadium battery projects were announced, contracted or under construction in the world. But 800MWh was from the Rongke ES project in Dalian, China (i.e. remaining projects were small).

Vanadium prices went up significantly until the end of 2018 but have fallen sharply in 2019. Vanadium is an additive to steel and steel demand or regulations (stricter China rules on quality forced the use of Vanadium) can impact the market. The cost of vanadium can be significant (30-50%) in a VRB, so prices can affect system costs and therefore demand.

Longer term, vanadium redox flow batteries are expected to be an important part of energy storage solutions, especially for grid energy storage and renewables + ES. Lithium ion is better placed for locations with space constraints, such as homes or commercial premises. According to Benchmark Mineral Intelligence, Vanadium flow batteries could represent 25% of the overall ES market by 2030, although it depends on the industry increasing the production scale and securing stable material pricing.

Other flow batteries

Other flow battery technologies include Iron-Chromium (ICB) and Zinc-Bromine (ZnBr), although these are not yet as established as vanadium flow batteries.

New battery technologies in future

Graphene based ultra-capacitors

Graphene based super-capacitors or ultra-capacitors hold a lot of promise when it comes to e-mobility as well as energy storage. Unlike batteries which hold energy in a chemical reaction, capacitors store electricity in an electrical field. This super-capacitors can benefit from much lower degradation and much faster response times (charging and discharging) than chemical batteries such as those based on Lithium-ion technology. However, there could be challenges such as super-capacitors hold less energy in the same space and there are also concerns around how long they can hold a charge.

One of the benefits of super-capacitors is that they can be combined with traditional batteries to improve the functionality of the whole battery system – e.g. super-capacitors can handle fast response better while Lithium-ion or flow batteries are left to handle longer duration applications. The added benefit would be that Lithium-ion batteries would be spared the high intensity use-cases by super-capacitors, thereby enhancing battery life.

There are a number of start-ups across the world working on graphene-based super or ultra capacitors. There seem to be some early successes across the world, e.g. Tesla acquired super-capacitor start-up Maxwell Technologies in 2019 while Skeleton from Estonia was named by the US Department of Energy as providing some of the best performance in energy storage. Still, its early days and performance/cost data is not available.

Nano technology for batteries

Using nanotechnology for batteries can offer benefits such as reducing fire risk via less flammable material, increasing power density, reducing charge/discharge time by increasing surface area and even enhancing life of batteries by using nanomaterials to separate liquids from the solid electrodes (source: understandingnano.com)

A number of university research projects are experimenting with using nanotechnology to enhance different aspects of batteries. Rice University researchers are using carbon nanotube films to stop the growth of anode dendrites, North Carolina State University researchers are using silicon coated carbon nanotubes to increase power density and Stanford University researchers are using silicon nanotechnology with graphene to reduce degradation (source: understandingnano.com). There are many more examples of experimental nanotechnology that could enhance future batteries significantly

Solid state batteries

In solid-state batteries, both the electrodes and the electrolytes are solid instead of liquid electrolytes used in traditional Lithium-ion batteries. Because of being solid, solid state batteries can get rid of separating membranes and some casings, making them thinner, lighter and more versatile. They may also have greater energy density and may also be safer (due to different non-flammable materials being used). Similar to other battery technologies such as ultra-capacitors and flow batteries, it's still early days for solid state batteries and although they could be a better alternative longer term, real-life data is quite limited at this stage.

Non-battery energy storage

Pumped Hydro

Legacy pumped hydro is currently the most abundant and more economical form of energy storage worldwide. However, building new pumped hydro is difficult due to environmental concerns, lack of suitable sites and costs for new pumped hydro capacity. We think pump hydro will struggle to grow much in the face of effective batteries.

Hydrogen

Hydrogen has been mooted as a long term winner in energy storage, especially due to the ability to store energy for long durations (e.g. from summer to winter). However, hydrogen faces many challenges, especially around round trip efficiency, and has not lived up to its hype so far.

A significant portion of the energy inputted is lost in hydrogen energy storage i.e. during conversion of electricity to hydrogen using electrolysis, during the storing process and finally, during the conversion of hydrogen back to electricity using fuel cells. Due to this efficiency loss, hydrogen has not yet become mainstream as an energy storage option, whether in stationary storage or in transport. The other problem so far has been the lack of scale in hydrogen solutions for energy storage. Still hydrogen has promise in some specific areas such as public transport, long haul road freight and in ships. Some countries like China, Japan and S. Korea are investing in hydrogen.

Solar thermal

Solar thermal technology comprises of flat or parabolic mirrors that concentrate the sun's rays onto pillars containing a molten salt solution, a medium which can store the heat of the sun for many hours. A power plant set-up in the same complex can then use the heat embedded in the molten salt to generate electricity, often with some help from fossil fuels such as gas. Solar thermal plants have been built as long ago as pre 2010 but costs have been high and the industry never benefitted from scale unlike wind and solar PV. Solar thermal does have some advantages, such as the ability to store the energy (in the form of heat) for many hours. There are certain very hot areas where solar thermal might work (deserts) but for now, adoption has been quite limited.

Flywheel & Compressed Air

Both flywheel and compressed air are niche technologies in energy storage. Both use a similar concept – store energy in the form of spinning mass in the case of flywheel and high pressured air in the case of compressed air, to release it later on demand to generate electricity. They benefit from some advantages such as quick response and long asset life (i.e. very high # of cycles). Both technologies are quite niche and do not benefit from scale unlike batteries which get massive scale from electric vehicles.

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