Integrating Storage With Renewable Energy: The many scales of Solar Electricity and Energy Storage

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The Socratic method will be used throughout - When I ask a question please provide an answer quickly if you feel you have one.

Background and History Large Scale Energy Storage

Because our electrical power grid must match electricity production to consumption, both of which vary drastically, energy storage and demand response has these advantages:

1) Standard power plants (i.e. coal, oil, gas, nuclear) can be more efficiently and easily operated at constant production levels

2) electricity generated by intermittent sources (solar, Wind) can be stored and used later, whereas it would otherwise have to be transmitted for sale elsewhere, or shut down

3) peak generating or transmission capacity can be reduced by the total potential of all storage plus deferrable loads saving the expense of this capacity

4) more stable pricing – the cost of the storage and/or demand management is included in pricing so there is less variation in power rates charged to customers, or alternatively (if rates are kept stable by law) less loss to the utility from expensive on-peak wholesale power rates when peak demand must be met by imported wholesale power

5) emergency preparedness – vital needs can be met reliably even with no transmission or generation going on while non-essential needs are deferred

To define & explain how Utility and Community Scale Energy Storage (U&CES) operates and the benefits of these systems I will reference LAZARD'S LEVELIZED COST OF STORAGE—VERSION2.0 published in December 2016.

Energy storage system are optimized for a particular use case requiring specified operating parameters (e.g., power rating, duration, etc.). However other sources of revenue may also be available for a given system.

Therefor the total of *all* potential value streams available for a given system thus defines the maximum, economically viable cost for that system.

LAZARD's outline lists the value streams for various applications and provides for understanding U&CES systems.

	USE CASE DESCRIPTION
TRANSMISSION SYSTEM	■ Large-scale energy storage system to improve transmission grid performance and assist in the integration of large-scale variable energy resource generation (e.g., utility-scale wind, solar, etc.) ■ Specific operational uses: provide voltage support and grid stabilization; decrease transmission losses; diminish congestion; increase system reliability; defer transmission investment; optimize renewable-related transmission; provide system capacity and resources adequacy; and shift renewable generation output
PEAKER REPLACEMENT	■ Large-scale energy storage system designed to replace peaking gas turbine facilities ■ Specific operational uses include: capacity, energy sales (e.g., time-shift/arbitrage, etc.), spinning reserve and non-spinning reserve ■ Brought online quickly to meet the rapidly increasing demand for power at peak; can be quickly taken offline as power demand diminishes ■ Results shown in $/kW-year as well as standard LCOS ($/MWh)

FREQUENCY REGULATION	■ Energy storage system designed to balance power by raising or lowering output to follow the moment-by-moment changes in load to maintain frequency to be held within a tolerance bound ■ Specific Use Case parameters modeled to reflect PJM Interconnection requirements ■ Results shown in $/kW-year as well as standard LCOS ($/MWh)
DISTRIBUTION SUBSTATION	■ Energy storage systems placed at substations controlled by utilities to provide flexible peaking capacity while also mitigating stability problems ■ Typically integrated into utility distribution management systems
DISTRIBUTION FEEDER	■ Energy storage systems placed along distribution feeders controlled by utilities to mitigate stability problems and enhance system reliability and resiliency ■ Typically integrated into utility distribution management systems
MICROGRID	■ Energy storage systems that support small power systems that can "island" or otherwise disconnect from the broader power grid (e.g., military bases, universities, etc.) ■ Provides ramping support to enhance system stability and increase reliability of service; emphasis is on short-term power output (vs. load shifting, etc.)
ISLAND GRID	■ Energy storage system that supports physically isolated electricity system (e.g., islands, etc.) by supporting stability and reliability, in addition to integrating renewable/intermittent resources; may also provide balancing service for isolated power grids that integrate multiple distributed resources (i.e., fast ramping) ■ Relative emphasis on discharge endurance vs. simply short-term power output (as in Microgrid Use Case) ■ Scale may vary widely across variations on Use Case (e.g., island nations vs. relatively smaller off-grid, energy-intensive commercial operations, etc.)

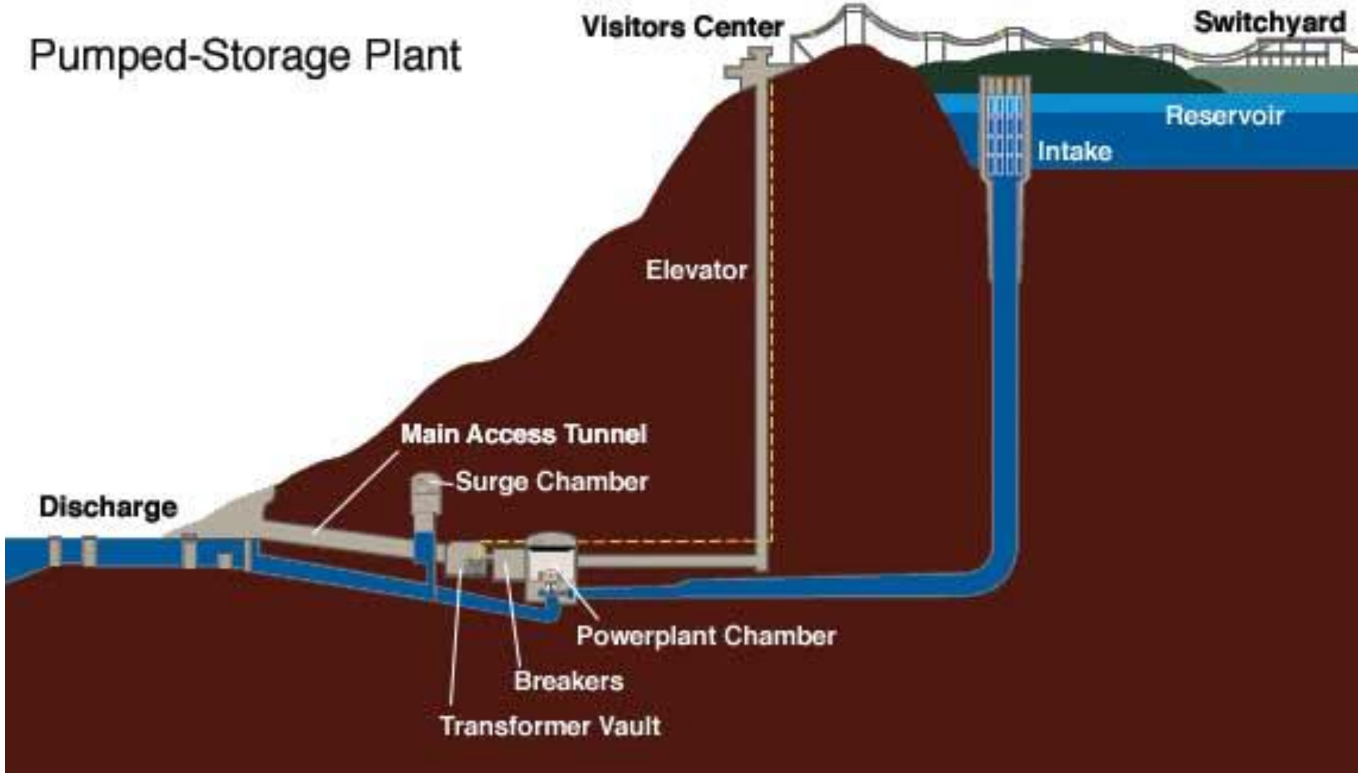
COMMERCIAL & INDUSTRIAL	■ Energy storage system that provides behind-the-meter peak shaving and demand charge reduction services for commercial and industrial energy users ■ Units typically sized to have sufficient power and energy to support multiple C&I energy management strategies, and provide option of system providing grid services to utility or wholesale market
COMMERCIAL APPLIANCE	■ Energy storage system that provides behind-the-meter demand charge reduction services for commercial and industrial energy users ■ Unit contains limited energy and power vs. Commercial & Industrial Use Case—geared toward more modest "peak clipping" to reduce demand charges
RESIDENTIAL	■ Energy storage system for behind-the-meter residential home use—provides backup power, power quality improvements and extends usefulness of self-generation (e.g., "solar plus storage") ■ Regulates the power supply and smooths the quantity of electricity sold back to the grid from distributed PV applications

Defining Storage types:

- Hydro
- Flywheel
- Compressed Air
- Capacitors
- Superconducting Magnetic Energy Storage (SMES)

- Batteries
  - Lead-Acid,
  - Lithium-Ion
  - Flow batteries – Vanadium Redox Vs: Zink Bromide
  - Sodium-sulfur batteries
  - Ni-Cd

Pumped storage is the largest-capacity form of grid energy storage available, and, as of 2017, the DOE Global Energy Storage Database reports that PSH accounts for over 96% of all active tracked storage installations worldwide, with a total installed nameplate capacity of over 168 GW.[3]



The main disadvantage of PHS is the specialist nature of the site required, needing both geographical height and water availability. Suitable sites are therefore likely to be in hilly or mountainous regions, and potentially in areas of outstanding natural beauty, and therefore there are also social and ecological issues to overcome.[9]

Hydro offers advantages of:

Mature technology (commercially available; leverages existing hydropower technology)

High power capacity solution

And disadvantages of:

Relatively low energy density

Limited available sites (i.e., water availability required)

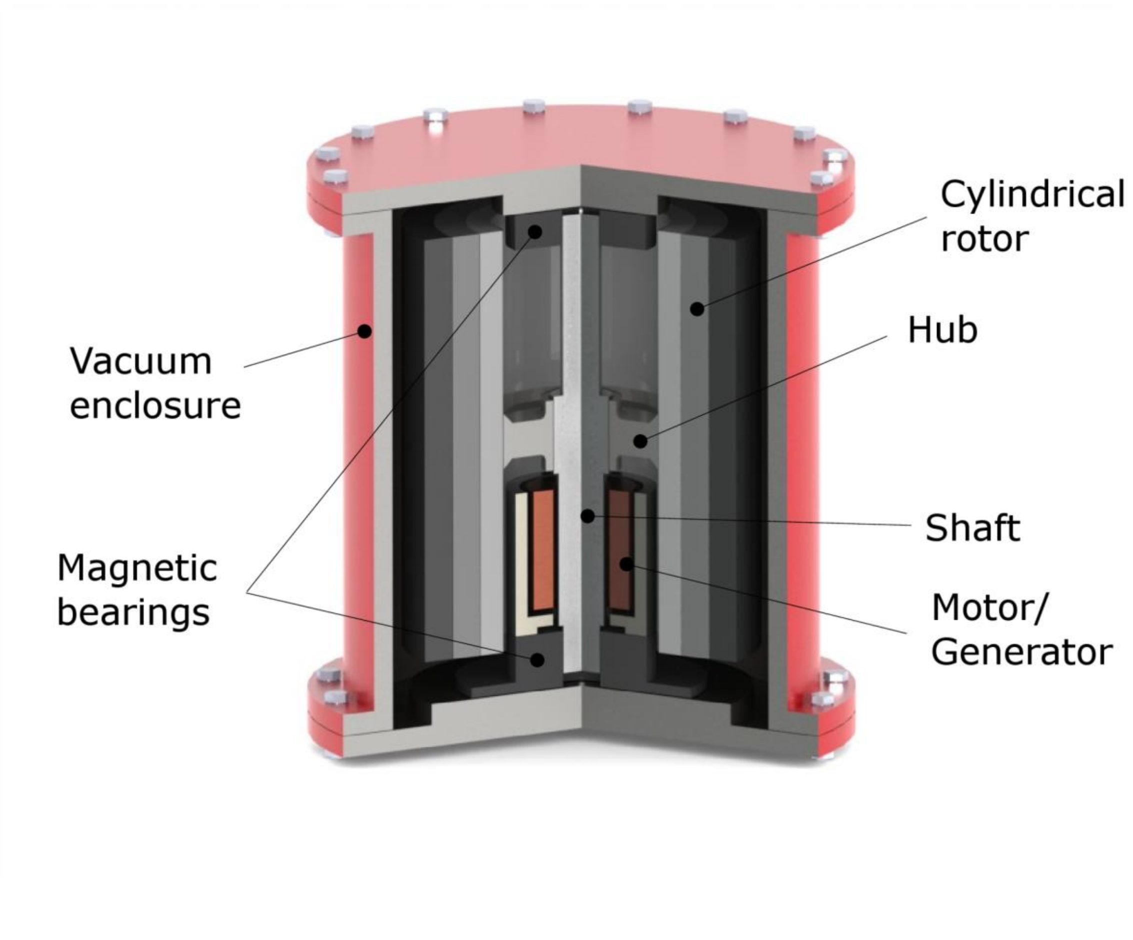
Flywheel:

Flywheel-storage power systems can be a comparatively small storage facilities with a peak power of up to 20 MW or more. They are typically is used to stabilize power grids, to help them stay on the grid frequency, and to serve as a short-term compensation storage. This differs from a Hydro pumped storage power plants that can have capacities up to 1000 MW. The benefits from flywheel storage power plants can be obtained with a facility in the range of a few kW to several 10 MW.

Typical applications are places where electrical energy can be obtained and stored, and must be supplied again to compensate for example, fluctuations in seconds in wind or solar power. These storage facilities consist of individual flywheels in a modular design. Energy up to 150 kW can be absorbed or released per flywheel.

Battery storage power stations can be built with flywheel storage power systems in order to conserve battery power. Flywheels can handle rapid fluctuations more quickly.

While traditional generators can take many minutes to ramp to desired power output levels, Tem



From LAZARD'S LEVELIZED COST OF STORAGE—VERSION 2.0

Flywheel storage has a price range of $342 to $555 for Peaker Replacement service and $502 to $1,251

Flywheel Technology offers-

Advantages of:

High power density and scalability for short duration technology; low power, higher energy for l

High depth of discharge capability

Compact design with integrated AC motor

And Disadvantages of:

Relatively low energy capacity

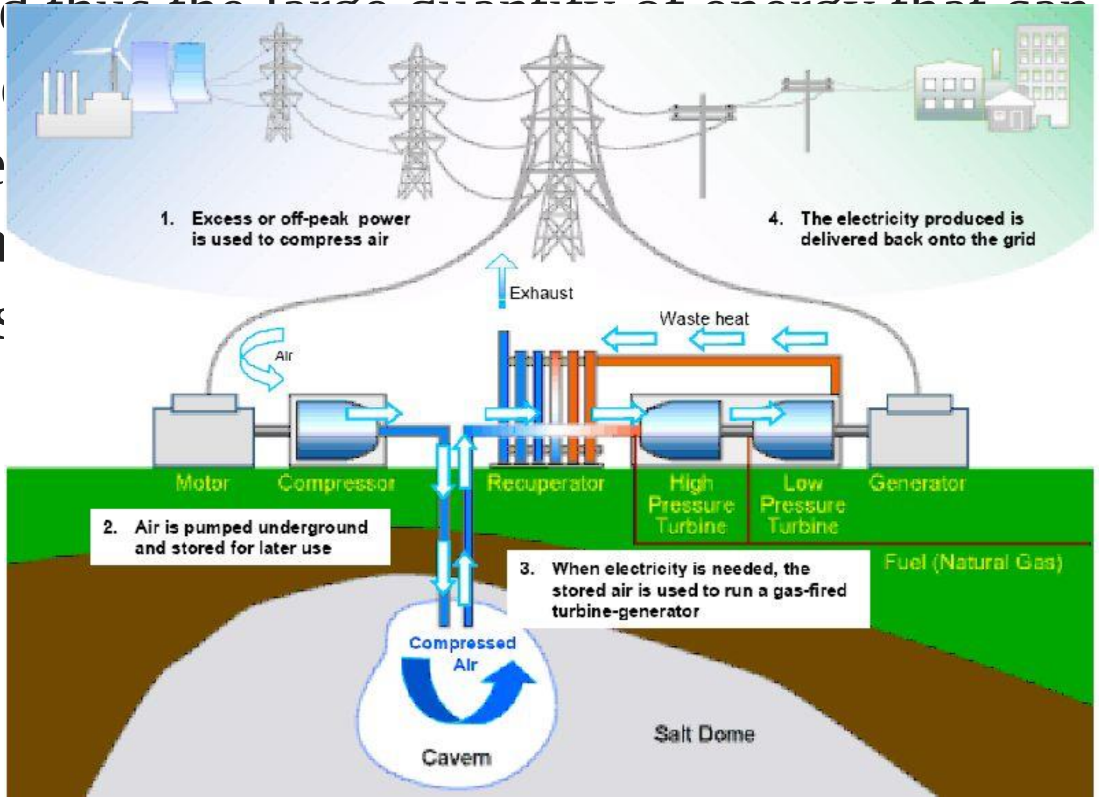
High heat generation

Sensitive to vibrations

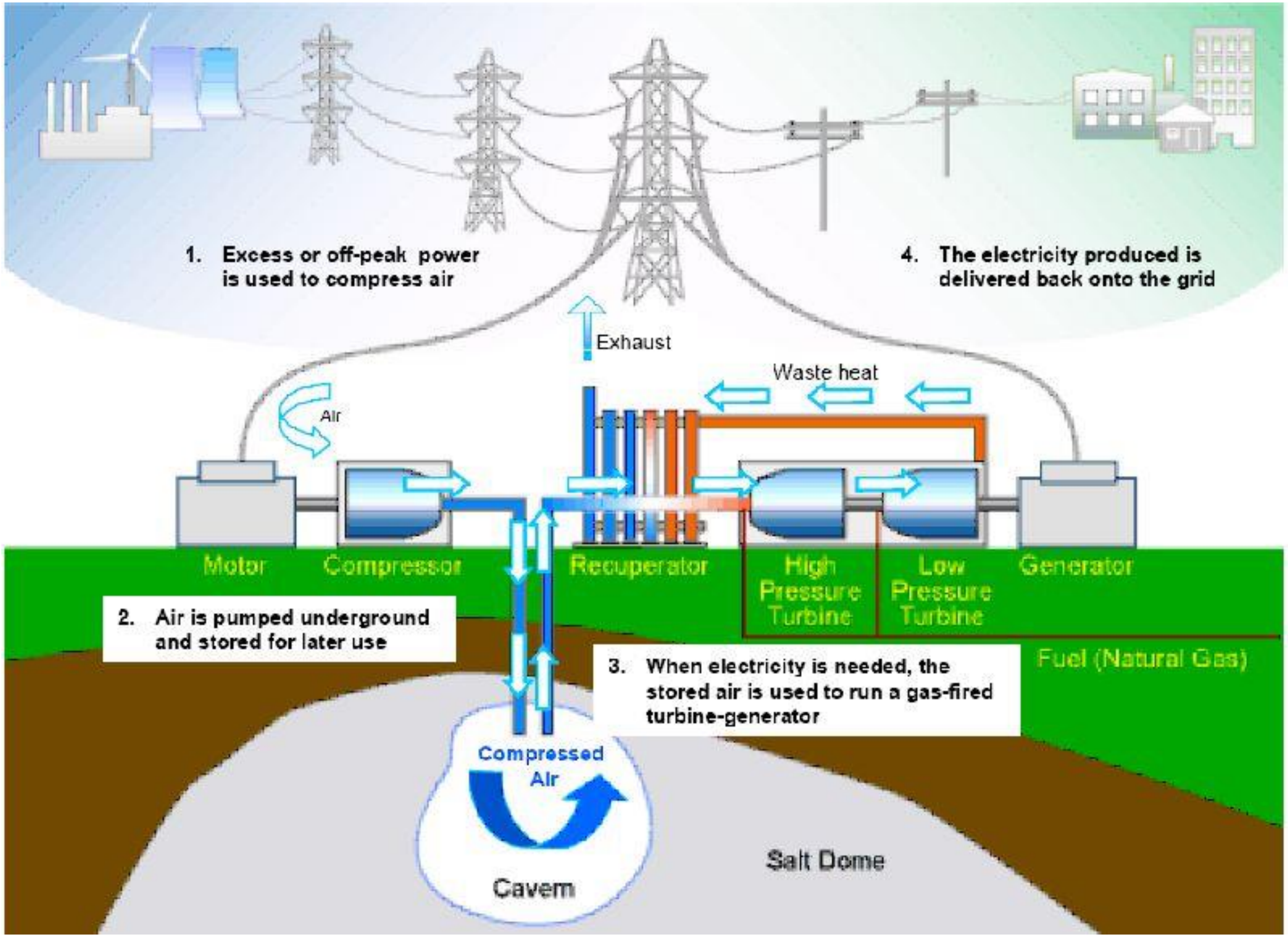
Compressed Air:

Compressed air energy storage (CAES) Stores energy generated at one time for use at another time using compressed air. For use at the utility scale, energy generated during off-peak can be released to meet peak load periods. Large scale applications must conserve the heat energy associated with compressing air; dissipating heat lowers the energy efficiency of the storage system.

Energy storage systems often use large underground caverns. This is the preferred system design, due to the very large volume, and thus the large quantity of energy that can be stored with only a small pressure change. Th
compressed adiabatically with little temperature
isothermal system) and heat loss (approaching a
addition to the low cost of constructing the gas s
walls to assist in containing the pressure.



The Electric Power Research Institute (EPRI) calls CAES a strong energy storage option, that is available now and can store large amounts of energy and release it over long periods of time — both of which are necessary if you're looking at energy storage for the electrical grid.



Compressed Air offers the advantages of:

- Low cost, flexible sizing, relatively large-scale
- Mature technology and well-developed design
- Leverages existing gas turbine technologies

And disadvantages of:

- Requires suitable geology
- Relatively difficult to modularize for smaller installations
- Exposure to natural gas price changes

Supercapacitors:

Supercapacitors for certain short duration services have advantages.

1)They maintain a long cycle lifetime they can be cycled hundreds of thousands times with minimal change in performance. With lifespans from 10 to 20 years.

2)With low equivalent series resistance (ESR), supercapacitors provide short duration high power density and high load currents to achieve almost instant charge in seconds.

3) Temperature performance is also strong, delivering energy in temperatures as low as –40◦C.

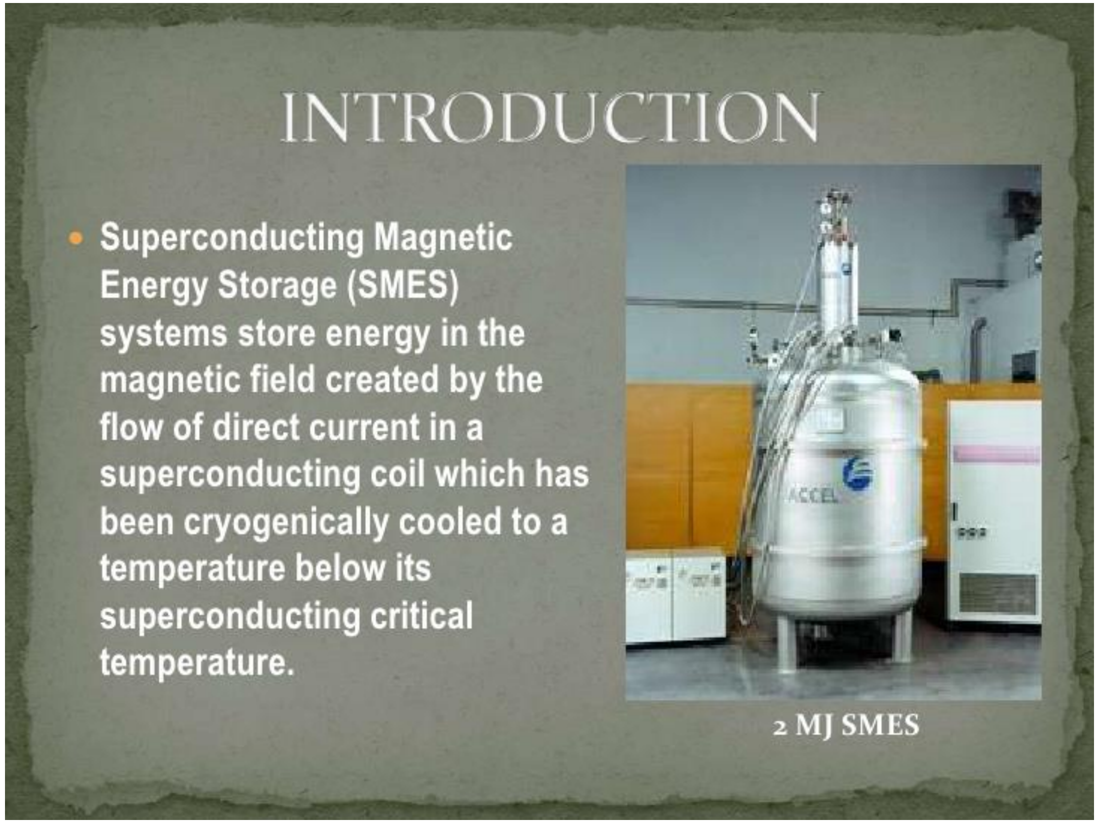
Supercapacitors benefits are offset by their low *energy* density. Thus, they can’t be used as a continuous power source. One cell has a typical voltage of 2.7 V, therefor many the cells must be connected in series to achieve useful voltages.

Superconducting Magnetic Energy Storage (SMES):

Due to its very high cycling capacity and high efficiency over short time periods SMES is very well suited to high power short duration applications. They are used in many voltage stability and power quality applications, for example to provide very clean power in microchip manufacture.

On-site SMES is suitable to mitigate the negative impacts of renewable energy in power quality related issues, especially with power converters – needed for solar photovoltaic and some wind farms – and wind power oscillations and flicker.

Disadvantages with SMES is the very high capital costs of the cooling units required, which use either liquid helium at 4.2K or super-fluid helium at 1.8K.



Video Break:
Elon Musk’s vision:

(View Tesla Introduction video:

Min.1-6,   + 11.50 to end…)

Batteries:

- Lead-Acid
- Lithium-Ion
- Flow batteries – Vanadium Redox Vs: Zink Bromide
- Sodium-sulfur batteries

Lead-Acid:

Lead-Acid(LA) batteries were deployed in Utility scale storage early on providing a mature solution to the use of batteries in energy storage.

With the competition from other battery chemistries LA batteries have evolved to attempt to compete. As of 2015 the 2nd largest battery energy storage project was Duke Energy Notrees Wind Storage Demonstration Project. Using Xtreme Power’s battery technology an advanced starved-electrolyte lead-acid battery developed for electric vehicle applications.

Lead-Acid:

Advantages:

Mature technology with established recycling infrastructure

Advanced lead-acid technologies leverage existing technologies

Disadvantages:

Poor ability to operate in a partially charged state

Relatively poor depth of discharge

and relatively short lifespan

The Disadvantages of LA batteries are highlighted by this story from GTM:

The Risks of Novel Batteries Wearing Out Before Their Time by Jeff St. John July 08, 2015

Duke Energy's decision to replace 36 MW of Xtreme lead-acid batteries shows the risks of backing emerging storage tech.

Last week, Duke Energy announced it is "repowering" its 36-megawatt, 24-megawatt-hour energy storage project at the Notrees wind farm in Texas. Over the next 18 months or so, Duke will be replacing the facility's advanced lead-acid batteries, built by bankrupt startup Xtreme Power, with lithium-ion batteries from Samsung SDI. The plan is to have the last Xtreme systems out by the end of next year.

"When we began participating more and more in ERCOT's fast-responding regulation service market, we found the original technology was not the best fit for the purpose we were using it [for]," Duke spokesperson Tammie McGee said in an email last week. "We expect the lithium-ion batteries to follow demand much more quickly. They'll boost rapid response capabilities, optimize the life/output of the batteries, and lead to a higher level of performance."

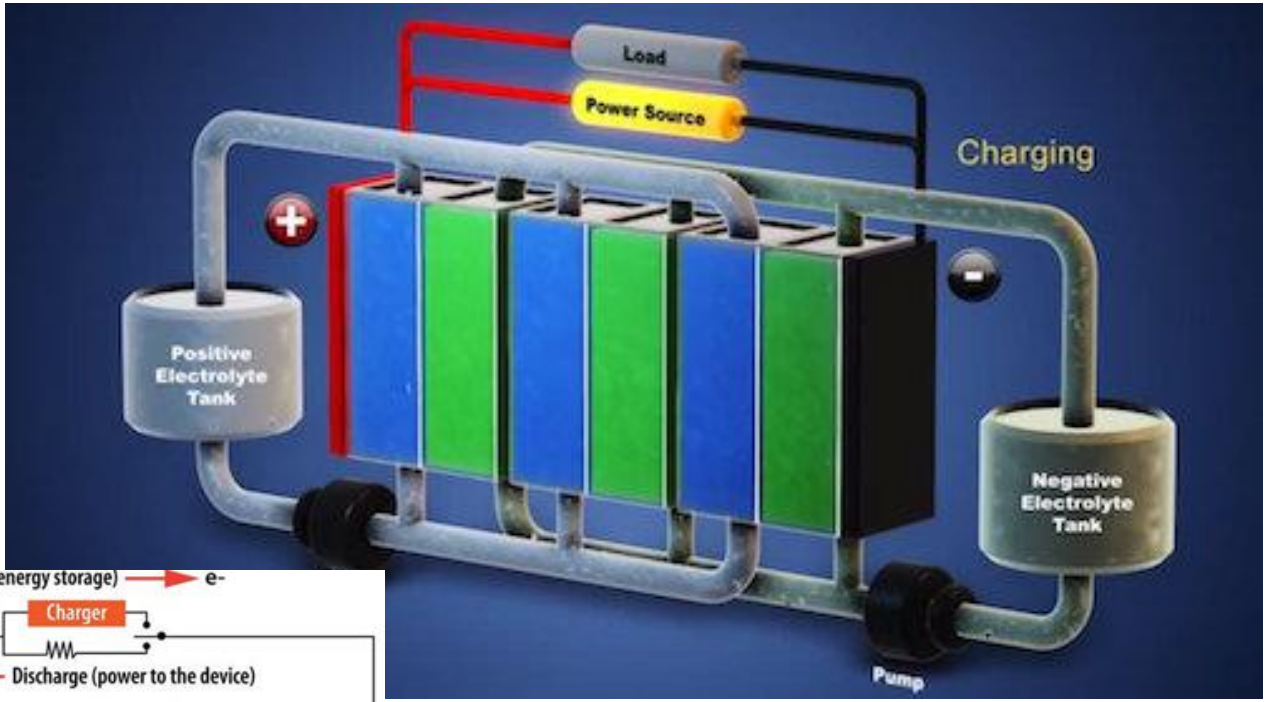
Duke declined to disclose how much this re-powering will cost. Nor would Younicos, the German energy storage control system provider that bought Xtreme Power's assets out of bankruptcy last year. That company now operates Xtreme's remaining installations, including Notrees.

"You have to remember that, as lead-acid ages, it becomes a lot less able to withstand the rapid charging and discharging action that frequency regulation demands, at least in the ERCOT market," Audrey Fogarty, Younicos' vice president of product management, said in a phone interview last week.

A link to the full article is included in the Links document provided in the Google Drive…

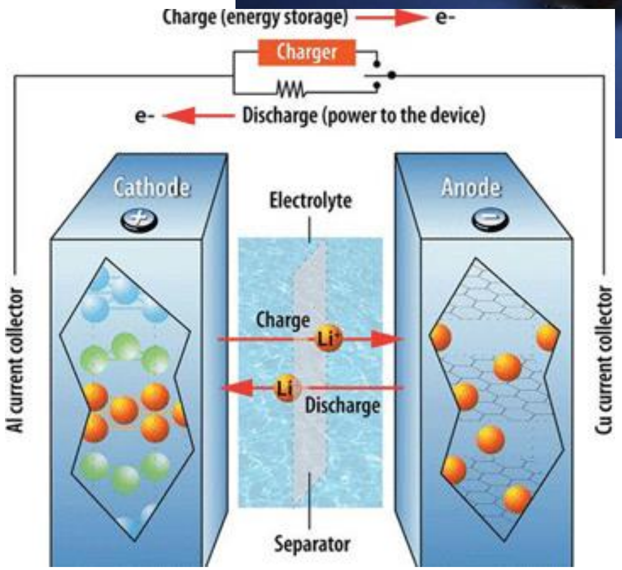
Two primary new battery types are dominating the PV + Storage market:

Flow batteries



and

LiOn batteries



Lithium-Ion:

Lithium-ion batteries are relatively established and have historically been used in the electronics and advanced transportation industries; they are increasingly replacing lead-acid batteries in many applications, and have relatively high energy density, low self-discharge and high charging efficiency

Lithium-ion systems designed for energy applications are designed to have a higher efficiency and longer life at slower discharges, while systems designed for power applications are designed to support faster charging and discharging rates, requiring extra capital equipment

Lithium-Ion:

Advantages -

Multiple chemistries available

Rapidly expanding manufacturing base leading to cost reductions

Efficient power and energy density

Disadvantages-

Remains relatively high cost

Safety issues from overheating

Requires advanced manufacturing capabilities to achieve high perfo

Tesla Power Electronics are integrated into the battery cells. Each Powerpack contains 16 individual battery pods. Each has an isolated DC-DC converter. This design can optimize performance across the array and enable easy swapping at any time.

Tesla Powerpack

Overall System Specs

AC Voltage
380 to 480V, 3 phases
Energy Capacity
210 kWh (AC) per Powerpack

Communications
Modbus TCP/IP; DNP3
Operating Temperature
-22°F to 122°F / -30°C to 50°C

Power
50kW (AC) per Powerpack
Enclosures
Pods: IP67
Powerpack: IP35/NEMA 3R
Inverter: IP66/NEMA 4

Scalable Inverter Power
from 50kVA to 625kVA (at 480V)

System Efficiency (AC) *
88% round-trip (2 hour system)
89% round-trip (4 hour system)

Depth of Discharge
100%
Certifications
Nationally accredited certifications to international safety, EMC, utility and environmental legislation.

Dimensions - Powerpack
Length: 1,308 mm (51.5")
Width: 822 mm (32.4")
Height: 2,185 mm (86")
Weight: 1622 kg (3575 lbs)
Industrial Inverter
Length: 1,014 mm (39.9")
Width: 1254 mm (49.4")
Height: 2192 mm (86.3")
Weight: 1200 kg (2650 lbs)

* Net Energy delivered at 25°C (77°F) ambient temperature including thermal control

Tesla officially unveiled the project Wednesday morning in Kauai following opening remarks by CTO JB Straubel and David Ige, governor of Hawaii. Tesla partnered with the Kauai Island Utility Cooperative (KIUC) to launch the project. The solar farm is composed of 54,978 solar panels with 13 megawatts of solar generation capacity. Tesla has also installed 272 of its large commercial battery, Powerpack 2, to store the solar energy to use at night.

The project is expected to reduce fossil fuel use by approximately 1.6 million gallons per year, Tesla estimates. Tesla will be
Tesla is also powering nearly the entire island of Ta’u in American Samoa with solar power and its Powerpacks.
KIUC signed a contract with Tesla to purchase 1 kilowatt-hour of electricity for $.139 over a 20-year time frame.

Video Break:
Elon Musk’s vision:

(View Tesla Hawaii Video)

Flow batteries:
Flow batteries contain two electrolyte solutions in two separate tanks, circulated through two independent loops; when connected to a load, the migration of electrons from the negative to positive electrolyte solution creates a current

The subcategories of flow batteries are defined by the chemical composition of the electrolyte solution; the most prevalent of such solutions are vanadium and zinc-bromine. Other solutions include zinc-chloride, ferrochrome and zinc chromate

Flow batteries – Vanadium Redox & Zink Bromide

Advantages:

Power and energy profiles highly and independently scalable (for technologies other than zinc-bromine)

Designed in fixed modular blocks for system design (for zinc-bromine technology)

No degradation in “energy storage capacity”

Disadvantages:

Power and energy rating scaled in a fixed manner for zinc-bromine technology

Relatively high balance of system costs

Reduced efficiency due to rapid charge/discharge

Sodium-sulfur:
“High temperature”/“liquid-electrolyte-flow” sodium batteries have high power and energy density and are designed for large commercial and utility scale projects;

“low temperature” batteries are designed for residential and small commercial applications

Sodium-sulfur:

Advantages:

High temperature technology: Relatively mature technology (commercially available); high energy capacity and long duration

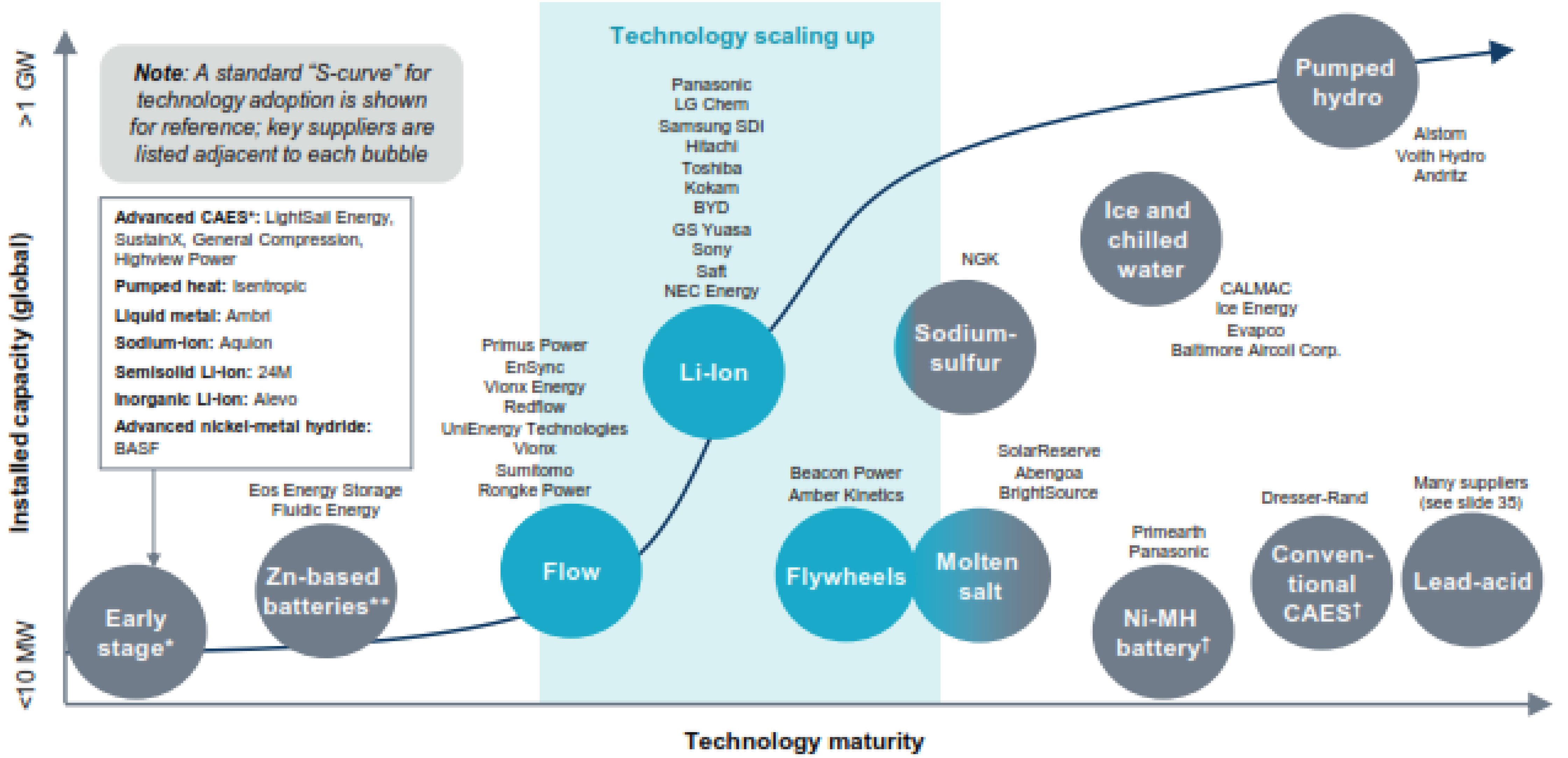
Low temperature technology: Smaller scale design; emerging technology and low cost potential; safer

Disadvantages:

Although mature, inherently higher costs—low temperature batteries currently have a higher cost with lower efficiency

Potential flammability issues for high-temperature batteries

Market maturity of grid storage technology



Note: *Early-stage companies do not yet have any operating capacity on the grid, nor any contracts for full-scale systems. **Zn-based batteries include Eos Energy Storage and Fluidic Energy; both are just past the demonstration phase and have either capacity installed or contracts with large utilities. †CAES = compressed air energy storage. Zn = zinc; Ni-MH = Nickel-metal-hydride.

Source: IHS

Next we Describe and identify components and specifications of a Battery based system:

- Batteries by type
- Inverters
- Transformers/Phase converters
- Points of interconnection –
  - Client
  - Utility

An **Energy Storage System (ESS)** is comprised of *three* major components.

The **Battery** which is the energy storage; the **Power Conversion System (PCS)** or ***inverter*** which converts the DC power of the battery system to the AC power system; and the **Power Plant Controller (PPC)** which governs, monitors and executes the intended functions of the energy storage application.

The Power Conversion System (inverter) - The PCS can be subjected to intense utilization because it is be expected to produce varying power levels in *both* directions through the day. When procuring a PCS, system owners should select power conversion technology that is designed for high reliability and availability, and up to three decades of service life. It is also essential that the equipment can be operator maintained, tracked, and managed. The PCS should be designed with grid support functionality and should facilitate *upgrades* as the energy ecosystem advances. Owners and operators should favor flexible and easily transportable architectures that can be repurposed as needs evolve.

The Power Plant Controller (also know as the Energy Management system or EMS)- It is imperative that control system providers have the means and experience to address important factors such as redundancy and *cybersecurity*.

System owners should select the ESS control provider based on demonstrated success and experience in related critical power control systems and industrial automation. They should also consider the longevity and market capitalization of the provider they choose. A poor choice of one or both of these two core components can result in an unprofitable and dysfunctional ESS that will be fraught with recurring repair and replacement costs.

The quality of the EMS will determine the effectiveness of the system to perform the various elements in the Value Stack of the design. High quality software is the heart of EMS performance.

Additionally both Transformers/Phase converters, Points of interconnection, Client and the Utility (for Community/Industrial and Commercial systems) must be included in the considerations of a U&CES System.

The point of connection of the system will influence the system design and the considerations of transforming voltage output and type of phase conversion that may be needed.

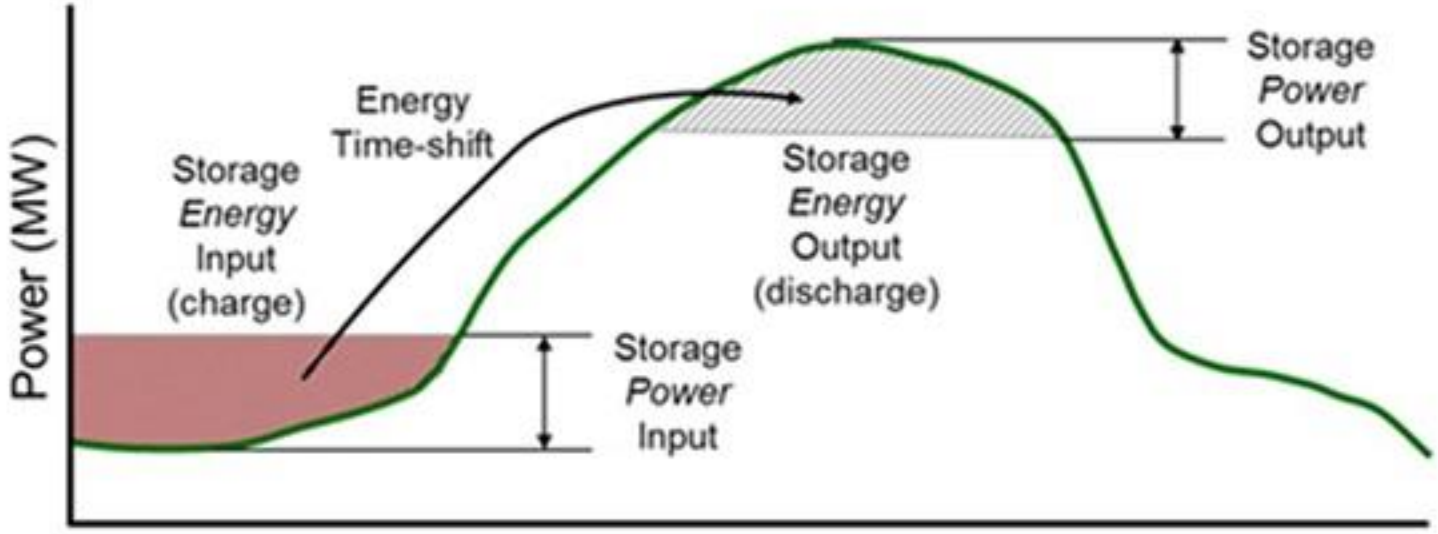
Finally the Client’s ability to monitor, operate and maintain the system is critical to the system performance over its life and for non-utility clients cooperation with the Utility the system feeds is essential.

- Next we Identify the best application and limitations of each system type and its range of applications:
  - Energy time shift
  - Load following
  - Frequency regulation
  - Renewable capacity continuity
  - Transmission congestions relief
  - Energy tariff cost management
- Application services and blending
- Use of ESS in a Virtual Power Plant (VPP)
- Integration of Solar PV with energy Storage

Energy time shift

Electric Energy Time-shift
Electric energy time-shift entails storing of electric energy when energy use and value are low, so that energy can be used or sold, later, when energy use and value are high. Energy time-shift is shown graphically in Figure 1.

The objective is use low priced energy during times when the cost to produce the energy or the price to buy the energy are high (i.e., during “peak demand” periods). The price to purchase that energy real-time (when needed) is high because the demand for electricity is high. Production cost for energy at that time is also high, primarily because the least fuel efficient generation is used. Those generation resources are commonly referred to as “peakers.”



Source: E&I Consulting

Figure 1. Electric Energy Time-shift.

Load following

The load following strategy is a dispatch strategy whereby whenever a generator operates, it produces only enough power to meet the primary load. Lower-priority objectives such as charging the storage bank or serving the deferrable load are left to the renewable power sources. The generator may still ramp up and sell power to the grid if it is economically advantageous.

By using load following and storage techniques to match demand a simple approximation of demand versus solar output allows solar integration to be higher than capacity factor because of load following. Storage is key in full integration of intermittent RE Resources.

Frequency regulation

In order to synchronize generation assets for electrical grid operation, the alternating current (ac) frequency must be held within tight tolerance bounds. Different methods available for "frequency regulation" include generator inertia, adding and subtracting generation assets, dedicated demand response and electricity storage.

In the group of "ancillary services" provided in the open market management of the grid, frequency regulation has the highest value.

Frequency regulation is mainly provided by ramping (up and/or down) of generation assets. This typically takes *minutes* rather than seconds. Electricity storage has the capability for doing the job in milliseconds, and Pacific Northwest National Laboratory (PNNL) has suggested millisecond electricity storage should have a value of at least twice that of 20 minute assets.

Renewable capacity continuity-

Affordable, reliable, and deployable storage is seen as the holy grail of renewable energy integration, and recent advances in storage technology are getting closer to finding it.

As higher levels of solar and wind energy are added to the grid, however, storage will become increasingly fundamental to ensuring that the power supply remains stable and demand is met.

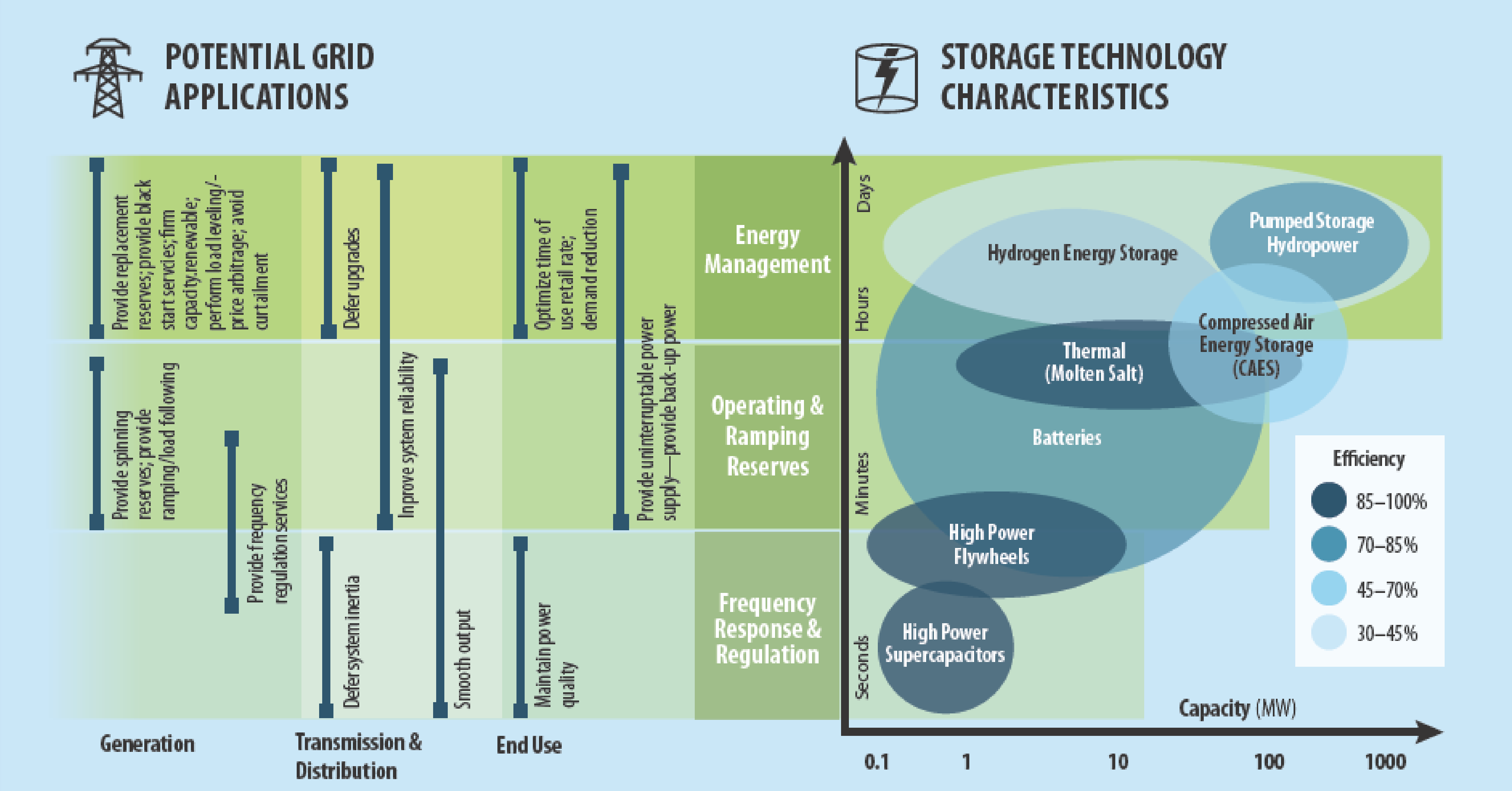
Transmission congestions relief - While energy storage is usually classified as a generation resource, the operational characteristics of advanced storage technologies and their use as transmission assets are are expanding rapidly.

When storage is owned by the utility it may also be well-suited to use for electric energy time-shift and to reduce the need for generation capacity and for electric supply reserve capacity but depending on location and circumstances, the same utility-owned storage can also be used for transmission congestion relief, to improve electric service reliability and power quality *and* to enable renewable energy generation into the grid.

Energy tariff cost management

Electricity storage can be used to reduce the cost incurred for electric service. The benefit can be significant. There are two variations on this value proposition. One involves electricity end-users that pay “time-of-use” (TOU) electric energy prices. That is, the price paid depends on the time that it is purchased. Second, commercial and Industrial end-users that use a significant amount of electricity qualify for electrical service pricing that includes both a) TOU energy pricing and b) demand charges. Demand charges reflect the end-user’s maximum power draw rather than energy use.

Battery Energy Storage Systems cover the widest range of potential applications and value streams.



- Use of ESS in a Virtual Power Plant (VPP)

- A virtual power plant (VPP) is a computer network controlled distributed power plant that aggregates the capacities of various Distributed Energy Resources (DERs) for the purposes of enhancing power generation, as well as trading or selling power on the open market. There are examples of virtual power plants in the United States, Europe, and Australia.

- A virtual power plant can integrate several types of power sources to give a reliable overall power supply. The sources often form a cluster of different types of dispatchable and non-dispatchable, controllable or flexible load (CL or FL) distributed generation (DG) systems that are controlled by a central authority and can include Combined Heat and Power (CHP), small-scale wind power plants (WPP)s, photovoltaics (PVs), run-of-river hydroelectricity plants, small hydro, biomass, back-up generation, and energy storage systems (ESS).

- Examples of a virtual power plant (VPP)

A trial project in Kentucky, the Glasgow Electric Plant Board is installing Sunverge Energy's smart energy storage devices as part of the municipal utility's effort to reduce CO_2 emissions by 25%

The batteries provide Glasgow with "an alternate source of power – a virtual power plant, in effect – to help further increase the load factor" for homeowners, who in turn save money on peak demand charges without making major lifestyle changes.

The pilot provides environ-mental benefits in an area where roughly half the power is supplied by coal- red generating capacity. Because each of the Sunverge battery-equipped homes stores surplus energy and uses it during high-demand periods, there could be that much less need to dispatch older, more polluting capacity during peak periods.

Sunverge's system increases flexibility, reliability and decreases cost. These are three main reasons virtual power plants are attractive to utilities. In addition, consumers who own them also have the assurance of reliability they have first call on their own power.

New York utility Con Ed, SunPower and Sunverge is involved in a $15 million virtual power plant pilot, part of New York's Reforming the Energy Vision (REV) effort, which will outfit about 300 homes in Brooklyn and Queens with leased high-efficiency solar panels and lithium-ion battery energy storage systems. The project is meant to explore the revenue streams made possible by software-enabled aggregation of energy storage. Applications might include T&D deferment, peak shaving, frequency regulation, capacity markets and wholesale markets.

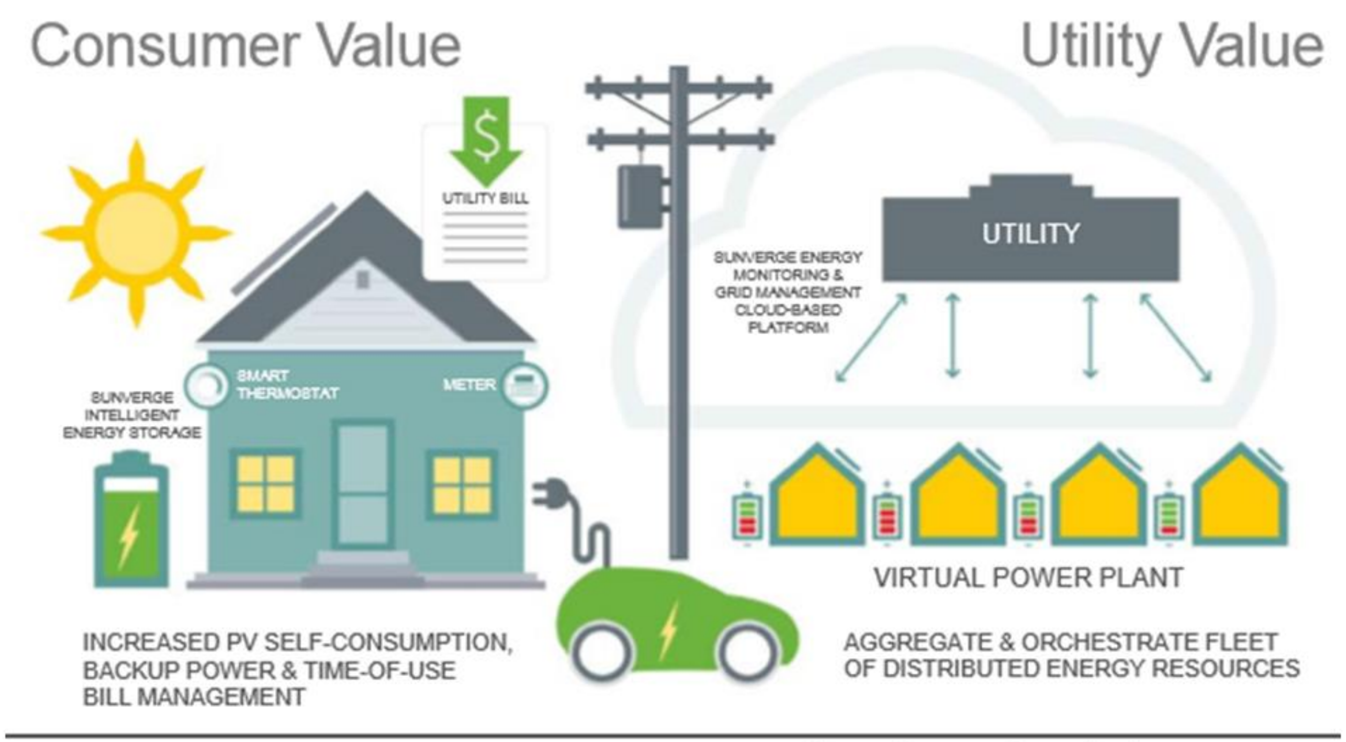
Each home will be outfitted with a 7-kilowatt to 9-kilowatt rooftop PV system and a 6-kilowatt/19.4-kilowatt-hour energy storage system. In addition to the utility-facing grid services, the installation provides homeowners with backup power for essential loads in the home. The SunPower/Sunverge platform provides aggregated control of individual residential resources, converting them into a 1.8-MW VPP with an aggregated energy output of 4 MWh.

Sacramento Municipal Utility District’s (SMUD) R Street demonstration project:

For its R Street Midtown Project, SMUD equipped 34 single-family homes with a 2.25 kW solar array, the Sunverge Solar Integration System energy storage product, smart plug load controllers, and smart thermostats.

“Each house is a nanogrid because it can island itself, the whole block can island as a microgrid, and, because it provides demand response to the SMUD distribution system, it can be considered a VPP,” Asmus said. “It can be all these things, at different times of the day, because battery storage is integrated into it.”

The Coupling of Consumer and Utility Value via VPPs



(Source: Sunverge Energy, Inc.)

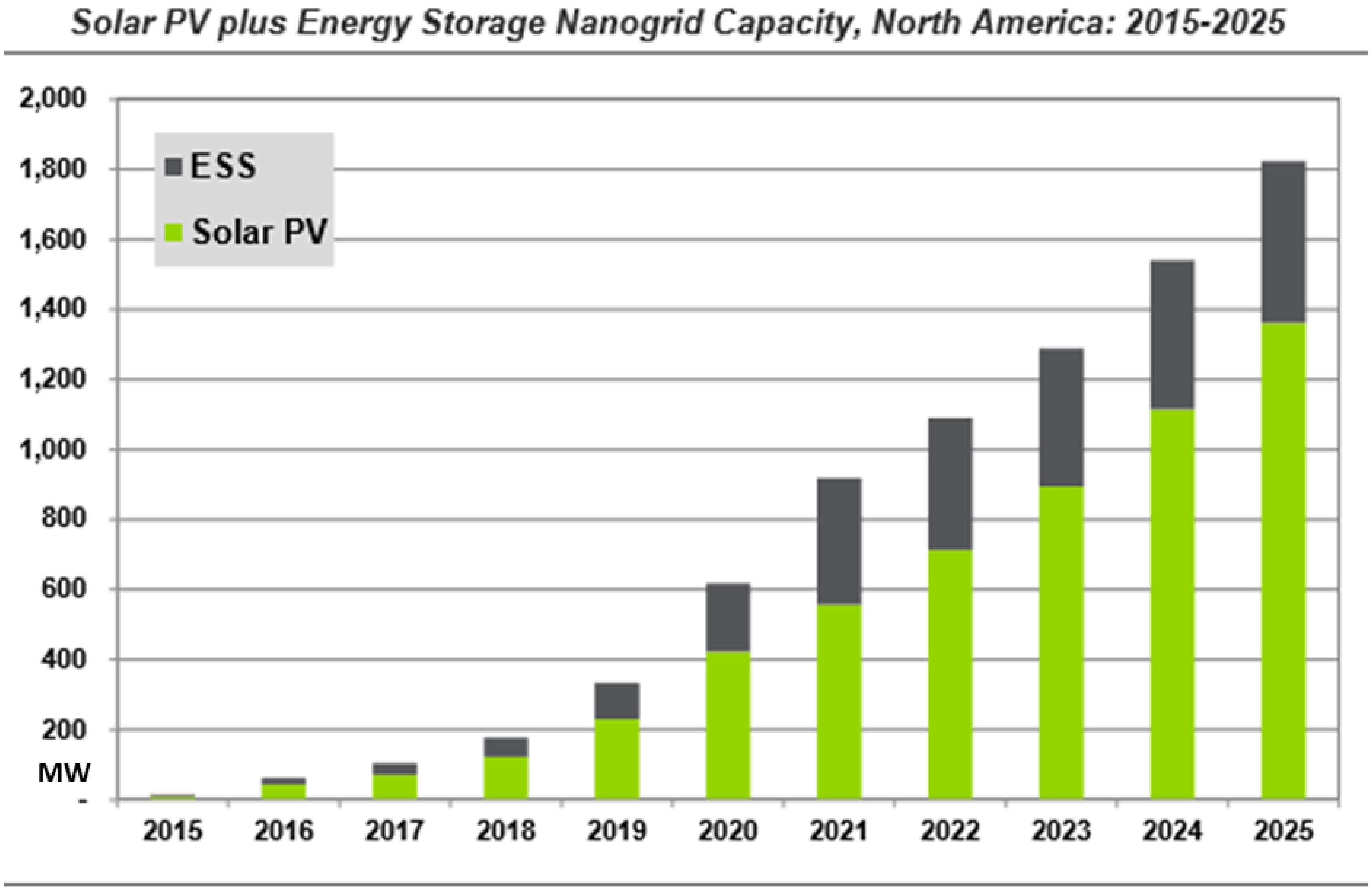
Storage can be charged from the utility at low-cost times, while power dispatched to other consumers through a VPP is done at times of high demand (cost).

Utilities will use this energy arbitrage to their own and their customers’ benefit in a variety of ways that have one thing in common. VPPs can deliver low cost power to their networks when the cost of electricity to the Utility is high.

In North America:

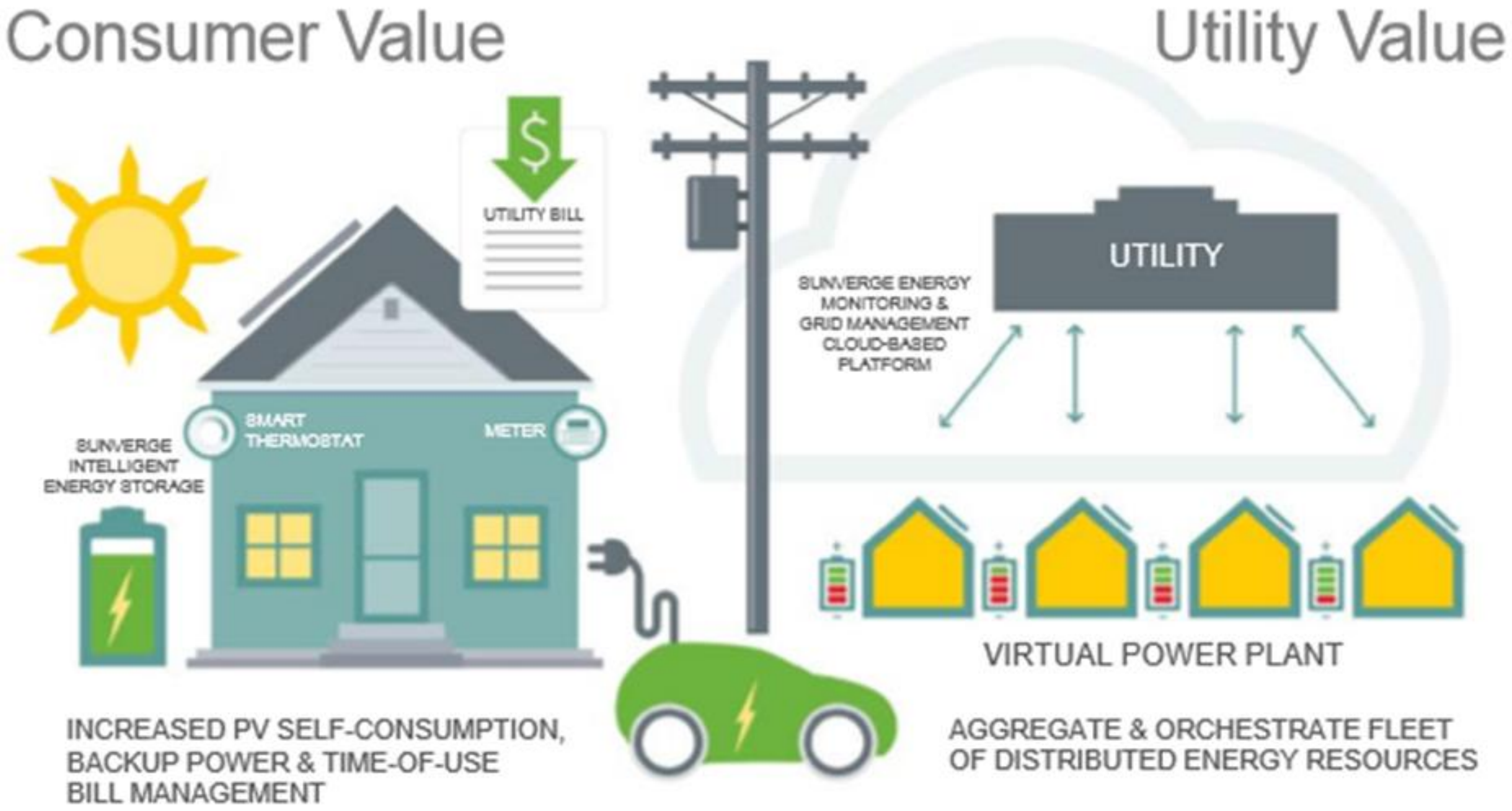
Forecasts to 2025 for residential solar PV plus energy storage nanogrids show growth to 1.8 GW, with 30% to 40% of those nanogrids aggregated into VPPs.

The use of solar and storage together in nanogrids is expected to continue expanding, leading to new markets for ancillary services with efforts by utilities and grid operators alike to manage increased DER portfolios in ways that capture value upstream.



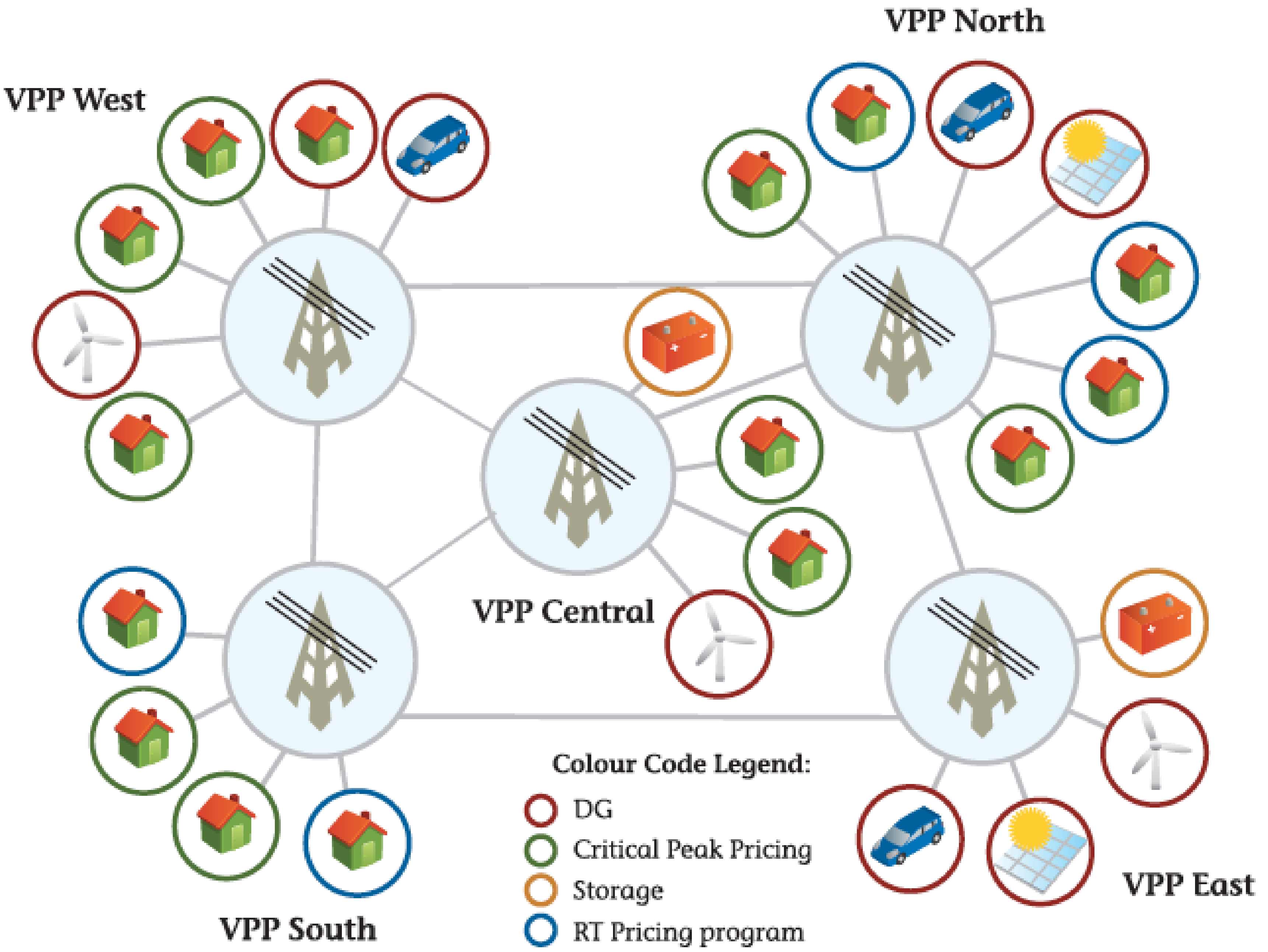
(Source: Navigant Research)

The Coupling of Consumer and Utility Value via VPPs

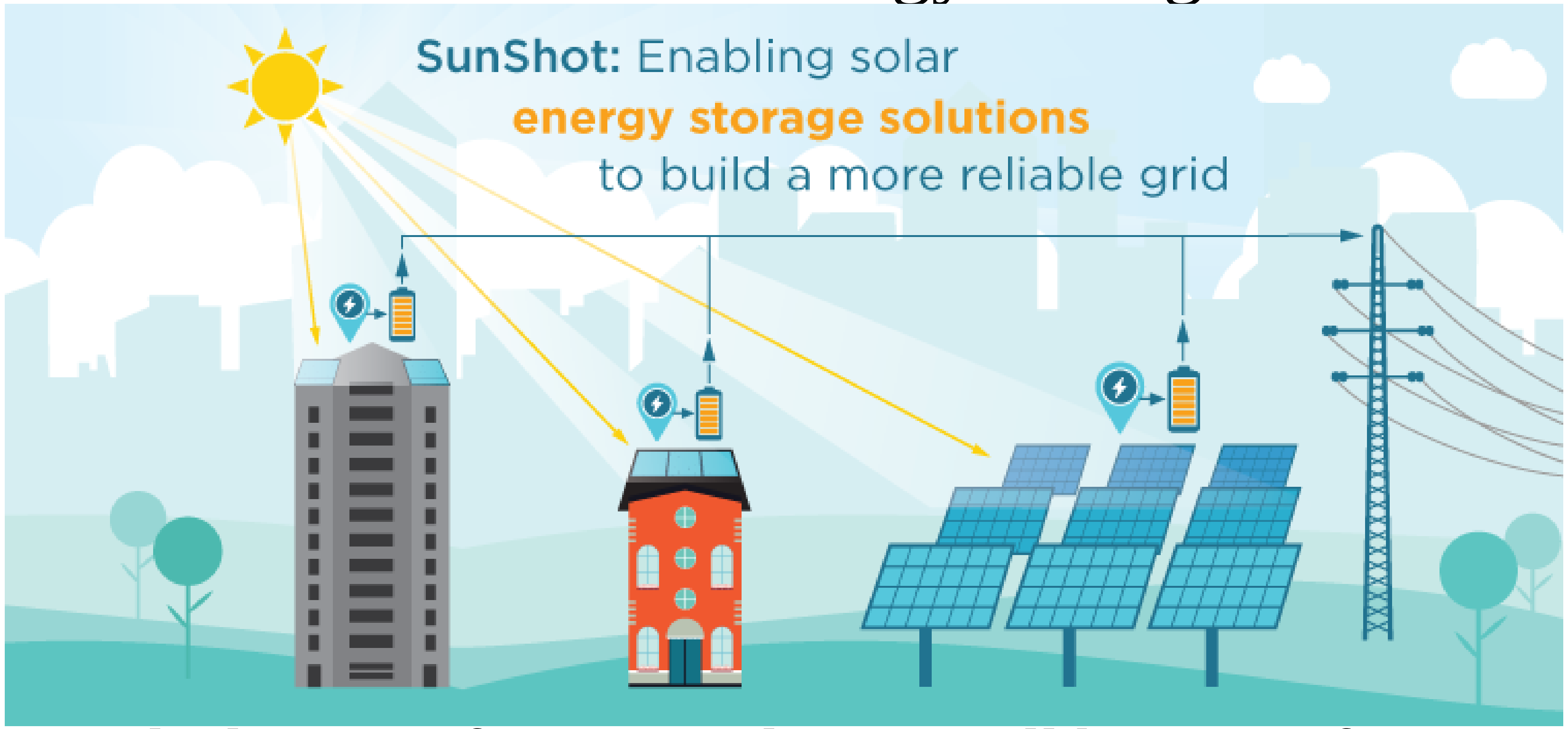


(Source: Sunverge Energy, Inc.)

Figure 1: Aggregations of Demand Response & Distributed Generation

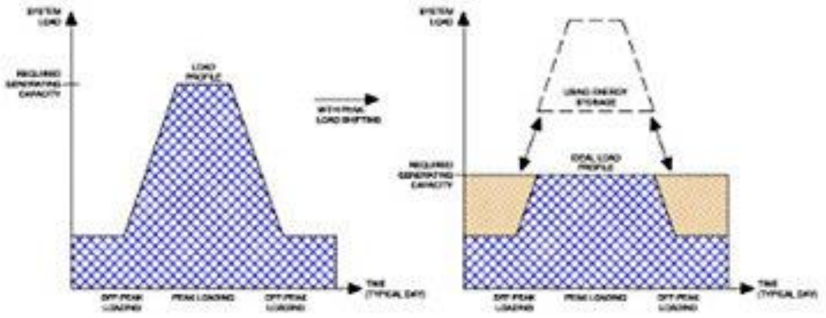


- Integration of Solar PV with energy Storage



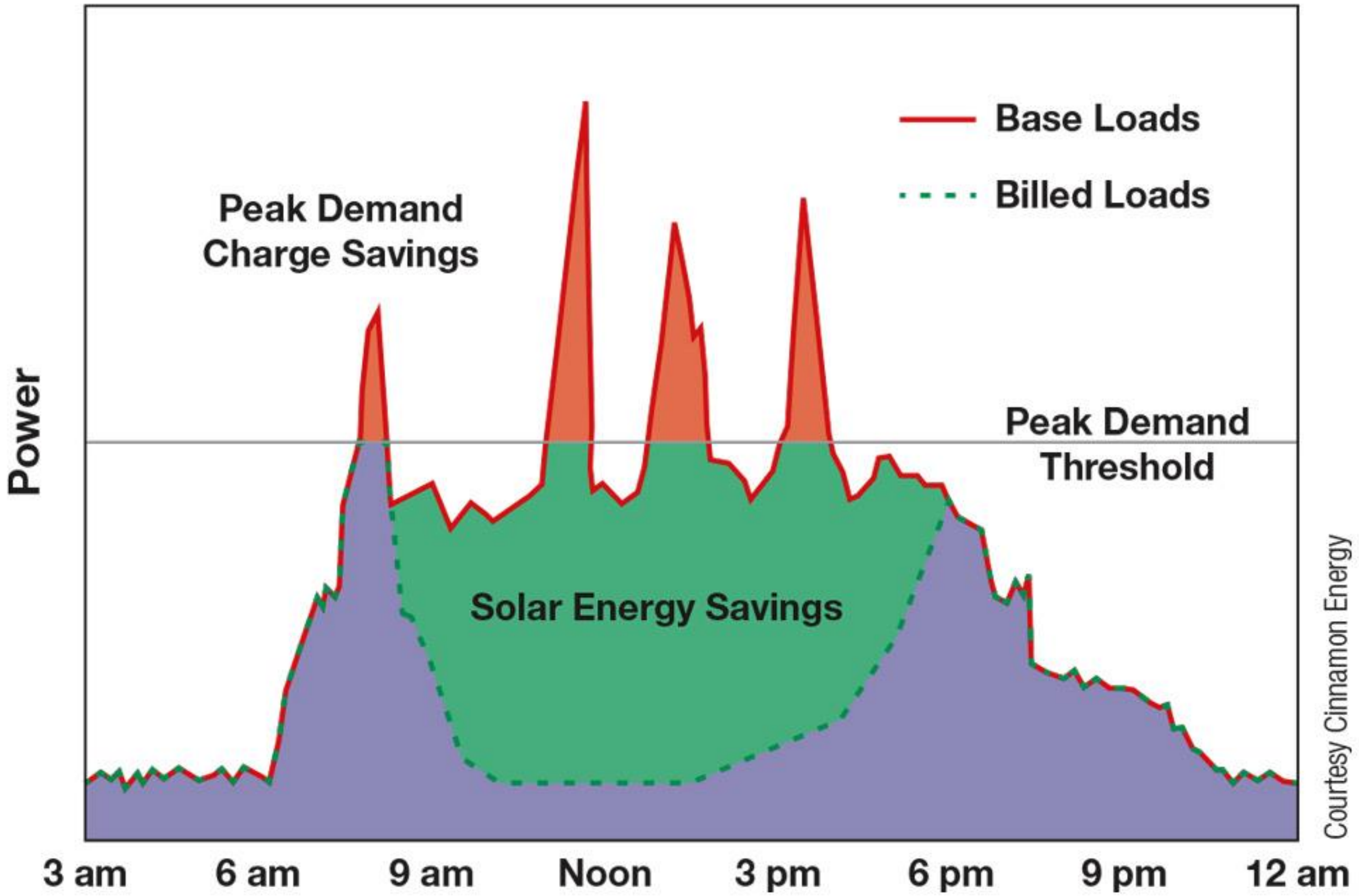
The widespread adoption of storage solutions will be a transformative influence on the current state-of-the-art of solar grid integration and will significantly contribute to an economically viable pathway toward energy efficient and sustainable integration of solar generation at much higher penetration levels than currently possible today. These solutions will enable widespread sustainable deployment of reliable PV generation and provide for successful integration of PV power plants with the electric grid at the system levelized cost of energy (LCOE) of less than 14 cent per KWh (as of 2017).

Peak-load shifting is the process of mitigating the effects of large energy load blocks during a period of time by advancing or delaying their effects until the power supply system can readily accept additional load. The traditional intent behind this process is to minimize generation capacity requirements by regulating load flow. If the loads themselves cannot be regulated, this must be accomplished by implementing energy storage systems (ESSs) to shift the load profile as seen by the generators.



Depending on the application, peak-load shifting can be referred to as "peak shaving" or "peak smoothing." The ESS is charged while the electrical supply system is powering minimal load and the cost of electric usage is reduced, such as at night. It is then discharged to provide additional power during periods of increased loading, while costs for using electricity are increased. This technique can be employed to mitigate utility bills. It also effectively shifts the impact of the load on the system, minimizing the generation capacity required.

Peak Demand Charge Savings with Solar Plus Energy Storage



Hartley Nature Center Retro-fit project illustrates as small commercial Electricity storage system that is used to reduce the cost incurred for electric demand charges. Demand charges reflect the end-user’s maximum power draw rather than energy use.

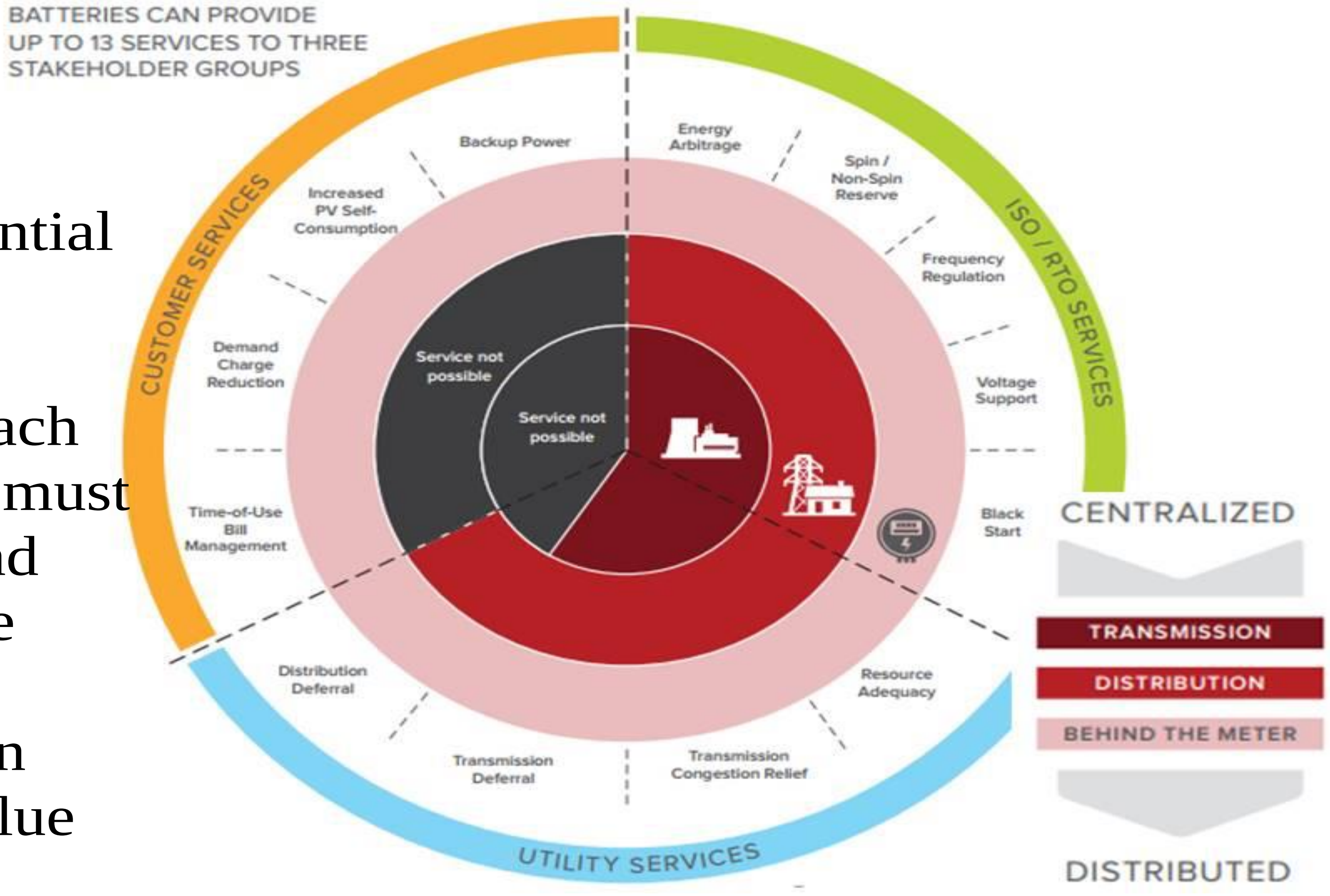
ESS Selection

- Sunverge, only company to meet project needs
- Small Commercial Unit (<15 kWh) & DC coupled (high voltage)
- Software ~ Energy Arbitrage, coming soon more sophisticated Peak Demand Shaving
- Other resiliency option – SPS outlet Sunny Boy grid tied inverter connected to 5 kW of roof array

In developing plans “stacking” System services leads to the best return on investment.

This creates the optimal economic benefits of ESS systems.

To achieve The total of all potential value streams available for a given system each potential value must be evaluated and that defines the maximum economic return and therefor value for a project.



ESS Residential commercial systems have the potential to provide for services in addition to simple Utility grid outage back-up…

Maximization of RE usage on site

Peak load shaving (Demand Charge Reduction)

Time-of-Use Bill Management

Increased PV Self-Consumption

Backup Power

Again, Large scale services…

Peak Shaving. During high demand periods, the ESS's can provide full output for up to 7 hours. This reduces the system peak, deferring the need for capacity additions on the distribution or transmission system.

Ancillary Services.

Frequency Regulation. This is mainly provided by ramping generation assets up and/or down. Frequency regulation is a power storage application of electricity storage that has been identified as one of the best values for increasing grid stability without being considered an energy arbitrage play.

Spinning Reserve. One of several reserve options, a spinning reserve is generation capacity that is online but unloaded. This reserve can respond within 10 minutes to compensate for generation or transmission outages. Spinning reserves are the first type used when shortfalls occur.

Resiliency, power supply during utility outages.

Questions?

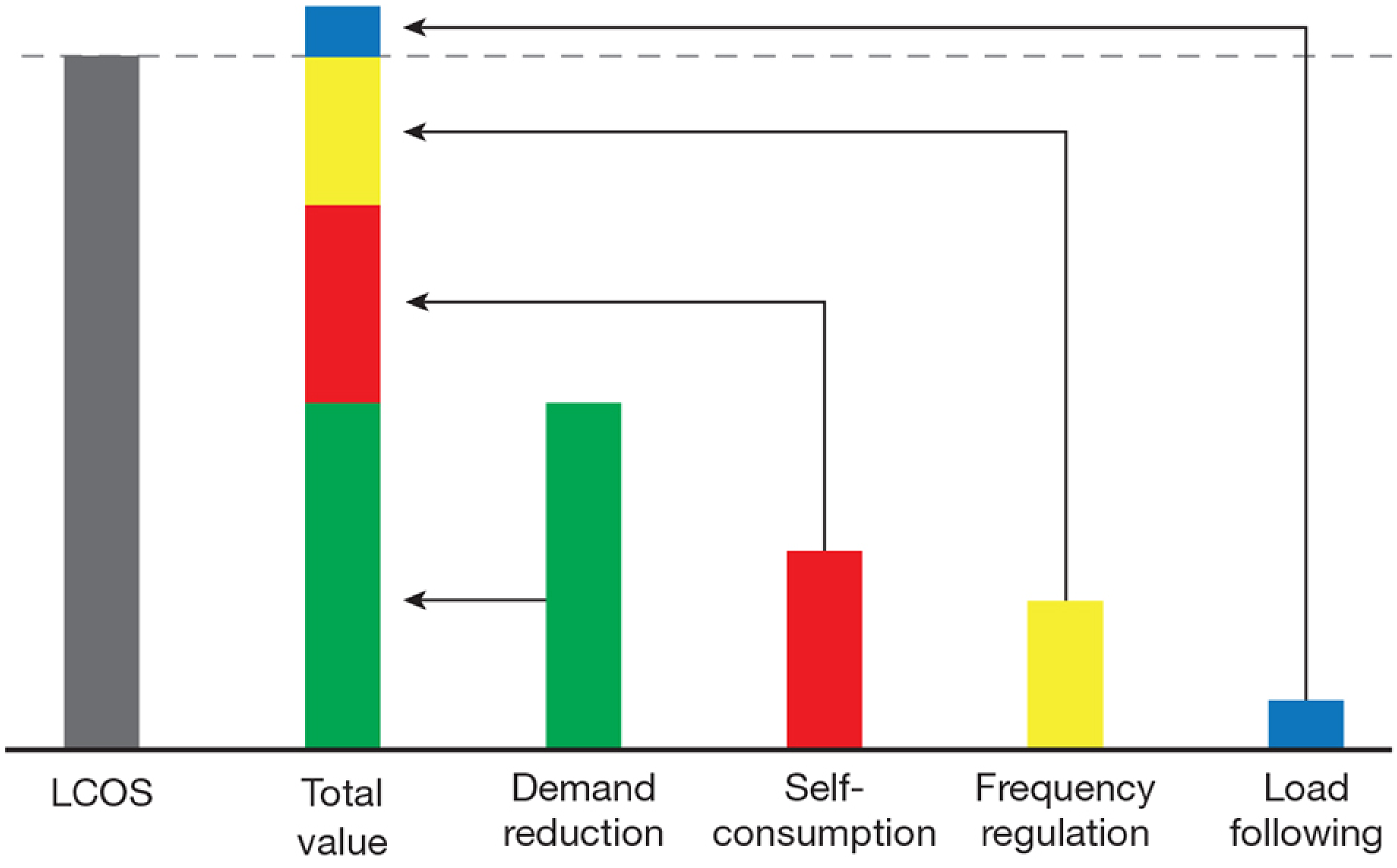


Figure 4 Removing regulatory barriers and developing new rate structures permits application stacking, whereby an energy storage system or network of systems can provide multiple services. This theoretical scenario shows how unlocking multiple revenue streams improves the value proposition for energy storage.