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Tapping Sun Energy coupled with affordable Energy Storage – Future Game Changer

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ABSTRACT

Sun provides abundant source of renewable energy that can be integrated with the electrical grid. Climate change issues have compelled policy makers to look into various ways to reduce carbon footprint and use green, renewable energy. Solar power, along with other alternative sources for energy, is quite popular these days. Talking about Solar, the primary disadvantage of solar power is that it obviously cannot be created during the night and power generated is also reduced during times of cloud cover. Energy Storage is a flexible asset that provides unprecedented flexibility in grid optimization. Cost effective solar energy storage methods are urgently needed due to the increased demand for solar power and due to its variability. But in today's scenario, energy storage systems are not commercially economic for all customers, and that to more work needs to be done by industry, government, and regulators to support the continuing cost reductions. It is expected that the Energy Storage costs would slide to 41% by 2020.The value that solar and storage can together add to the energy system is leading to a more efficient, cleaner, and more secure future. However, solar energy storage becomes critical when unsteady sources of energy provide. Thus, affordable energy storage system along with the cheaper Solar energy would be lethal combination making an ultimate Game Changer for the Power Industry and Sustainability.

Keywords: Renewable energy, Solar energy storage, life cycle, grid integration, sustainable, Solar thermophotovoltaic, Perovskite Solar Cells

Introduction

Today's commercially available renewable technologies can't meet all of the world's energy demands, even if they're scaled up aggressively. U.N.'s Intergovernmental Panel on Climate Change concluded that the world must cut greenhouse gas emissions by as much as 70 percent by mid-century, and to nearly zero by 2100, to have any chance of avoiding warming levels that could ensure sinking cities, mass extinctions, and widespread droughts. So, we need more highly efficient renewable energy sources, cheaper storage, smarter grids, and effective systems for capturing greenhouse gases.

The sun, like most renewables, is not always available. Thus, after the sun set we can't produce solar electricity. So, if affordable mechanism for storing solar energy is available, it will be mother of all innovation and would change the way solar energy is being used. This will clearly help us to limit the use of fossil fuels thereby reduction in global warming, environmental pollution, health hazards and severe consequences on the habitats. Since 2009, solar prices are down 62 percent, with every part of the supply chain trimming costs. By 2025, solar may be cheaper than using coal on average globally, according to Bloomberg New Energy Finance. The solar supply chain is experiencing "a Wal-Mart effect" from higher volumes and lower margins. The speed at which the price of solar will drop below coal varies in each country. Places that import coal or tax polluters with a carbon price, such as Europe and Brazil, will see a crossover in the 2020s.

Currently major focus of scientists is to find new ways to store energy produced by solar PV systems. Currently, electricity is largely a "use it or lose it" type resource whereby once it's generated by a solar PV system the electricity goes onto the grid and must be used immediately or be lost. With the technological advancement, battery storage has offered a way to store energy chemically-especially renewable energy, so that it can be used at the point of demand or to balance grid. With surge in solar and wind power generation and their intermittent nature, the battery storage demand has increased manifold, and now batteries are big enough to give power backup to mega cities. The cost of batteries as of today is big constraint for deployment of grid-connected energy storage systems, but with technological advancement and reduction of battery cost, in near future it is possible to make storage affordable.

Electricity Characteristics and Solar Energy

Two unique characteristics of electricity are: -

1. Electricity is consumed at the same time as it is generated and hence proper amount of electricity must always be provided to meet the varying demand. Due to this, an imbalance between supply and demand will damage the stability and quality (voltage and frequency) of the power supply.
2. Places where electricity is generated are usually located far from the locations where it is consumed and are connected through power grids and transmission, distribution system. This may cause congestion and if a failure on a line occurs due to this congestion, the supply of electricity will be interrupted.

With high PV and wind penetration in some regions, cost-free surplus energy is sometimes available. This surplus can be stored in Electrical Energy Storage (EES) and used to reduce generation costs. EES can lower electricity costs since it can store electricity bought at low off-peak prices and they can use it during peak periods in the place of expensive power. Consumers who charge batteries during off-peak hours may also sell the electricity to utilities or to other consumers during peak hours. Second issue that Utilities face due to characteristic of electricity is to maintain a continuous and flexible power supply for consumers. If the proper amount of electricity cannot be provided at the time when consumers needs it, the power quality will deteriorate and at worst this may lead to a service interruption. To meet changing power consumption appropriate amounts of electricity should be generated continuously, relying on an accurate forecast of the variations in demand.

Power generators therefore need two essential functions in addition to the basic generating function. First, generating plants are required to be equipped with a "kilowatt function", to generate sufficient power (kW) when necessary. Secondly, some generating facilities must possess a frequency control function, fi ne-tuning the output so as to follow minute-by-minute and second-by second fluctuations in demand, using the extra power from the "kilowatt function" if necessary. Renewable Energy (RE) facilities such as solar and wind do not possess both a kW function and a frequency control function unless they are suitably modified. Such a modification may be a negative power margin (i.e. decreasing power) or a phase shift inverter.

Advancement in tapping Sun Energy

Solar PV has specific advantages as an energy source: its operation generates no pollution and no greenhouse gas emissions once installed, it shows simple scalability in respect of power needs and silicon has large availability in the Earth's crust. Growth in solar deployment looks set to continue and will increasingly be recognized as a mainstream energy source. In recent years, solar technology has advanced significantly, with modern panels requiring only daylight, not sunlight to generate electricity. Since solar is a technology, not a fuel, it has seen efficiency increases and costs have fallen over recent years as the technology has matured. However, it is anticipated that there is still significant scope for additional efficiency gains and further cost reductions well into the future as greater research and development is undertaken and overall investment increases.

Cumulative global installed solar photovoltaic (PV) capacity is set to continue its growth from 271.4 Gigawatts (GW) in 2016 to 756.1 GW by 2025, registering a compound annual growth rate (CAGR) of 13.1%, according to research and consulting firm Global Data.

PV systems have the major disadvantage that the power output is dependent on direct sunlight, so about 10-25% is lost if a tracking system is not used, since the cell will not be directly facing the sun at all times. Dust, clouds, and other things in the atmosphere also diminish the power output. Another main issue is the concentration of the production in the hours corresponding to main insolation, which don't usually match the peaks in demand in human activity cycles.

A series of new developments in solar PV technology also promise to contribute to the industry's success. Researchers have longed looked for ways to improve the efficiency and cost-effectiveness of solar cells - the life blood of solar PV systems.

A. Solar thermophotovoltaic (STPV) systems

MIT Researchers in 2014, have developed a new approach to harvesting solar energy that could improve efficiency by using sunlight to heat a high-temperature material whose infrared radiation would then be collected by a conventional photovoltaic cell. This technique could also make it easier to store the energy for later use. In this case, adding the extra step improves performance, because it makes it possible to take advantage of wavelengths of light that ordinarily go to waste.

Conventional silicon-based solar cell doesn’t take advantage of all the photons, because converting the energy of a photon into electricity requires that the photon’s energy level match that of a characteristic of the photovoltaic (PV) material called a bandgap. Silicon’s bandgap responds to many wavelengths of light, but misses many others.

To address that limitation, the researchers inserted a two-layer absorber-emitter device — made of novel materials including carbon nanotubes and photonic crystals — between the sunlight and the PV cell. This intermediate material collects energy from a broad spectrum of sunlight, heating up in the process. When it heats up, as with a piece of iron that glows red hot, it emits light of a particular wavelength, which in this case is tuned to match the bandgap of the PV cell mounted nearby.

Solar thermophotovoltaic (STPV) systems could provide a way to circumvent a theoretical limit on the energy-conversion efficiency of semiconductor-based photovoltaic devices. The Shockley-Queisser limit, imposes a cap of 33.7 percent on such efficiency, but with TPV systems, the efficiency would be significantly higher — it could ideally be over 80 percent. Further optimization, it should be possible to get the same kind of enhancement at even lower sunlight concentrations, making the systems easier to operate. Such a system, combines the advantages of solar photovoltaic systems, which turn sunlight directly into electricity, and solar thermal systems, which can have an advantage for delayed use because heat can be more easily stored than electricity. The new solar thermophotovoltaic systems, could provide efficiency because of their broadband absorption of sunlight; scalability and compactness, because they are based on existing chip-manufacturing technology; and ease of energy storage, because of their reliance on heat.

Thus, this breakthrough in solar thermophotovoltaics, which in principle may achieve higher efficiency than conventional solar cells because STPV can take advantage of the whole solar spectrum. This achievement paves the way for rapidly boosting the STPV efficiency.

B. Perovskite Solar Cells

In April 2017, Researchers from the Australian National University have set a new record efficiency for semi-transparent perovskite solar cells. The record 26 percent sunlight-to-energy conversion was achieved by mechanically combining perovskite with silicon solar cells, a breakthrough that could lower the cost of rooftop solar power systems.

Perovskite solar cells is also promising technology that is cheap, easy to produce, and very efficient at absorbing light. Perovskite’s lattice-like atomic structure gives the material tremendous light-absorbing abilities, and the researchers hope that by pairing it with established silicon solar technology – which currently accounts for 90 percent of the global solar market – they could create a new generation of high-efficiency perovskite-based solar panels.

One of the critical challenges with regards to Perovskite Solar cells has been its durability. The compounds that actually absorb solar energy tend to quickly degrade, particularly in wet and hot conditions.

Energy Storage and its Roles

Energy Storage is one of the key technologies which has unique capabilities in handling critical characteristics of electricity, for variations in demand and price. EES is the way forward towards achieving Energy affordability and will become indispensable in the use of more Renewable Energy (RE).

ES can play following three main roles in Energy space:
1. It can reduce electricity costs by storing electricity obtained at off-peak times, Interestingly, the price during off-peak is lower and this low-cost power can be used at peak times instead of buying electricity at higher prices.
2. It can improve the reliability of the power supply, particularly during natural or manmade disaster during which the power network collapses.
3. It can maintain and improve power quality, frequency and voltage.

ES can solve problems of excessive power fluctuation and undependable power supply – particularly while we use large amounts of RE. In the off-grid domain, electric vehicles with batteries are the most promising technology to replace fossil fuels by electricity from mostly renewable sources.

Key Applications of Energy Storage

A Seasonal storage

The ability to store energy for days, weeks, or months to compensate for a longer-term supply disruption or seasonal variability on the supply and demand sides of the energy system (e.g. storing heat in the summer to use in the winter via underground thermal energy storage systems).

B. Arbitrage/Storage trades

Storing low-priced energy during periods of low demand and subsequently selling it during high priced periods within the same market is referred to as a storage trade. Similarly, arbitrage refers to this type of energy trade between two energy markets.

C. Frequency regulation

The balancing of continuously shifting supply and demand within a control area under normal conditions is referred to as frequency regulation. Management is frequently done automatically, on a minute-to-minute (or shorter) basis.

D. Load following

The second continuous electricity balancing mechanism for operation under normal conditions, following frequency regulation, is load following. Load following manages system fluctuations on a time frame that can range from 15 minutes to 24 hours, and can be controlled through automatic generation control, or manually.

E. Voltage support

The injection or absorption of reactive power to maintain voltage levels in the transmission and distribution system under normal conditions is referred to as voltage support.

F. Black start

In the rare situation when the power system collapses and all other ancillary mechanisms have failed, black start capabilities allow electricity supply resources to restart without pulling electricity from the grid.

G. T&D congestion relief and infrastructure investment deferral

Energy storage technologies use to temporally and/or geographically shifting energy supply or demand in order to relieve congestion points in the transmission and distribution (T&D) grids or to defer the need for a large investment in T&D infrastructure.

H. Demand shifting and peak reduction

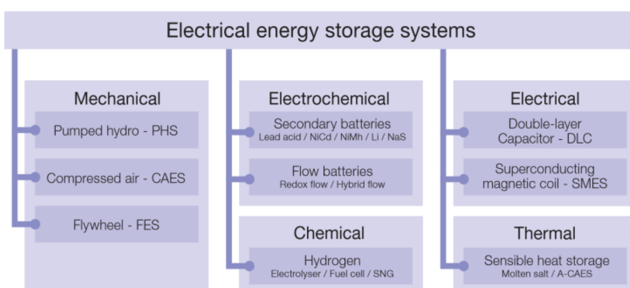
Energy demand can be shifted in order to match it with supply and to assist in the integration of variable supply resources. These shifts are facilitated by changing the time at which certain activities take place (e.g. the heating of water or space) and can be directly used to actively facilitate a reduction in the maximum (peak) energy demand level.

I. Off-grid

Off-grid energy consumers frequently rely on fossil or renewable resources (including variable renewables) to provide heat and electricity. To ensure reliable off-grid energy supplies and to support increasing levels of local resources use, energy storage can be used to fill gaps between variable supply resources and demand.

Classification of Energy Storage System

A widely-used approach for classifying EES systems is the determination according to the form of energy used. EES systems are classified into mechanical, electrochemical, chemical, electrical and thermal energy storage systems.



Issues with Solar Power Generation and Role of Energy Storage

A. Congestion in power grids

This issue is a consequence of the problem, a long distance between generation and consumption. The power flow in transmission grids is determined by the supply and demand of electricity. In the process of balancing supply and demand power congestion can occur. Utility companies try to predict future congestion and avoid overloads, by dispatching generators outputs or ultimately by building new transmission routes. ES established at appropriate sites such as substations at the ends of heavily-loaded lines can mitigate congestion, by storing electricity while transmission lines maintain enough capacity *and by using it when lines are not available due to congestion. This approach also helps utilities to postpone or suspend the reinforcement of power networks.*

B. Transmission by cable

Electricity always needs cables for transmission, and supplying electricity to mobile applications and to isolated areas presents difficulties. ES systems such as batteries can solve this problem with their mobile and charge/discharge capabilities. In remote places without a power grid connection recharging an electric vehicle may present a challenge, but ES can help realize an environmentally friendly transport system without using conventional combustion engines.

C. On-grid areas

In on-grid areas, the increased ratio of Solar generation may cause several issues in the power grid First, in power grid operation, the fluctuation in the output of solar and other RE generation makes system frequency control difficult, and if the frequency deviation becomes too wide system operation can deteriorate. Renewable generation units themselves in most cases only supply a negative margin. If ES can mitigate the output fluctuation, the margins of thermal generators can be reduced and they can be operated at a higher efficiency.

Solar energy output is undependable since weather conditions affect it. The solution for this problem is either we increase the amount of Solar generation, i.e. provide overcapacity, so that even with undependability enough power can be secured. Or else to spread the installations of renewable generators over a wide area, to take advantage of weather conditions changing from place to place and of smoothing effects expected from the complementarity of wind and solar generators. These measures are possible only with large numbers of installations and extension of transmission networks. Considering the cost of extra renewable generation and the difficulty of constructing new transmission facilities, EES is a promising alternative measure.

D. Off-grid areas

In off-grid areas where a considerable amount of energy is consumed, particularly in the transport sector, fossil energy will be replaced with less or non-fossil energy in such products as plug-in hybrid electric vehicles (PHEVs) or electric vehicles (EVs). More precisely, fossil fuels can be replaced by low-carbon electricity produced mainly by renewable generation. The most promising solution is to replace petrol or diesel-driven cars by electric ones with batteries. In spite of remaining issues (short driving distance and long charging time) EES is the key technology for electric vehicles.

E. Smart Grid uses

ES is expected to play an essential role in the future Smart Grid. EES installed in customer-side substations can control power flow and mitigate congestion, or maintain voltage in the appropriate range. EES can support the electrification of existing equipment so as to integrate it into the Smart Grid. Electric vehicles (EVs) are a good example since they have been deployed in several regions, and some argue for the potential of EVs as a mobile, distributed energy resource to provide a load-shifting function in a smart grid. A third role expected for EES is as the energy storage medium for Energy Management Systems (EMS) in homes and buildings.

Advantages from Utility point of view	Advantages from Consumer point of view	Advantages from Generators point of view
• *Deployment of electricity as per demand* • *Supply of Electricity with appropriate voltage and frequency* • *Making more efficient use of the transmission network* • *Isolated grids to supply power to small area*	• *Time shifting/cost savings* • *Emergency power supply and sudden surge in use* • *Use of power for Electric vehicles and mobile appliances*	• *Solar Energy during non-peak hour can be stored using ES* • *Effective connection to grid cost effectively*

Technological Advancement in Energy Storage

Energy storage technologies are receiving a great deal of attention today to make it more reliable and affordable because of their potential to play a key role in the transformation to a low-carbon, clean energy future.R & D efforts are typically focused on advances to make storage affordable with the goal of creating new opportunities for storage on the grid - particularly for technologies that can provide very fast response at high efficiencies.

A company called Sinetech is already designing and building one of the first and most cost-effective lithium solutions available in South Africa: The Power Bank. The PowerBank is a high power and compact 48 V, 6.5 kWh energy storage solution capable of being discharged to 80% for approximately 5000 discharge cycles. One of the best features of The Power Bank is its versatility and affordability, allowing it to be a true competitor even when compared to lead-acid battery prices.

The Omni power Lithium-Ion storage system is extremely cost effective even when compared to high-cycle lead-acid batteries; this is mainly due to The Power Bank's longevity and high cycle life. In order to compare the costs of The Power Bank with that of lead-acid we compare the Rand per kilowatt hour (R/kWh) each technology can deliver, calculated by taking the cost and total kWh over the batteries' life time into account. The life cycle cost of The Power Bank (±5000 cycles) is approximately R 1.85 / kWh compared to that of a high cycle lead-acid battery (±1500 cycles), which is approximately R 3.65 / kWh. From this it can be seen that The Power Bank comes in at almost half the life-cycle cost when compared to lead acid batteries.

Many more companies, institutes, research agencies are investing heavily in this space and some have deployed successful models already, which are expected to become affordable and can be deployed in large quantum.

Solar Affordibility in Future

Levelized cost of electricity (LCOE) is often cited as a convenient summary measure of the overall competitiveness of different generating technologies. It represents the per-kilowatt hour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle. Key inputs to calculating LCOE include capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type.

As per presentation by Michael Taylor,The International Renewable Energy Agency, Photovoltaic Conference 2016. By 2025, LCOEs could fall by: 26% for onshore wind, 35% for offshore wind, 37% for PTC, 43% for ST 59% for solar PV.

Renewable Energy	Investment Costs			LCOE		
	USD/KW		% Change	USD/kWh		% Change
	2015	2025		2015	2025	
Solar PV	***1810***	***790***	***-57%***	***0.13***	***0.06***	***-59%***
CSP (PTC: Parabolic trough collector)	5550	5700	-33%	0.15	0.09	-37%
CSP (ST: Solar Tower)	5700	3600	-37%	0.15	0.08	-43%
Onshore Wind	1560	1370	-12%	0.07	0.06	-26%
Offshore Wind	4650	3950	-15%	0.18	0.12	-35%

Solar Affordability in India

India has been a pioneer in allocating utility scale solar projects through competitive tender process. In contrast to most other large solar markets around the world (China, US, Germany, Japan), which have been allocating projects on a preferential basis by offering attractive feed-in-tariffs (FITs), India started using the auction route for project allocations back in 2010. From July 2015 to December 2016, India allocated 15.9 GW of solar projects.

Recently announced price of INR 3.30/kWh tariff at Rewa Solar Park auction in Madhya Pradesh was among lowest in the world, and marks continuation of downward trend. Although this is the lowest tariff ever recorded in India, this auction had attractive preposition for bidderssuch as recent module price crash, escalation for 15 years, payment assurance, size and location of the projects, deemed generation benefit and construction timeline.

Solar with Storage International

In a report by GlobalData estimated the installed capacity of global battery energy storage system (BESS) from 1.5 Gigawatts (GW) in 2015 to over 14 GW by 2020, as many projects are scheduled to be commissioned over the period.

The report projected the US to continue to lead the BESS market over the next five years, reaching a market value of approximately $1.7bn by 2020.

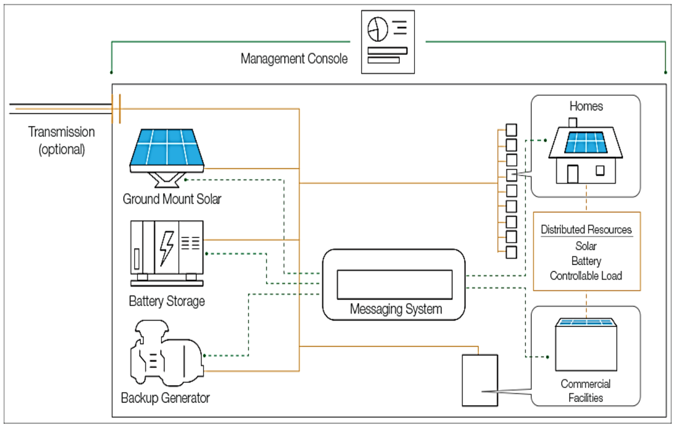
BESS prices are also forecast to decline by about 50% over the 2015 to 2020 period, due to technological innovations, improvement in manufacturing processes, and increase in competitiveness.

The biggest battery storage projects across the globe are:

1. The Alamitos Battery Energy Storage System – AES – 300 MW interconnected and 600 MW of flexible, zero emission battery energy storage
2. EDF Energy Renewables West Burton 49MW Battery Storage Project
3. Centrica’s 49MW Battery Storage System at Roosecote Coal and gas fired power stations in Barrow-in-Furness, Cumbria, UK
4. Tohoku Electric Power Company 40MW lithium-ion Battery Energy Storage System in a power transmission substation in Minami-Soma, on Japan’s east coast in Fukushima prefecture.
5. San Diego Gas & Electric (SDG&E) 37.5MW Battery Projects in San Diego County
6. Duke Energy’s 36MW Notrees Battery Storage Project in west Texas with lithium-ion technology
7. AES 32MW Laurel Mountain Battery Energy Storage at the Laurel Mountain facility
8. Invenergy’s 31.5MW Grand Ridge Energy Storage using BYD America's Containerized Energy Storage System in LaSalle County
9. AltaGas Pomona Energy 20MW of capacity Storage Facility in North America.
10. Southern California Edison (SCE) 20MW Mira Loma lithium-ion Battery Storage Facility by Tesla.

Grid Logic is a turnkey solution from Sun city to obtain clean, affordable and resilient energy as a single service. It's a microgrid-as-a-service solution that provides communities with a way to use locally generated energy to hedge energy costs, while powering critical facilities when the central grid is unavailable. Grid Logic leverages a portfolio of distributed energy resources – including rooftop solar, ground-mounted solar and battery storage – to deliver and balance energy.

The Lyon Group is developing one of the world’s most advanced combined solar and battery storage plant in South Australia’s mining heartland. Known as the Kingfisher Project, the initiative will feature a solar PV plant and a battery storage facility that uses sophisticated system management processes and is connected to a grid with operational mining activities. The project will be connected to the National Electricity Market (NEM) – the wholesale electricity market in Australia. Stage 1 will deliver 20MWdc of solar PV plus a minimum of 2MWhr lithium-based battery storage. Stage 2 will deliver 100MW of solar PV with a minimum 20MWh of battery storage and is expected to operate commercially before the end of 2017. Given current volatility in the South Australian energy market, the battery storage may upgraded to an initial 40MWh. The combination of solar and storage means the facilities can provide high quality, reliable power to large energy users while also potentially avoiding the costs of grid upgrades.



$1 billion battery and solar farm will be built at Morgan in South Australia's River land by year's end in a project the Lyon Group describe as "the world's biggest". River land Solar Storage's 330-megawatt solar generation and 100-megawatt battery storage system will be Australia's biggest solar farm with 3.4 million solar panels and will also include 1.1 million batteries

A. Solar with Storage India

Solar Energy Corp. of India (SECI), is planning to construct two projects of 50 MW Solar each in Andhra Pradesh & four projects of 50 MW solar each in Karnataka with a battery energy storage system of 5 MW/2.5 MW-Hour attached.

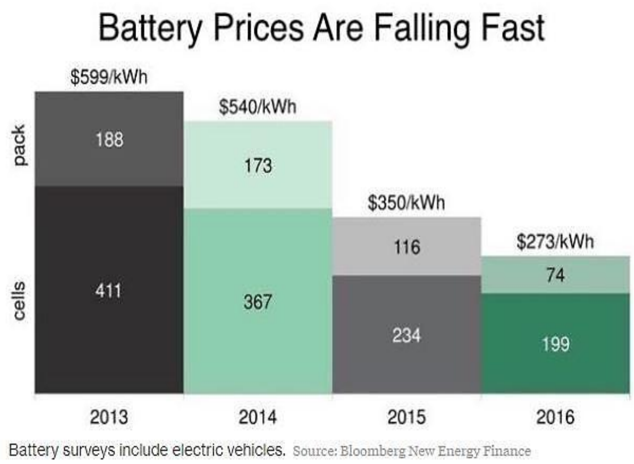
B. Estimated Energy Storage Required

To support electricity sector decarbonization in the ETP 2014 2DS, an estimated 310 GW of additional grid-connected electricity storage capacity would be needed in the United States, Europe, China and India. Significant thermal energy storage and off-grid electricity storage potential also exists.

Probabilities and economics around the affordable Storage

R&D work is currently underway with the primary goals of realizing technology cost reductions and improving the performance of existing, new and emerging storage technologies. Furthermore, many government and industry stakeholders are identifying and attempting to address non-technical barriers to deployment. Looking forward, the most important drivers for increasing use of energy storage will be:

- improving energy system resource use efficiency
- increasing use of variable renewable resources
- rising self-consumption and self-production of energy (electricity, heat/cold)
- increasing energy access (e.g. via off-grid electrification using solar photovoltaic (PV) technologies)
- growing emphasis on electricity grid stability, reliability and resilience
- increasing end-use sector electrification (e.g. electrification of transport sector).



The costs of lithium-ion batteries, which are common in grid-tied residential storage systems, fell by an average of 23% per year from 2010 to 2015, and continued cost reductions contribute to the projections of higher storage deployment in the future (Deloitte 2015, GTM 2016). Still, the costs of residential storage systems remain high relative to the value proposition of these systems—in part due to regulatory and market barriers that impede deployment of storage systems (e.g., see Bhatnagar et al. 2013, Fitzgerald et al. 2015).

While some energy storage technologies are mature or near maturity, most are still in the early stages of development and currently struggle to compete with other non-storage technologies due to high costs. They will require additional attention before their potential can be fully realized. Governments can help accelerate the development and deployment of energy storage technologies by supporting targeted demonstration projects for promising storage technologies and by eliminating price distortions that prevent storage technologies from being compensated for the suite of services they provide.

Levelized Cost of Storage Analysis

Lazard's Levelized Cost of Storage study analyzes the levelized costs associated with the leading energy storage technologies given a single assumed capital structure and cost of capital, and appropriate operational and cost assumptions derived from a robust survey of Industry participants.

Understanding the economics of energy storage is challenging due to the highly-tailored nature of potential value streams associated with an energy storage installation. Rather than focusing on the value available to energy storage installations, Lazard analyses the levelized cost of energy storage technologies operationalized across a variety of use cases; the levelized cost of storage may then be compared to the more specific value streams available to particular installations.

Capital Cost Outlook by Technology from 2015 to 2020			
Sr. No.	**Technology**	**Capital Cost Reduction - Average**	
1	Flow Battery Vanadium	CAGR 5 Year	7% 24%
2	Flow Battery Zinc Bromine	CAGR 5 Year	5% 19%

3	Flow Battery Other	CAGR 5 Year	7% 24%
4	Flywheel Short Duration	CAGR 5 Year	6% 23%
5	Flywheel Long Duration	CAGR 5 Year	11% 37%
6	Lithium Energy	CAGR 5 Year	11% 38%
7	Lithium Power	CAGR 5 Year	7% 24%
8	Sodium	CAGR 5 Year	11% 37%
9	Zinc	CAGR 5 Year	8% 28%
10	Lead	CAGR 5 Year	15% 49%
11	Compressed Air	CAGR 5 Year	1% 5%
12	Pumped Storage Hydro	CAGR 5 Year	1% 5%

Conclusion

From above deliberations, it can be evident that the growth in Renewable Energy is obvious considering climate change obligations and minimizing usage of fossil fuels. From various research reports and trends, it is found that the cost of Solar energy would be lowest in next decade and if coupled with technological advances, affordability of energy storage can become reality in near future. According to Bloomberg New Energy Finance by 2025, solar may be cheaper than using coal on average globally, As per predictions made by International Renewable Energy Agency (IRENA) in conference held in 2016, the LCOE of Solar PV is expected to drop by 59% whereas the Capital cost of installation would come down to 57% during same period. This makes Solar PV one of the cheapest source of Renewable Energy source to be tapped if compared with other RE source.

To support electricity sector decarbonization in the ETP 2014 2DS, an estimated 310 GW of additional grid-connected electricity storage capacity would be needed in the United States, Europe, China and India. Thus, huge storage capacities are required in all developed as well as developing nations. Other than climate change other most important drivers for increasing use of energy storage are demand for improving energy system, use of variable solar power and other RE source, rising consumption, energy access, grid stability and end use sector electrification such as Electrical Cars and Vehicles.

ES is expected to play an essential role in the future Smart Grid. ES installed in customer-side substations can control power flow and mitigate congestion, or maintain voltage in the appropriate range. ES can support the electrification of existing equipment so as to integrate it into the Smart Grid. Electric vehicles (EVs) are a good example since they have been deployed in several regions, and the potential of EVs as a mobile, distributed energy resource to provide a load-shifting function in a smart grid. ES can be utilized as the energy storage medium for Energy Management Systems (EMS) in homes and buildings. Synergies between the transportation due to usage of Electrical Vehicle and power sector along with the expansion of smart grid technologies present very good prospects for energy storage that would benefit all consumers and the entire Power Eco-system.

The cost of batteries as of today is big constraint for deployment of grid-connected energy storage systems as well as the market penetration of plug-in electric vehicles. It is believed that if Battery second-use strategies is applied the scenario would change. In Battery second use strategy, a battery first serves an automotive application and then, when its overall performance no longermeets more stringent automotive requirements, is redeployedinto a secondary grid application—this helps it to address both problems.

Globally lot of installations are being planned with combination of Solar PV with Energy storage. Utility scale PV project with energy storage is being planned in Karnataka and Andhra Pradesh, internationally, Australia has announced one of biggest solar plus energy storage installation. Cost of storage is the biggest constraint but the Lazard Levelized Cost of Storage study have predicted substantial drop is expected in capital cost for all sections of storage technologies from 2015 to 2020. The drop-in Storage capital cost and advancement in storage technology will certainly make Energy Storage affordable in next 5 to 10 years or even earlier. Drop in solar power plant capital cost and technological advancement in solar will bring down solar PV cost and make it most affordable RE source and also lower than Coal Energy. Thus, the combination of affordable Energy storage coupled with affordable, unlimited Solar Energy would make a lethal combination and can be termed as ‘**GAME CHANGER’** in overall Energy Space.

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