Welcome to:
Solar + Energy Storage –
Don't miss the clean energy wave!

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Welcome to - Solar + Energy Storage - Don't miss the clean energy wave!

Energy Storage is a KEY topic in the Renewable Energy world
The technology is shaking up the electrical energy industry.

Today we will look into:
The way solar is paired with storage for greater effectiveness of both technologies,
How Solar + Storage operates,
The basic technical benefits of these systems,
The Solar + Storage systems financial benefits,
How Utilities and consumers will use S+S systems,
Compare the many applications of S+S Systems,
and how the coupling of solar and storage is *revolutionizing* the energy field

Nomenclature of Solar + Storage

We start with key terms, their abbreviations and definitions -

kW: Kilowatt is the unit of electric power. One kilowatt is equal to 1000 watts: 1kW = 1000W.

kWh: Kilowatt-hour is the unit of energy equal to one kilowatt (kW) of power sustained for one hour and is used as a billing unit for energy delivered to consumers by electric utilities.

Mw: A megawatt is a unit for equivalent to one thousand kW.

Mwh: A megawatt hour (Mwh) is equal to 1,000 Kilowatt hours (Kwh).

BESS: Battery Energy Storage System - A battery-based system that charges and discharges energy

BTM: Behind the meter - When the system interconnects behind the utility meter (On the client's side of the meter)

IFM: In front of meter - When the system interconnects in front of the utility meter (on the utilities side of the meter)

LCOE: Levelized Cost of Energy - A way of determining the cost of energy from a power plant over time used to compare different technologies

RTO: Regional Transmission Organization in the United States, the RTO's are responsible for ensuring sufficient power and electricity in a regional electricity grid

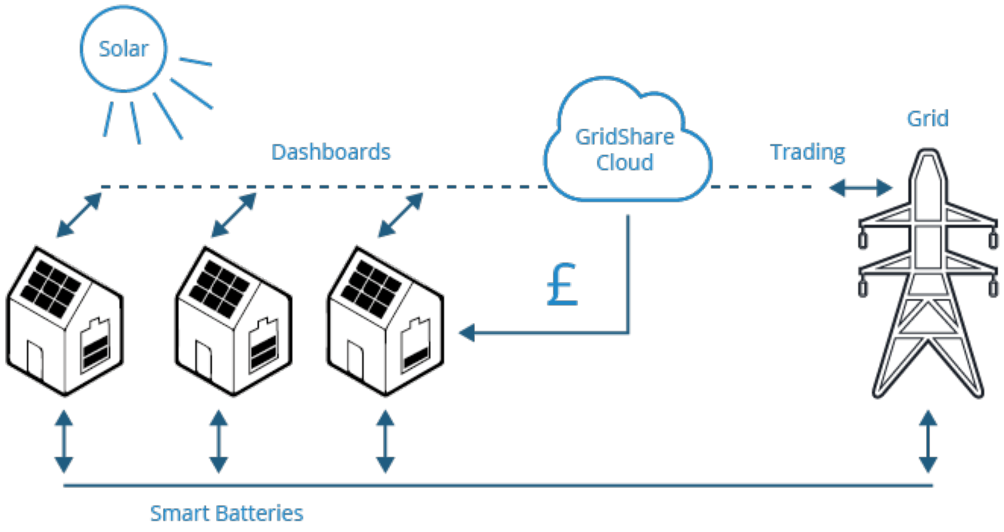
PPA: Power Purchase Agreement - A method of buying and selling electricity from an onsite (or remote) energy generating system

ROI: Return on Investment - the % of profit generated as a function of investment

S+S: Solar + Storage - an electrical system that has both PV and ESS

TOU: Time of Use - a type of billing used by the utility where there is variability in the rate per kWh based on when the consumer uses power

VPP: Virtual Power Plant - a network of power generators (most often with energy storage) combined into a plant controlled by a single operator



Solar+Storage Systems - This technology works by…

Using advanced controls to provide users with specific services that can benefit the user in multiple ways.

The user gets value from the services which optimize their energy use and generation allowing the user to receive maximum benefit and profit.

The goals of the client determines the “services” and directs the design of the specific system and its control methods.

To derive the maximum value designers “stack” different services to receive the greatest value - this “value stacking” creates the optimum system with the greatest ROI.

Understanding the way solar is paired with storage for the greater effectiveness of both technologies..

The pairing of the Renewable Energy generation with energy storage at all scales removes the difficulties of the intermittent nature of both solar and wind generation resources.

Energy Storage provides greater value propositions when paired with Renewable Energy Resources by adding in the many environmental and economic advantages of low cost clean Renewable Energy (RE) generation.

Adding dispatchability and time shifting to RE generation allows for the acceleration of our transition away from fossil fuel energy sources and reducing the catastrophic climate change consequences of their previous and continued use.

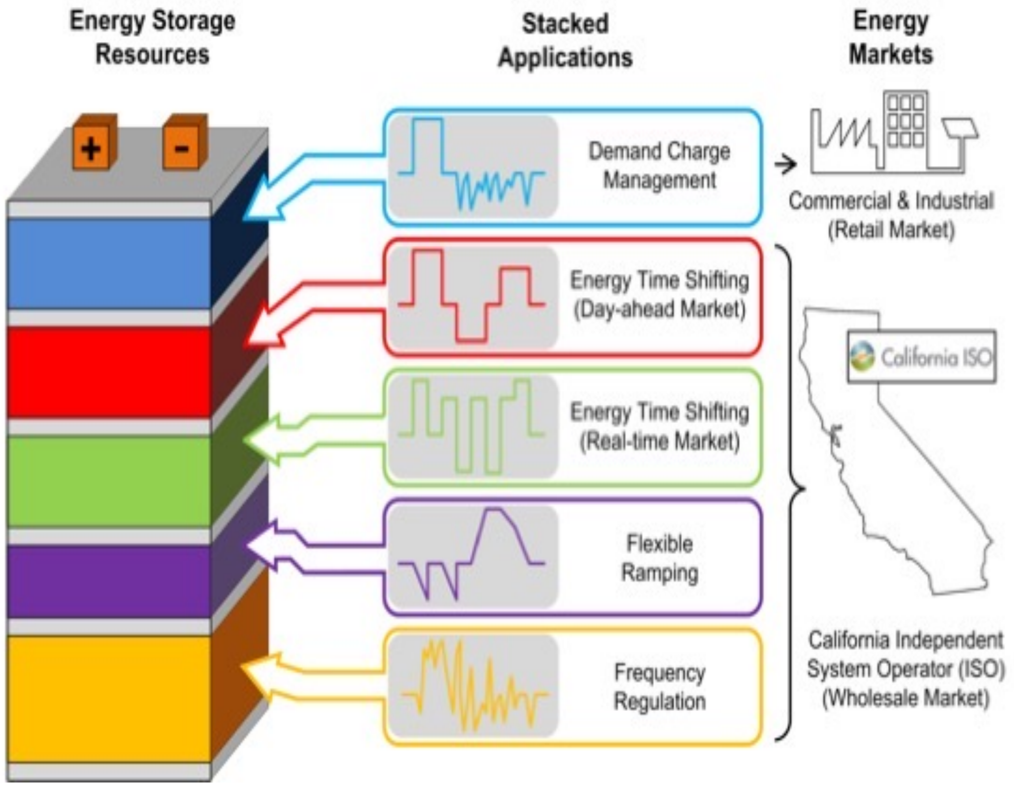
“Services” that benefit the Residential or small commercial user can include:

- Maximization of Renewable Energy usage on site
- Peak load shaving (Demand Charge Reduction)
- Time-of-Use Bill Management
- Increased PV Self-Consumption
- Backup Power

All of these services increase the value of on-site Solar Power systems.

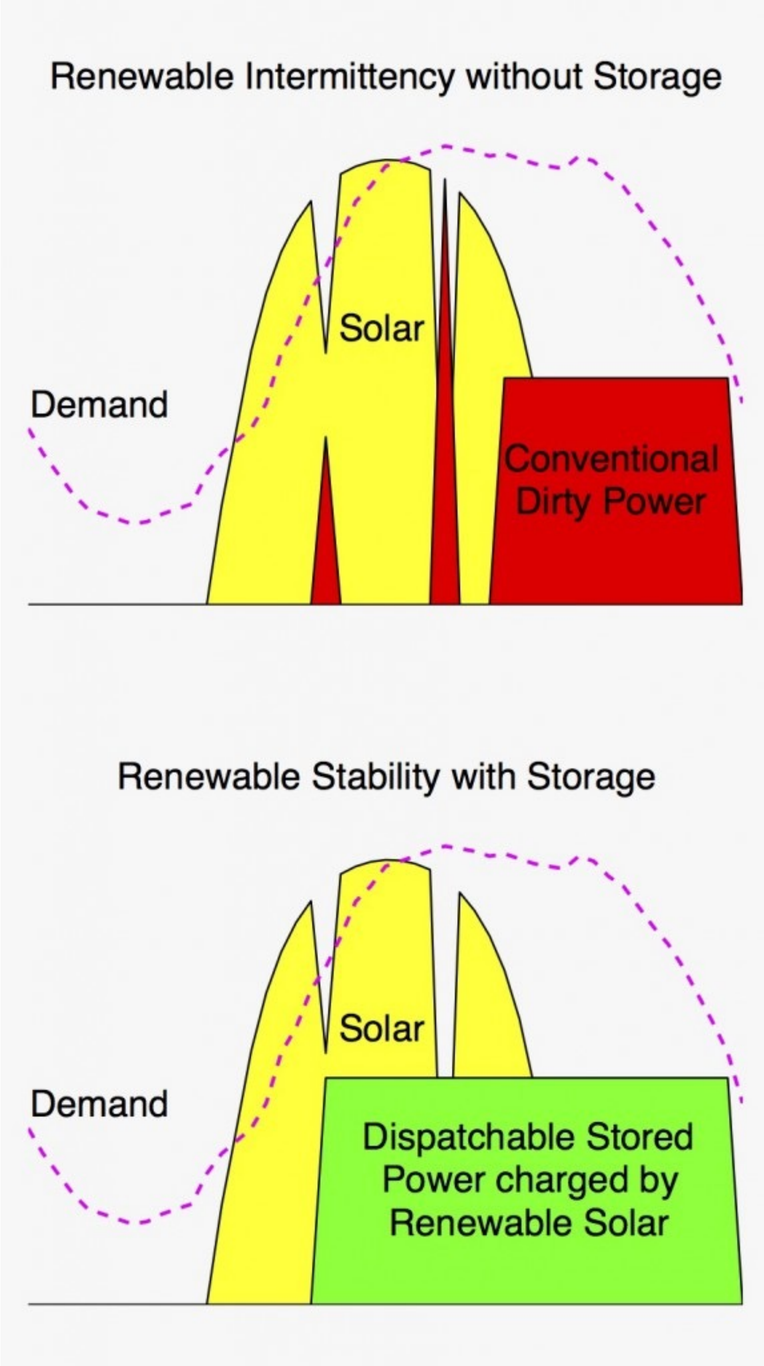
With S+S systems the user gets value and revenue from the services. The value of each service determines its revenue streams and shapes the design of the specific system and its control methods.

It is the different values that direct how designers “stack” the different services to receive the greatest value – “service value stacking” leads to the optimum ROI.



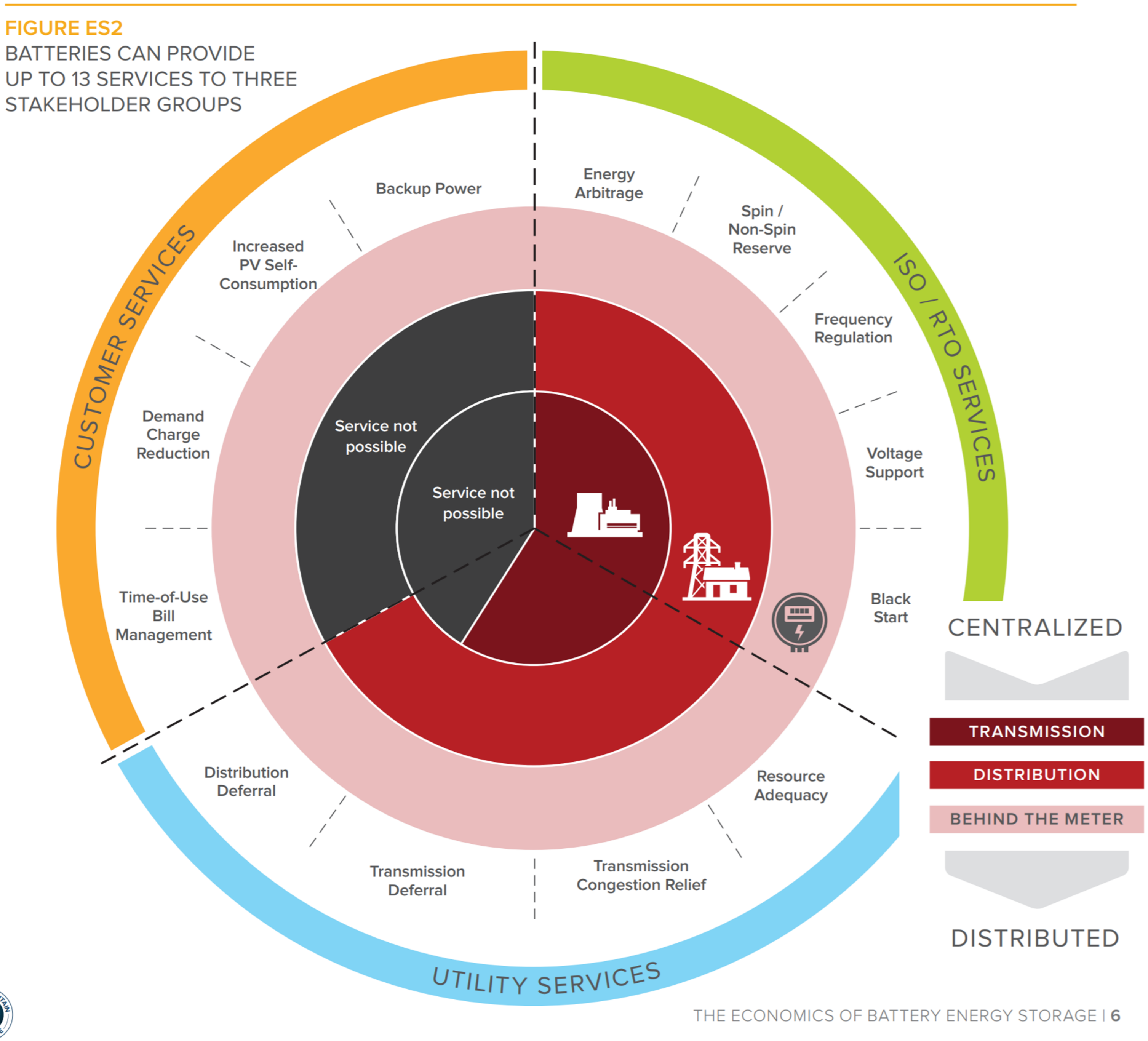
The benefits of dispatchable Solar Energy stored in quick reacting batteries appeals to Utilities for the ancillary services they can provide: energy time shift, load following, frequency regulation, renewable capacity continuity, transmission congestions relief…

While at the same time offering benefits to end users such as businesses (peak load shaving) and homeowners (time of use metering options and resiliency).



Orientation to Value Stacking

Value stacking improves project economics



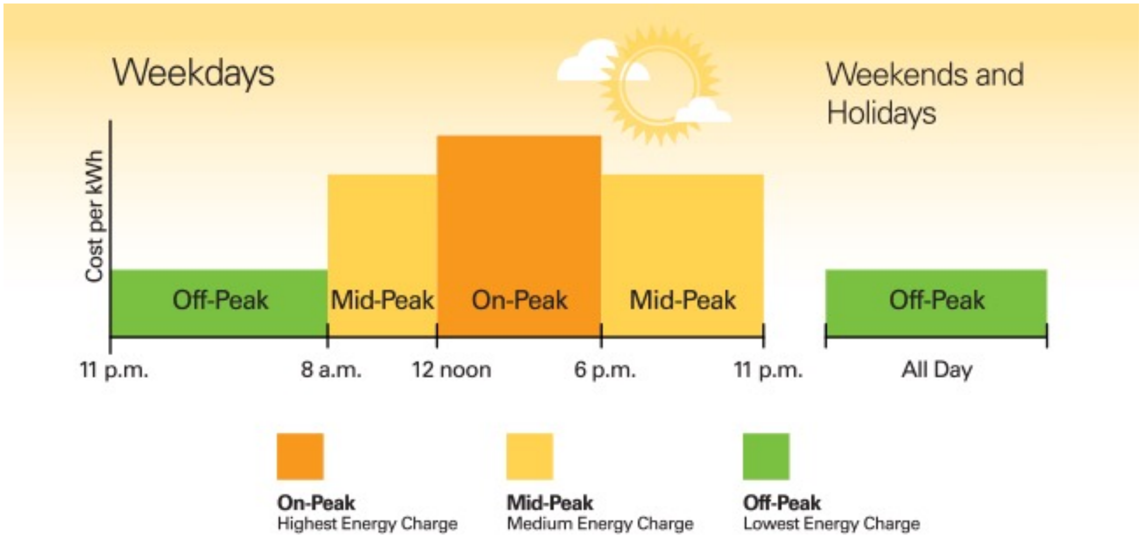
Typical service stacks:

Residential –

Time-of-Use Bill Management +
Increased PV Self-Consumption +
Backup Power

Commercial –

Peak load shaving
(Demand Charge Reduction) +
Time-of-Use Bill Management +
Increased PV Self-Consumption +
Backup Power



Typical service stacks:

For Residential clients, a typical service stack starts with resiliency

Service 1 = resiliency – the desire to have electricity stored for use during Utility outages is the most common starting point here.

Service 2 = Time-of-Use Bill Management – Users who are eligible for time-of-use (TOU) electric energy pricing can use solar + storage to reduce electricity cost by retail energy time-shift. This involves storing of energy when the price for energy is low. That energy is used later when prices are high and thereby not purchasing high priced energy. The benefit is the difference in price between on-peak and off-peak less the cost for energy losses during the storage charge-discharge cycle.

Service 3 = Increased Self-consumption of photovoltaic (PV) renewable energy. This model is when the building uses PV electricity for its own electrical needs, thus acting as both producer and consumer, or prosumer. ... Energy Storage can enable buildings to consume their own solar energy.

Additional revenue streams can be achieved through joining an aggregator.

These systems will be fairly small in storage capacity However the units can be "aggregated" by a third party who then provides ancillary services to the Utility or the transmission authority. This creates additional revenue streams.

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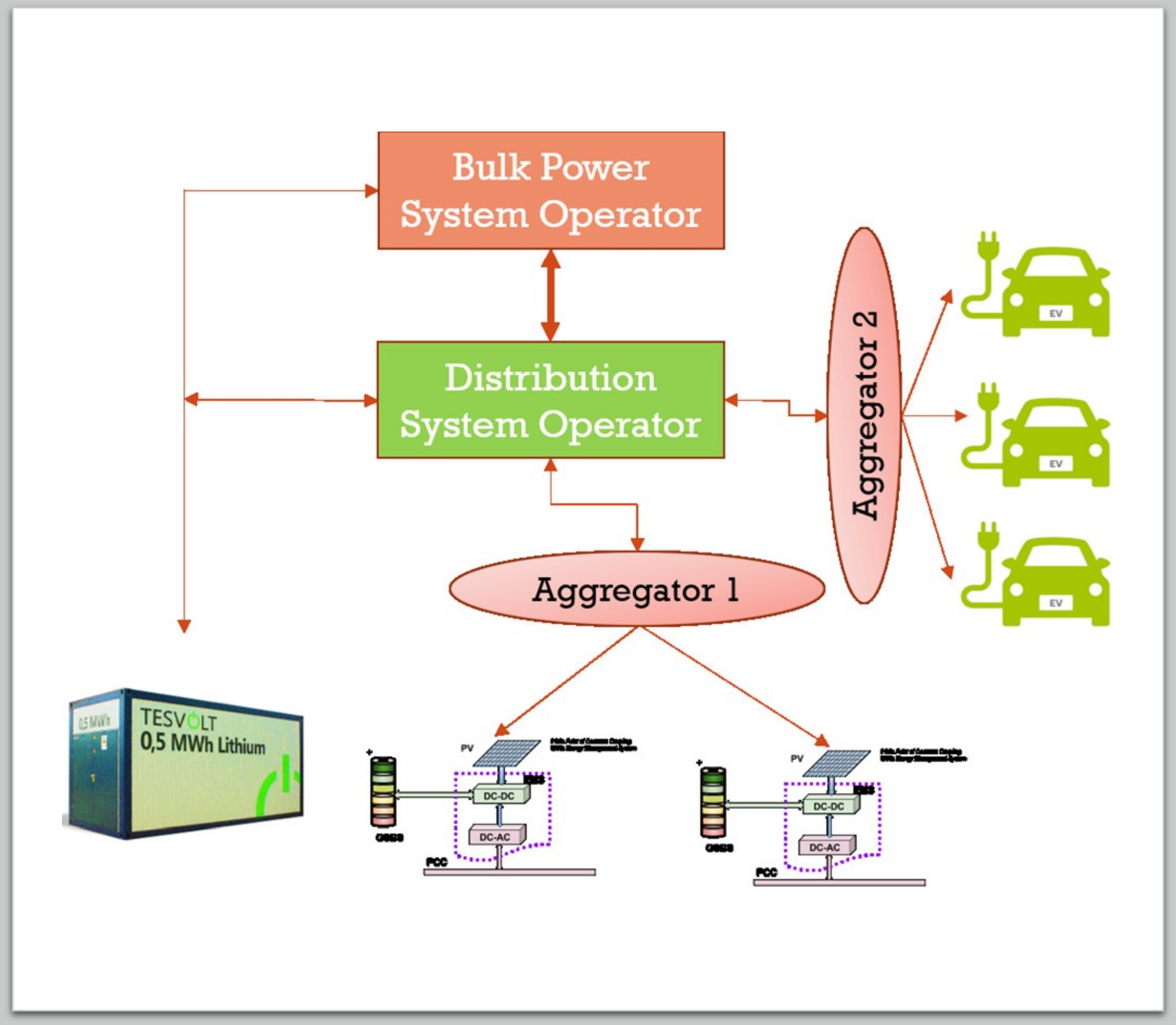


Conflicts between services:

Each service requires some portion of a storage unit's capacity… When one service requires more capacity than the unit's reserve capacity (reserved for back-up power for example) the services create a conflict.

Conflicts between services need to be anticipated and can be controlled if the systems control software anticipates and controls the allocation of the unit's capacity. This advanced set of algorithms should compare the value of each service, the anticipated need of the service and the level of criticality of each service.

Service Stacking strategies:

Single-use Scenarios – are the most simple and predictable strategy.

Multi-use Scenarios - spread the dependence from a single revenue stream to multiple service revenue streams. Multi-use provides diversification to moderate changes in future price developments of the respective services. Here services are provided sequentially based on more static planning.

Dynamic multi-use - The dynamic multi-use approach can yield the highest profit, as it combines the advantages of behind-the-meter (client services) and in front-of-the-meter (aggregated ancillary services). It is much more complicated and requires advanced software and real-time data input.

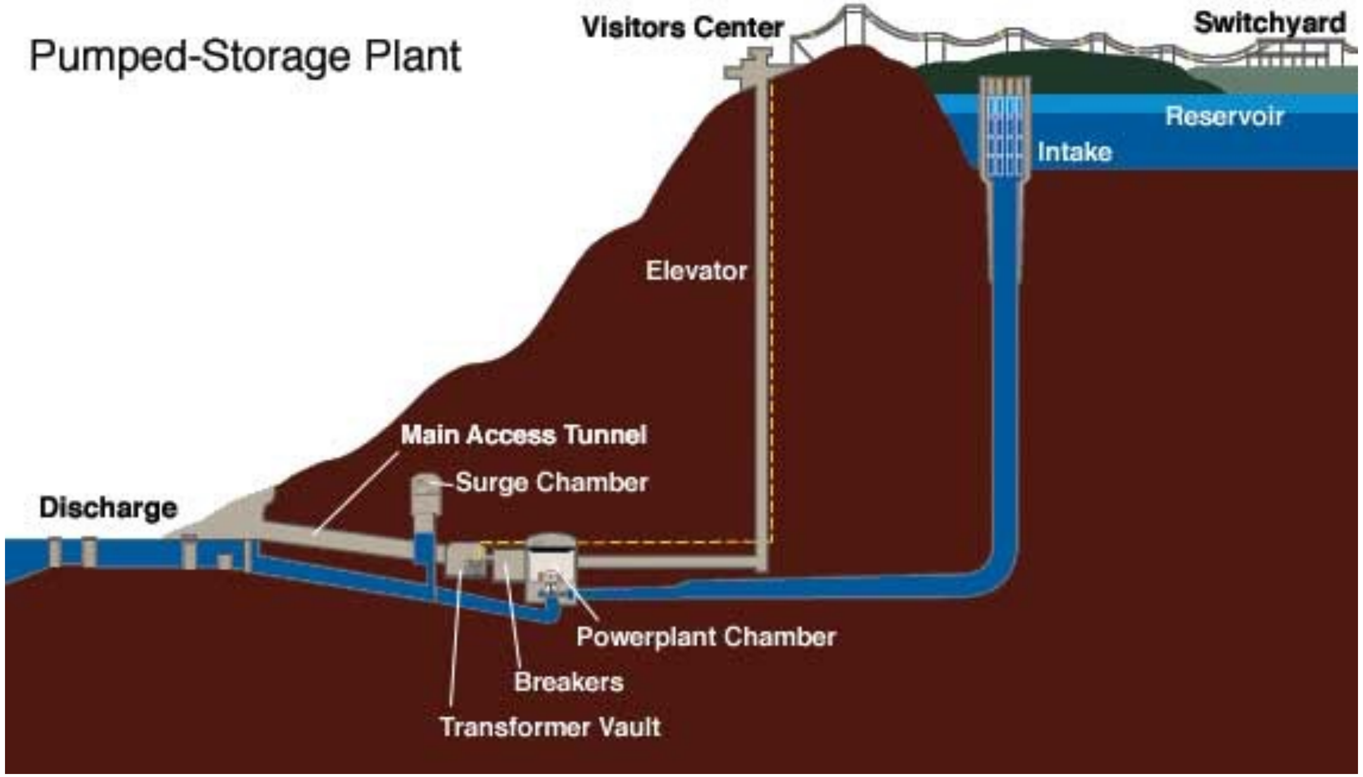
Our main topic will be Battery Energy Storage Systems –

First let us review the other major players in the Energy Storage field -

Defining Non- Battery Storage types:

- Hydro
- Flywheel
- Compressed Air
- Hydrogen – (Nascent)

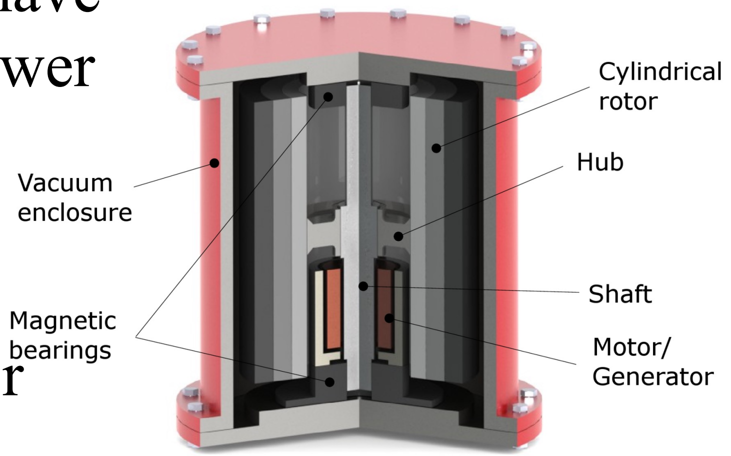
Pumped Hydro storage is the largest-capacity form of grid energy storage available, and, as of 2020, the DOE Global Energy Storage Database reports that PSH accounts for over 92.6% of all active tracked storage installations worldwide, with a total installed nameplate capacity of over 168 GW.[3]



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]

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.



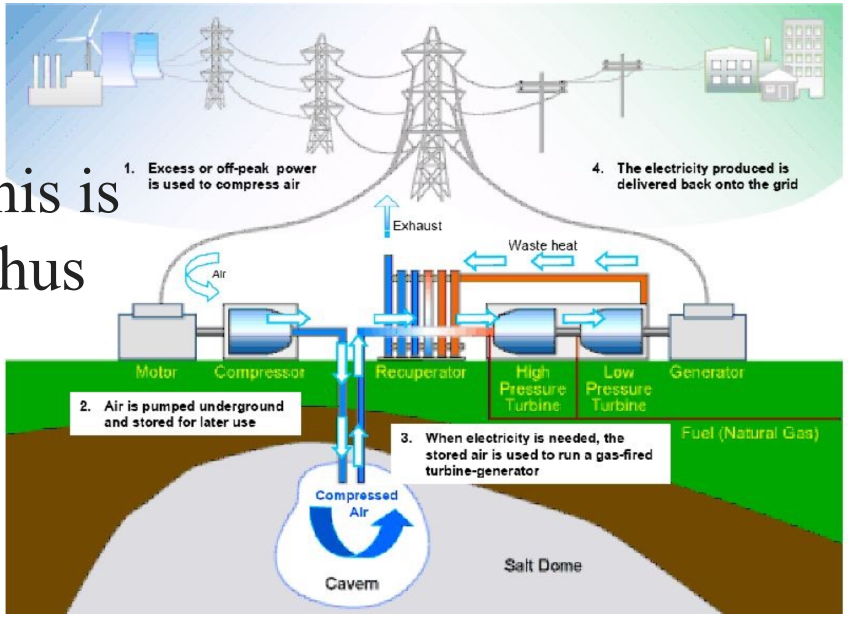
Typical applications are places where electrical energy can be obtained and stored, and must be supplied again to compensate for example, fluctuations in seconds in wind or solar power. These storage facilities consist of individual flywheels in a modular design. Energy up to 150 kW can be absorbed or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

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.

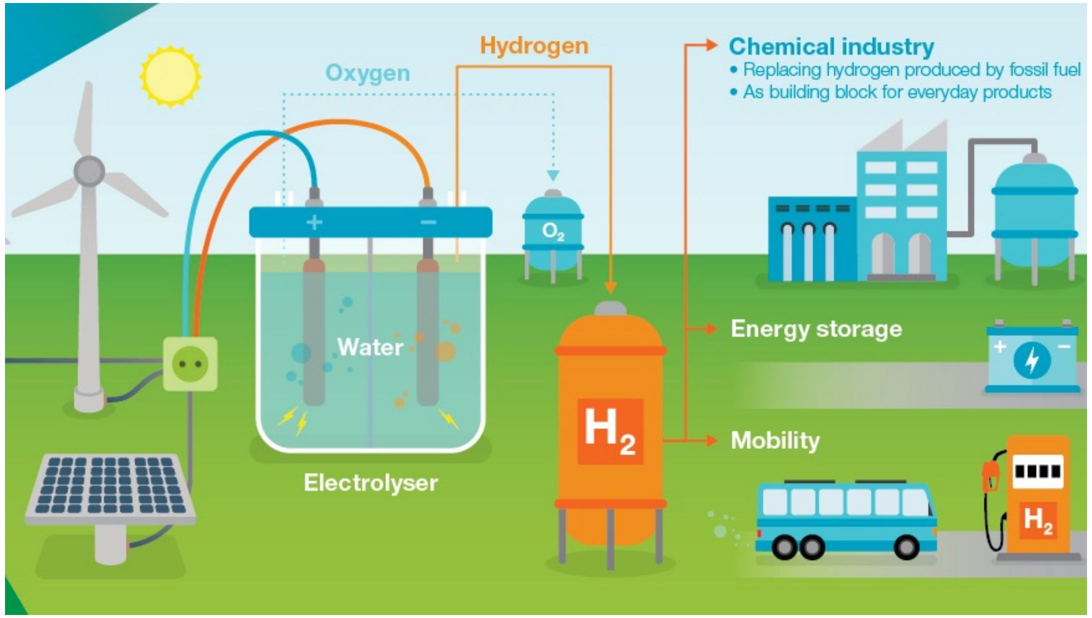
Energy storage systems often use large underground caverns. This is the preferred system design, due to the very large volume, and thus the large quantity of energy that can be stored with only a small pressure change. The cavern space can be easily insulated, compressed adiabatically with little temperature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



Hydrogen has many environmentally beneficial elements
as an energy storage medium…

Hydrogen can reduce the pollution caused by fossil fuels - used in a fuel cell to create power, it is a fairly clean technology. The only byproduct is water. The use of it also eliminates other dangers like oil spills and other pollution associated with Fossil fuel production.
When hydrogen is separated from water by the process of electrolysis it does not add greenhouse gases to the environment. This can be clean full cycle -- electrolysis produces hydrogen from water, and then hydrogen combines with oxygen to create water and power in a fuel cell.
The reduction of economic dependence on non-local players - eliminating the use of fossil fuels brings the energy system close to home and eliminates layers of cost both economic and environmental.

Hydrogen can be produced in a decentralized fashion and at many different scales of generation and use.



The interest in hydrogen energy storage is growing due to the much higher potential storage capacity compared to batteries (small scale) or pumped hydro and Compressed Air Energy Storage CAES (large scale).

As with any energy storage system the amount of energy that the system can deliver relative to the amount of energy injected into the system during the "charging" of the storage system is referred to as the "Round Trip Efficiency" (RTE). This is a key facet to any storage systems effectiveness and return on investment (ROI)

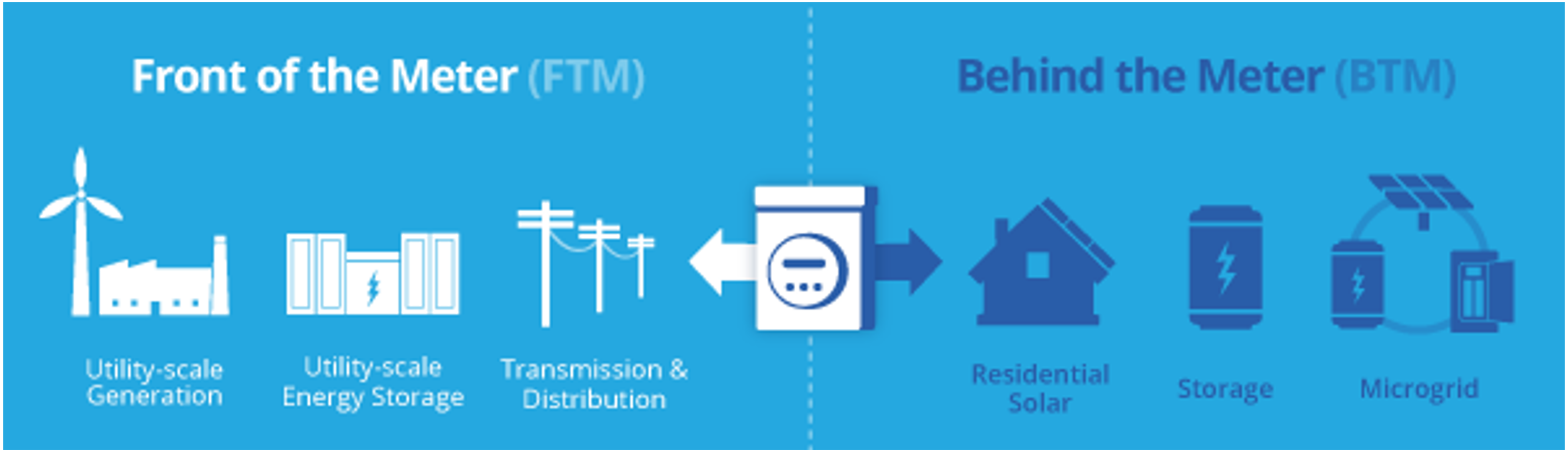
The round trip efficiency for systems that use electrolysis to generate Hydrogen and then re-electrify it with fuel cells today is as low as 30 to 40%.

Storage technologies Round trip efficiency:

Hydro from 65% in older installations to 75-80%for modern deployments

Flywheels	80% to 90%
Batteries	75% to 90%
Compressed air (CAES)	65% to 75%
Hydrogen	30% to 40%

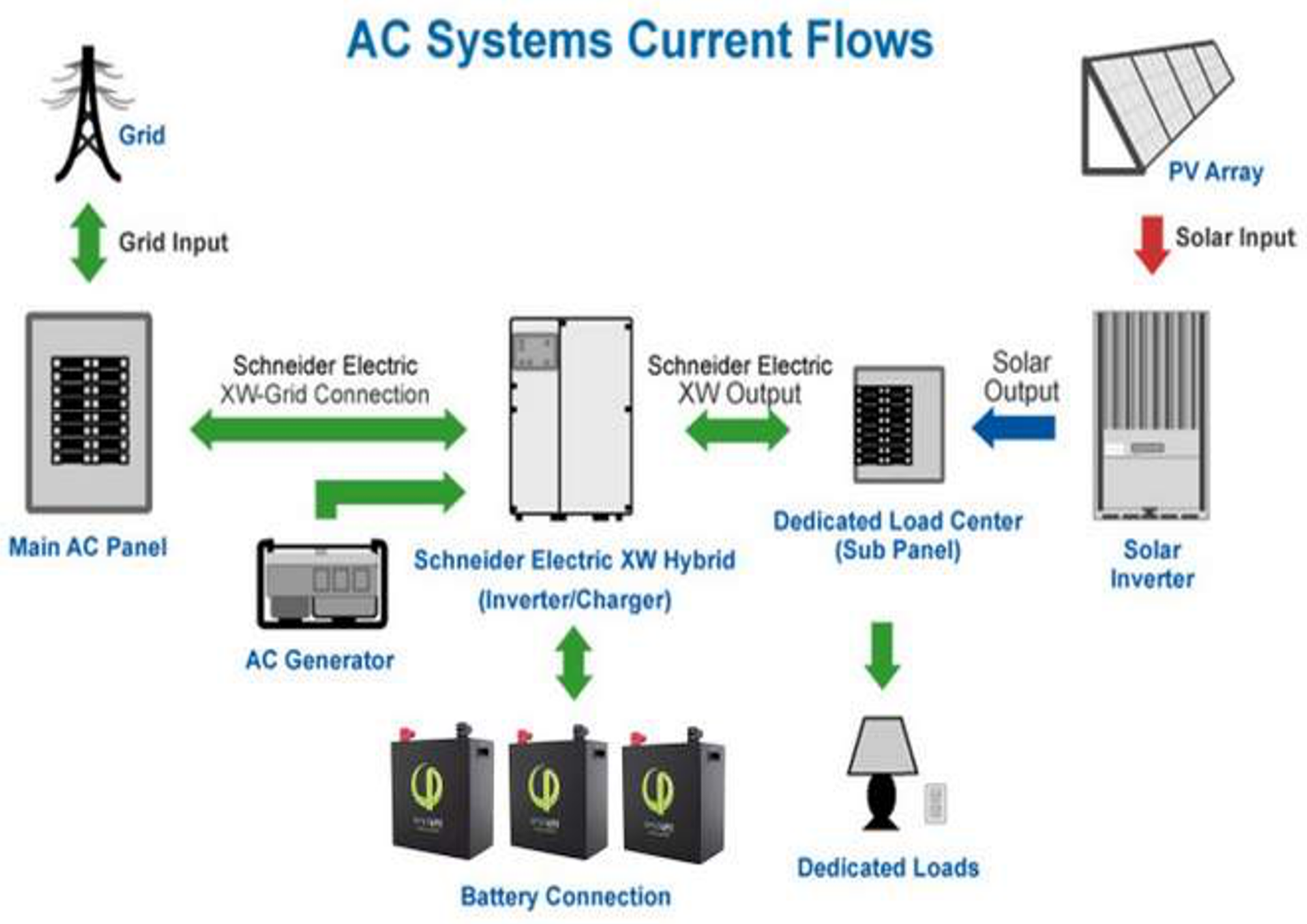
Types of Battery Energy Storage Systems: In Front of the meter (IFM), Behind the meter (BTM)



Courtesy Energy Sage

Types of Systems: AC coupled

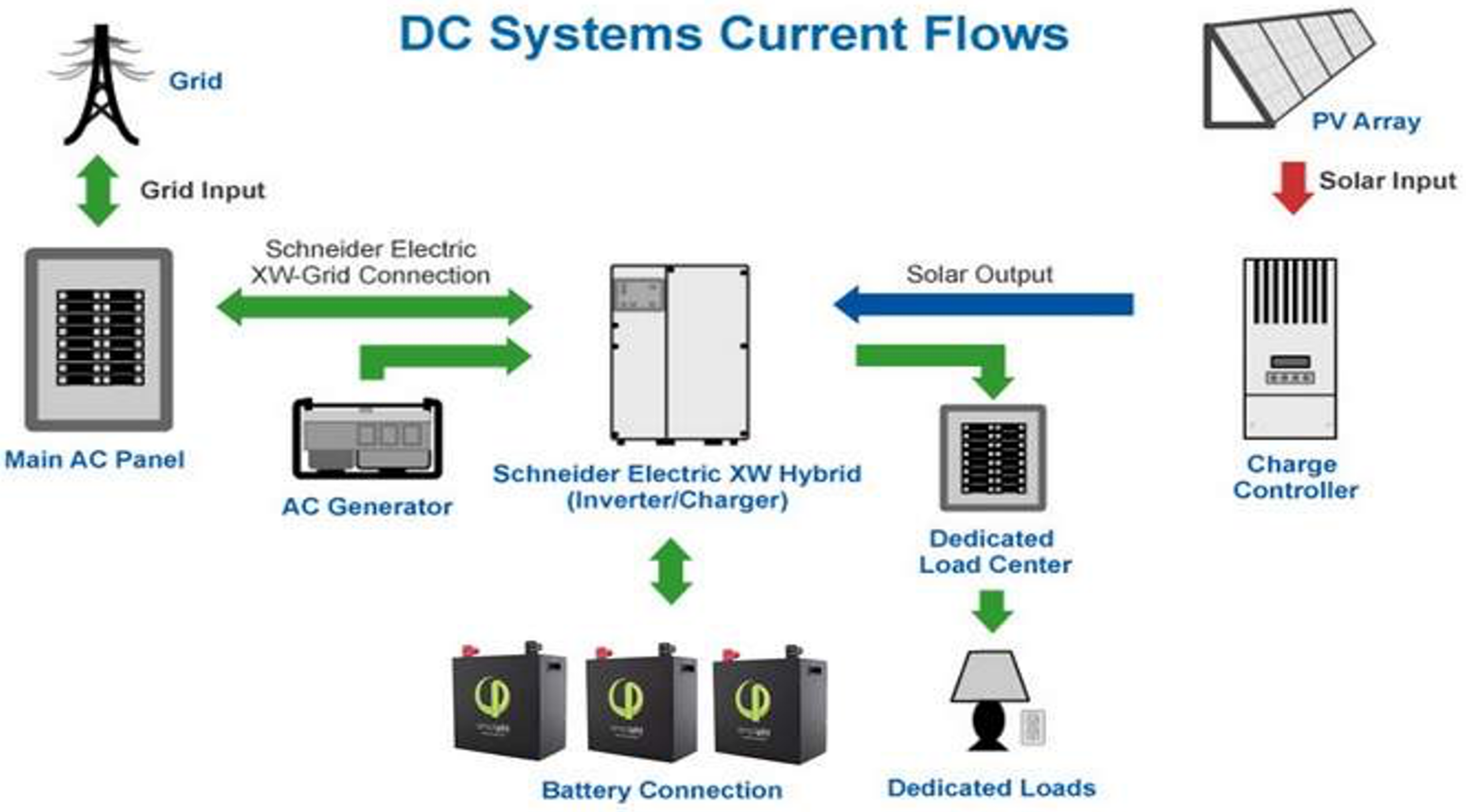
AC Coupling: AC coupled systems Employ two inverters: a standard grid-tied PV inverter and a grid tied battery-based inverter. The energy from the PV array(DC) inverts to AC to a load center through the PV inverter, some is then inverted back to DC to charge batteries through the battery-based inverter, and once more with that inverter back to AC to power home loads and then transfer extra power to the utility grid.



Types of Systems: DC coupled

DC coupling

DC coupled systems employ a charge controller to directly charge the battery with the PV source. Then a battery-based inverter is employed to to power home loads and transfer extra power to the utility grid.



The basic technical benefits of these systems

Eliminating Intermittency of RE Resources

Resiliency – Providing electrical energy to sites during Utility power outages

Energy tariff cost management

Solar optimization – Time shifting the use of solar generation to optimize the usefulness and revenue generation of all RE Systems.

Utility ancillary services - Load following, Frequency regulation Transmission congestions relief, Resource adequacy, Transmission and Distribution deferral, and Power Quality.

Choosing correct design:

Understand Project goals

Create Service Value list

Build an optimum Value stack

Design the system to most efficiently and cost effectively meet the operations for providing the service values

Types of projects and applicable services:

Residential Scale -

- Optimizing Renewable Energy
- Allowing RE use in areas with high penetration of RE
- Time of Use - energy arbitrage
- Resiliency

Commercial scale -

- Microgrid
- Demand Charge reduction
- Optimizing Renewable Energy
- Resiliency

How to judge systems:

Services Provided

Cost Per Service

System Efficiency

Flexibility over the life of the system

Understanding a Solar + Storage systems financial benefits

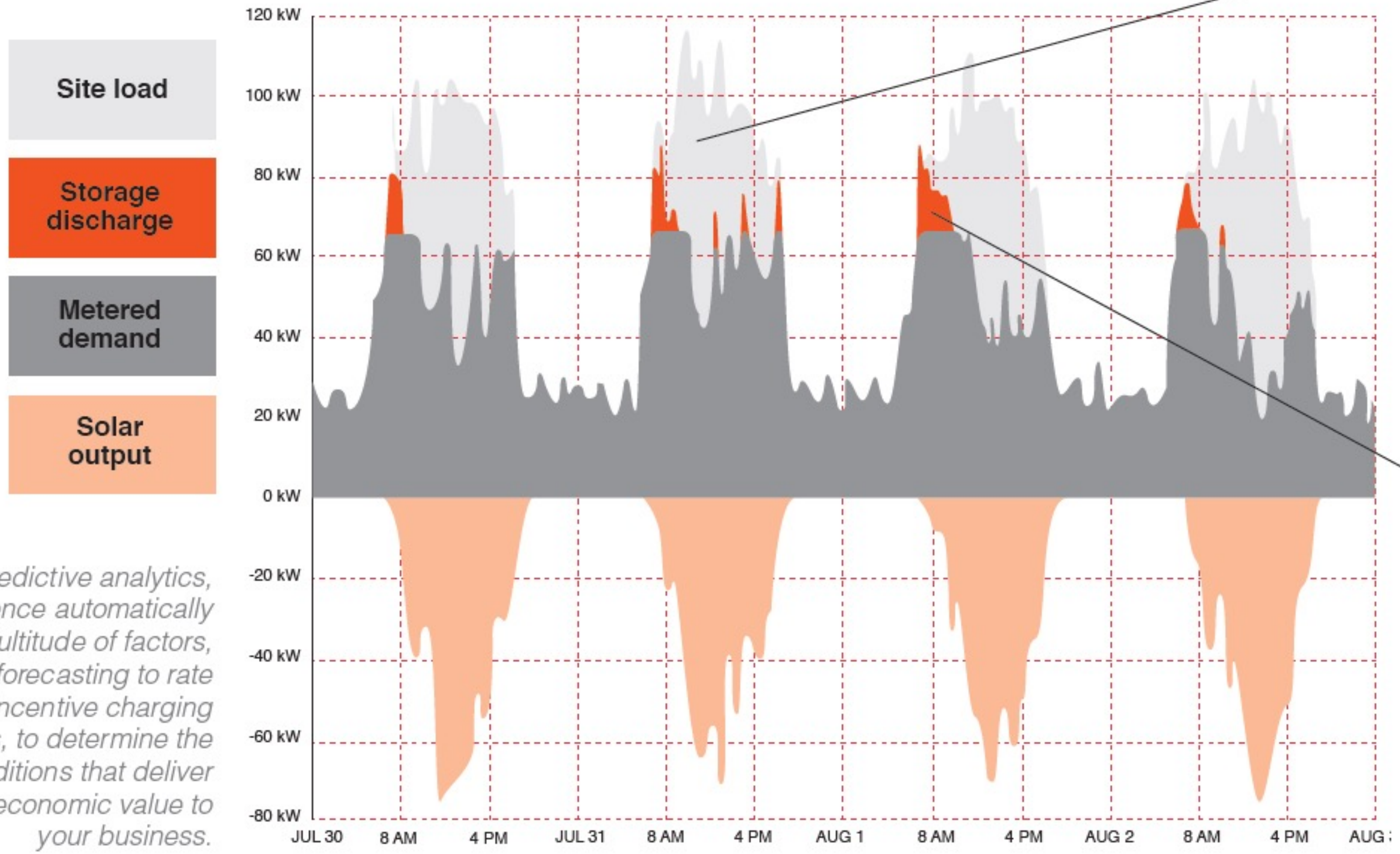
Monetized revenue streams:

- Utility ancillary services –
    - Frequency Regulation
    - State and RTO incentivized services –
    - Capacity markets
- RE - Optimization

Non-monetized benefits:

- Resiliency – (now having models developed to present the monetary value to this stream)
- Access to markets with high RE penetration

Commercial Values - Optimization of Renewable Energy



Shoulder Peaks
Solar generation produces shoulder peaks in the morning as solar ramps up and in the evening as solar ramps down.

Storage Discharge
Artificial intelligence predicts the site load and solar generation, discharging stored energy to shave off shoulder peaks created by solar.

Using predictive analytics, artificial intelligence automatically analyzes a multitude of factors, from load forecasting to rate tariffs to incentive charging requirements, to determine the operating conditions that deliver maximum economic value to your business.

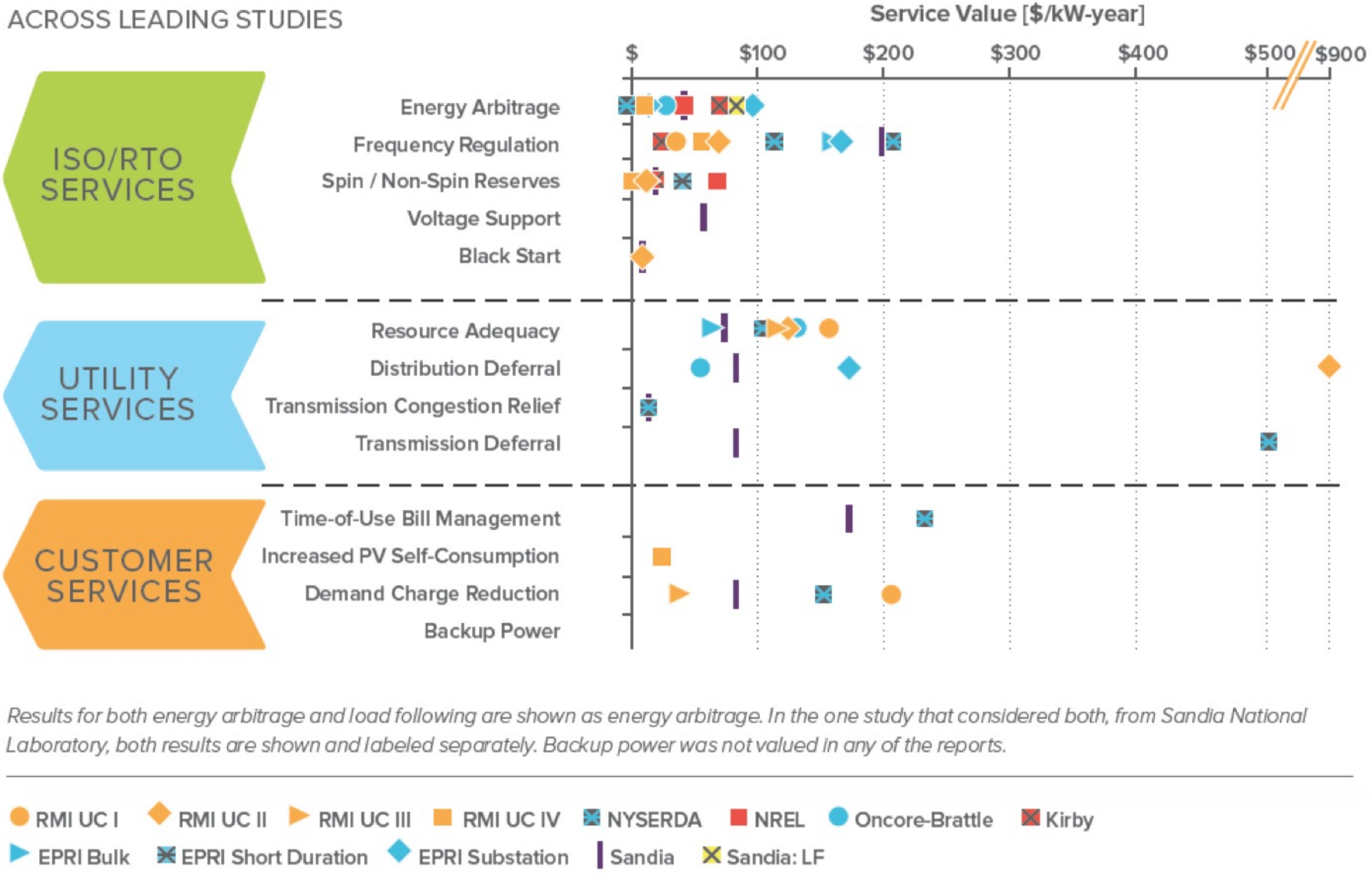
How Utilities and consumers will use S+S systems:

Solar+Storage is rapidly being deployed at the Utility scale for all the services previously described…

Consumers are now beginning to see the potential for revenue streams adequate to make the economics of S+S work at the small commercial and residential scale…we are becoming *Prosumers* ...

FIGURE ES1

ENERGY STORAGE VALUES VARY DRAMATICALLY ACROSS LEADING STUDIES



Results for both energy arbitrage and load following are shown as energy arbitrage. In the one study that considered both, from Sandia National Laboratory, both results are shown and labeled separately. Backup power was not valued in any of the reports.

Compare the many applications of S+S Systems

Types of projects and applicable services:

Residential Scale -

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- Time of Use - energy arbitrage
- Resiliency

Commercial scale -

- Microgrid
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- Optimizing Renewable Energy
- Resiliency

Paul Helstrom:. "Connective not disruptive…"

Questions?

End of Our Session