Energy Storage basics - options, equipment, requirements.

In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,

"This educational offering is recognized by the Minnesota Department of Labor and Industry as satisfying **1.5 hours** of credit toward **Building Officials and Residential Contractors code /1 hour energy** continuing education requirements."

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28 years Training with MREA and other organizations

Emeritus

Welcome to - ENERGY STORAGE BASICS:

Energy Storage is the hot topic in the Renewable Energy world and this disruptive technology stands to shake up much of the energy industry.

Today we will look into what the components are that make up an energy storage system, how this technology works, and how the coupling of solar and storage is *revolutionizing* the energy field.

Energy Storage System (ESS) Components –

A) Energy Source–Solar/Wind–other (Utility grid, generators)
B) Storage Device(s)
C) Inverter(s) and DC to DC Converters
D) BOS - Balance of System
E) Digital System Controllers and Communication Devices

Energy Storage System (ESS) Components –
Energy Source–Solar/Wind–other (Utility grid, generators)

All Systems will start with an energy source. Today the most valuable systems with the greatest Return on Investment (ROI) are Solar or Wind generation systems mated with an appropriate storage system.

Components of an ESS - The Storage Device

Required

Cells

Packs/Modules

Racks

Containment

Additional Elements

HVAC

Inverter

DC DC Converter

Enhanced Safety

Components of an ESS - Inverter(s)
DC to DC Converters and other essentials...

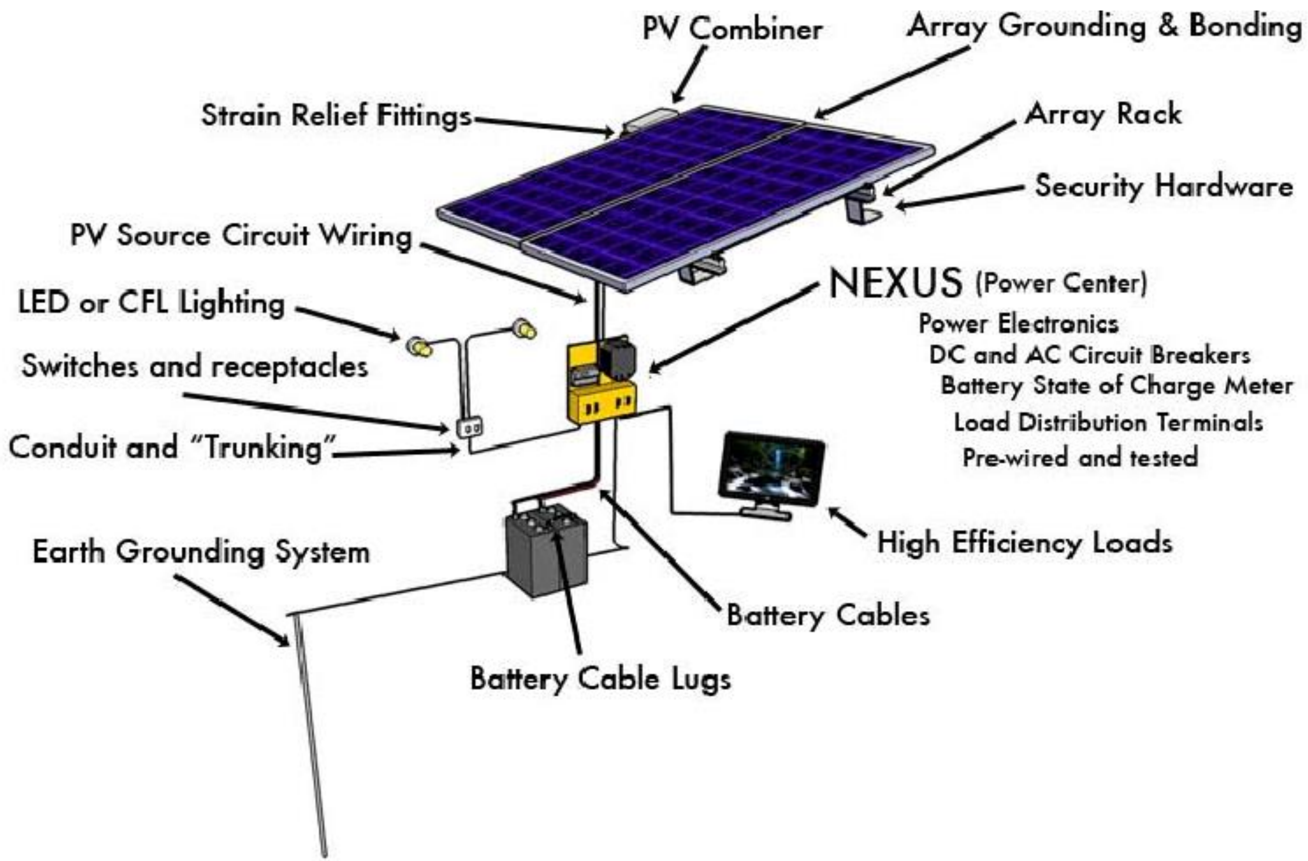
HVAC

Inverter

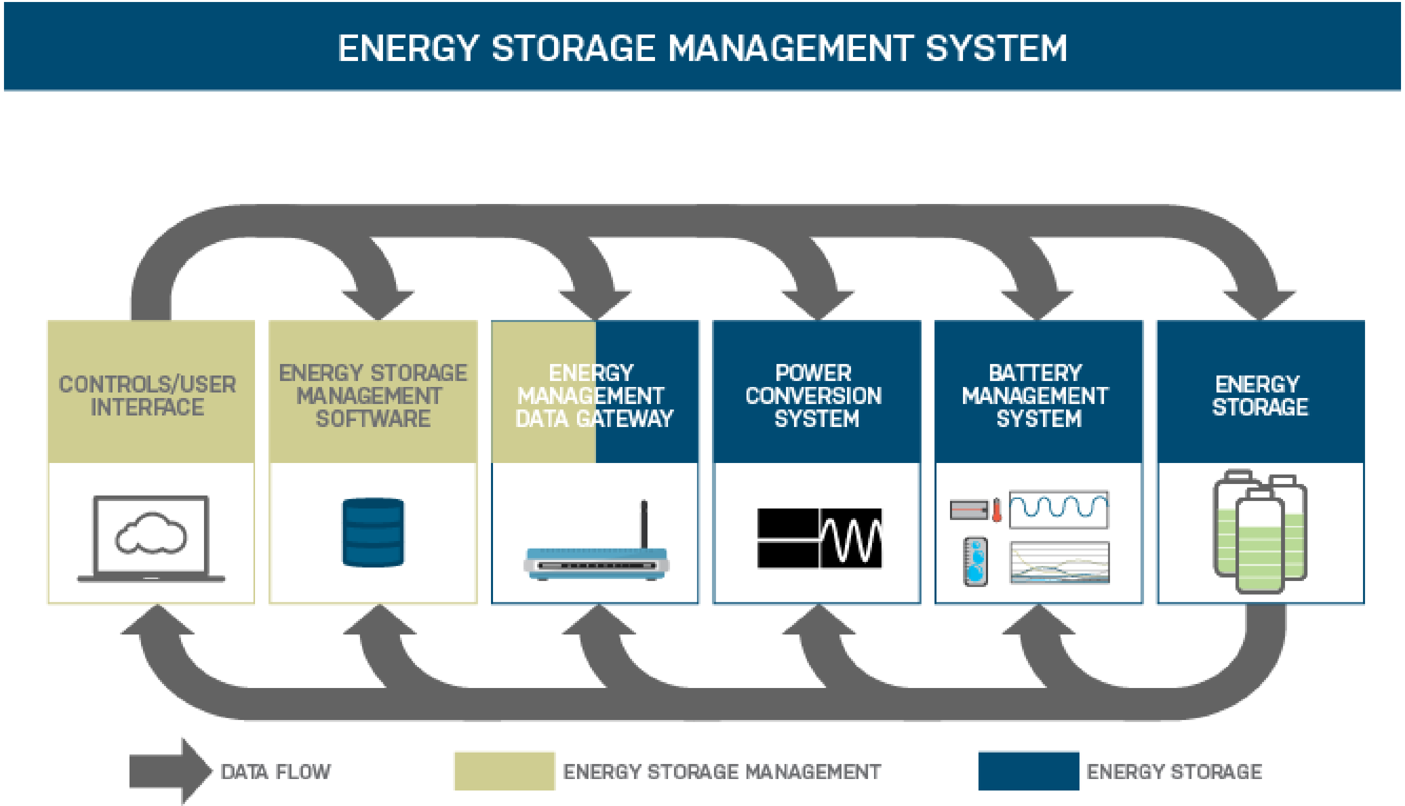
DC DC Converter

Enhanced Safety

Components of an ESS - BOS - Balance of System



Components of an ESS - Digital System Controllers And communication Devices

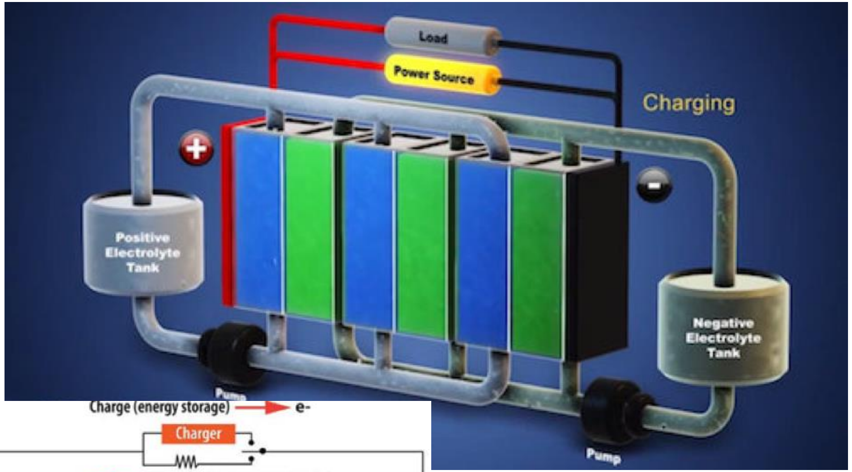


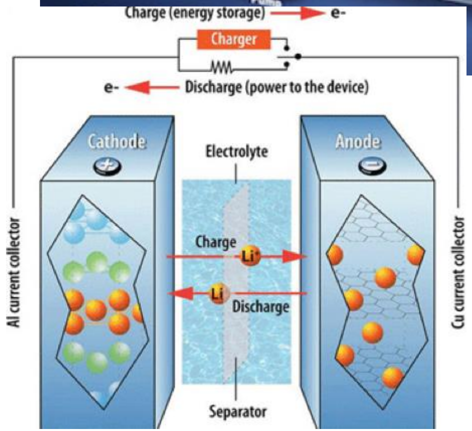
Two primary new battery types are dominating the PV + Storage market:

Flow batteries

And

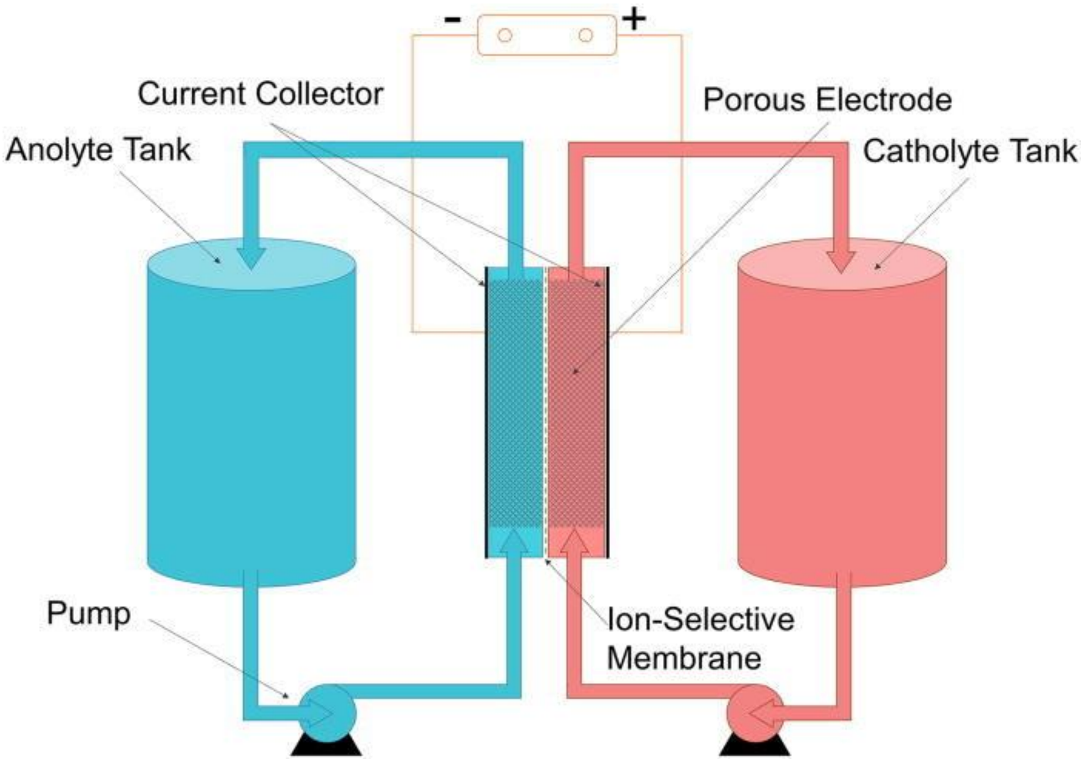
LiOn batteries





Flow Battery Technologies

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.



Flow batteries – Vanadium Redox & Zinc 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

May have reduced efficiency due to rapid charge/discharge

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-

Has traditionally had high cost

Safety issues from overheating

Requires advanced manufacturing capabilities to achieve high performance

ESS - How this technology works

Energy Storage vs. Coffee Pot

Energy Storage vs. Coffee Pot	
kWh	Pot
kW	Spout
Inverter	Tap

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ESS - This technology works by…

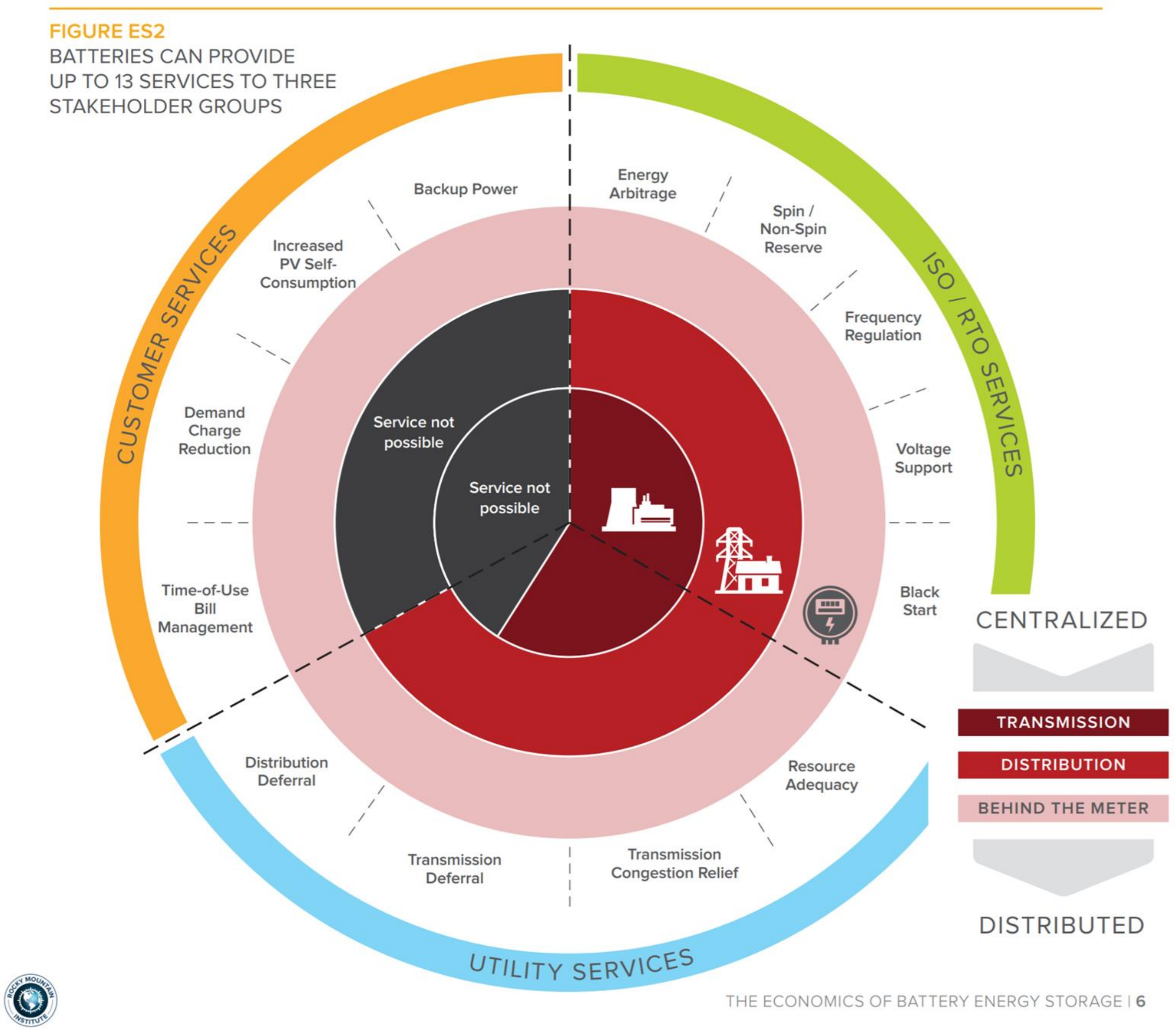
Using advanced controls to provide users with specific services that benefit the user in multiple ways.

The user gets value from the services and employs the technology to receive maximum benefit and profit.

The value of each service determines the goals of the client 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.

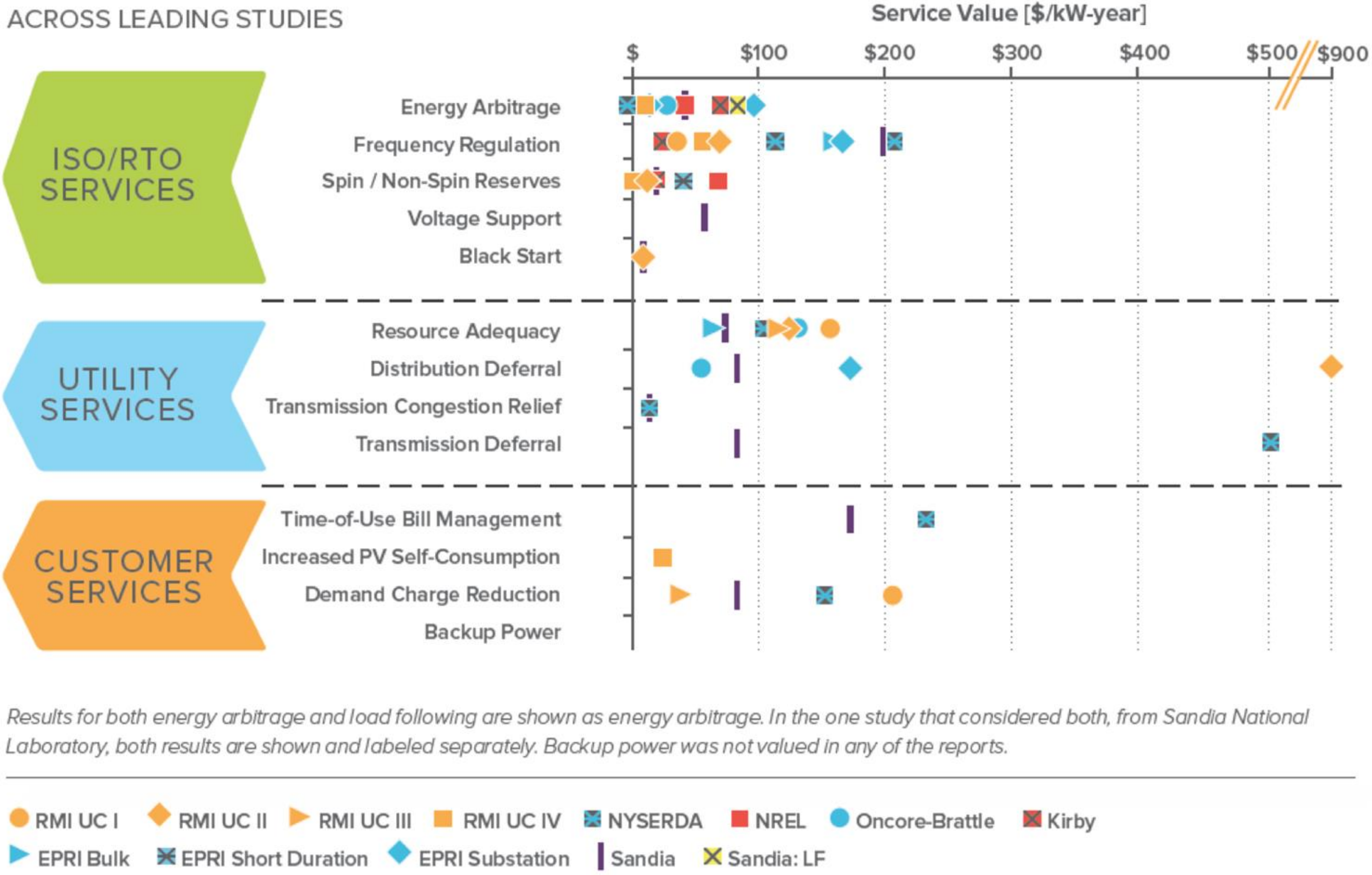
Orientation to Value Stacking



Financial Benefits

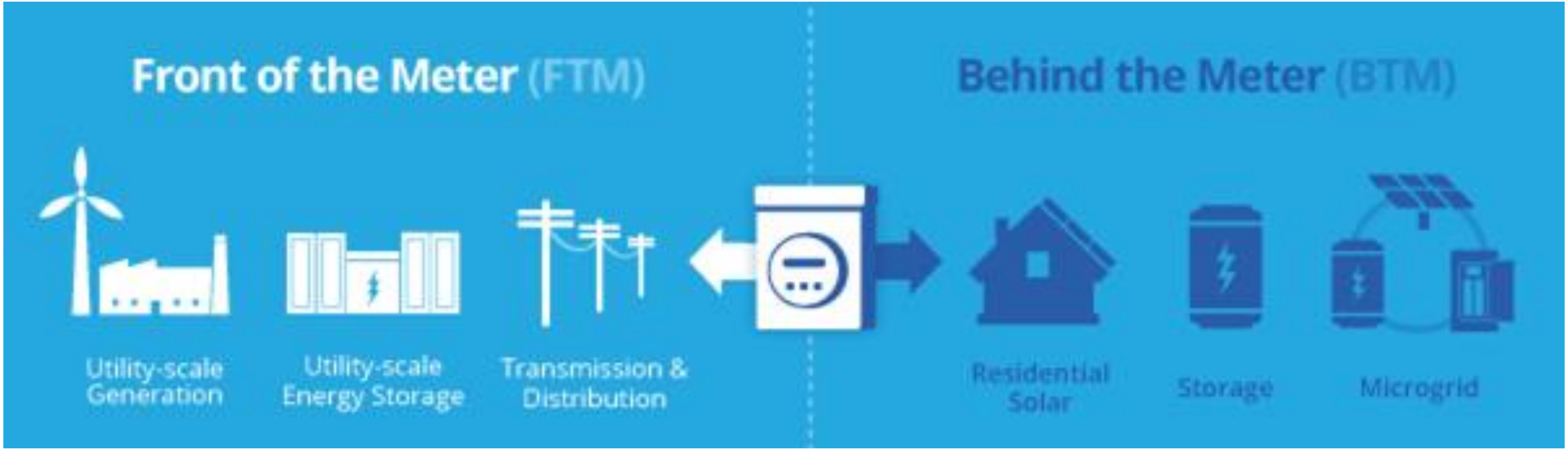
Value stacking improves project economics

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.

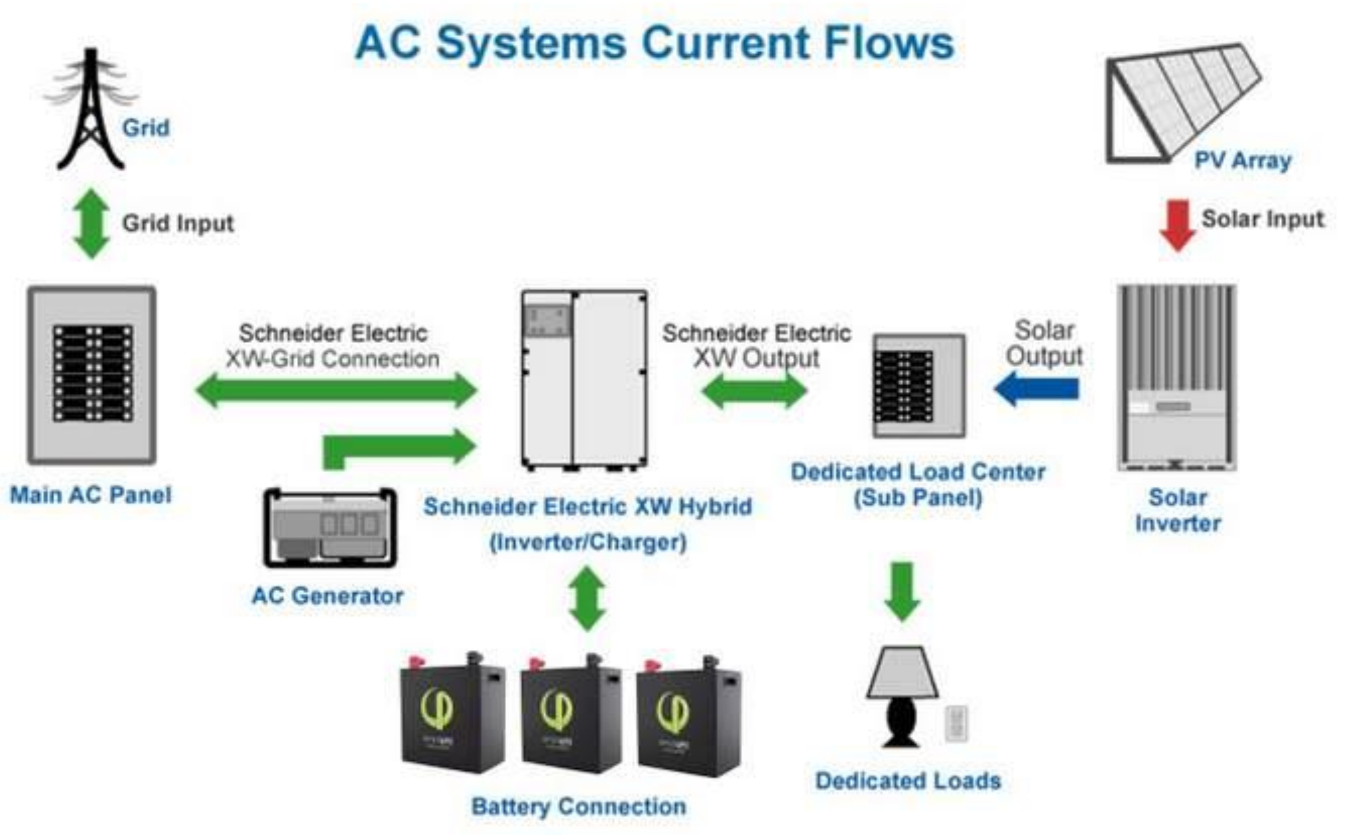
Types of Systems: In Front of the meter (IFM), Behind the meter (BTM)



Courtesy Energy Sage

Types of Systems: AC coupled

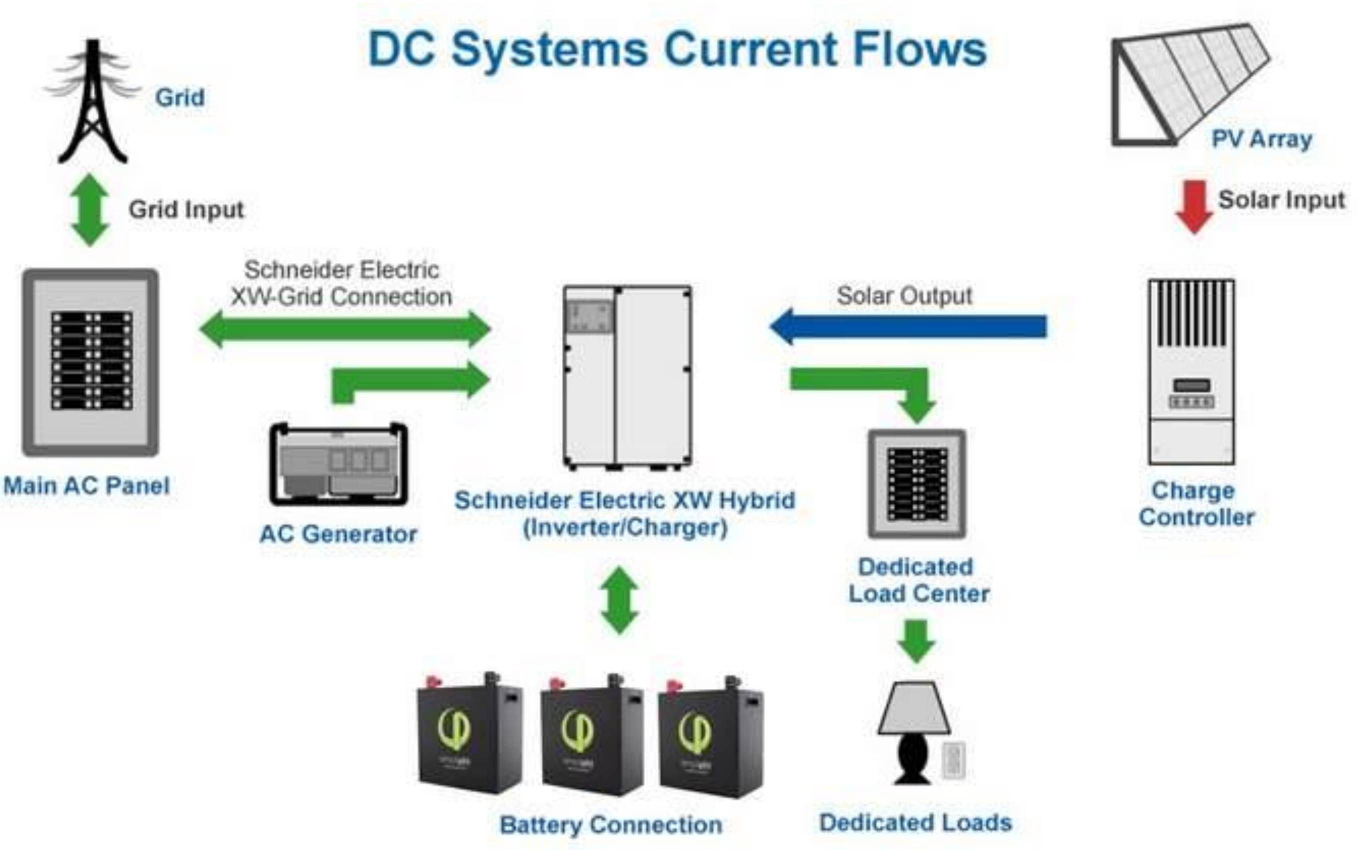
AC Coupling: AC coupled systems Employ two inverters: a standard grid-tied PV inverter and a grid tied battery-based inverter. The energy from the PV array(DC) inverts to AC to a load center through the PV inverter, some is then inverted back to DC to charge batteries through the battery-based inverter,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



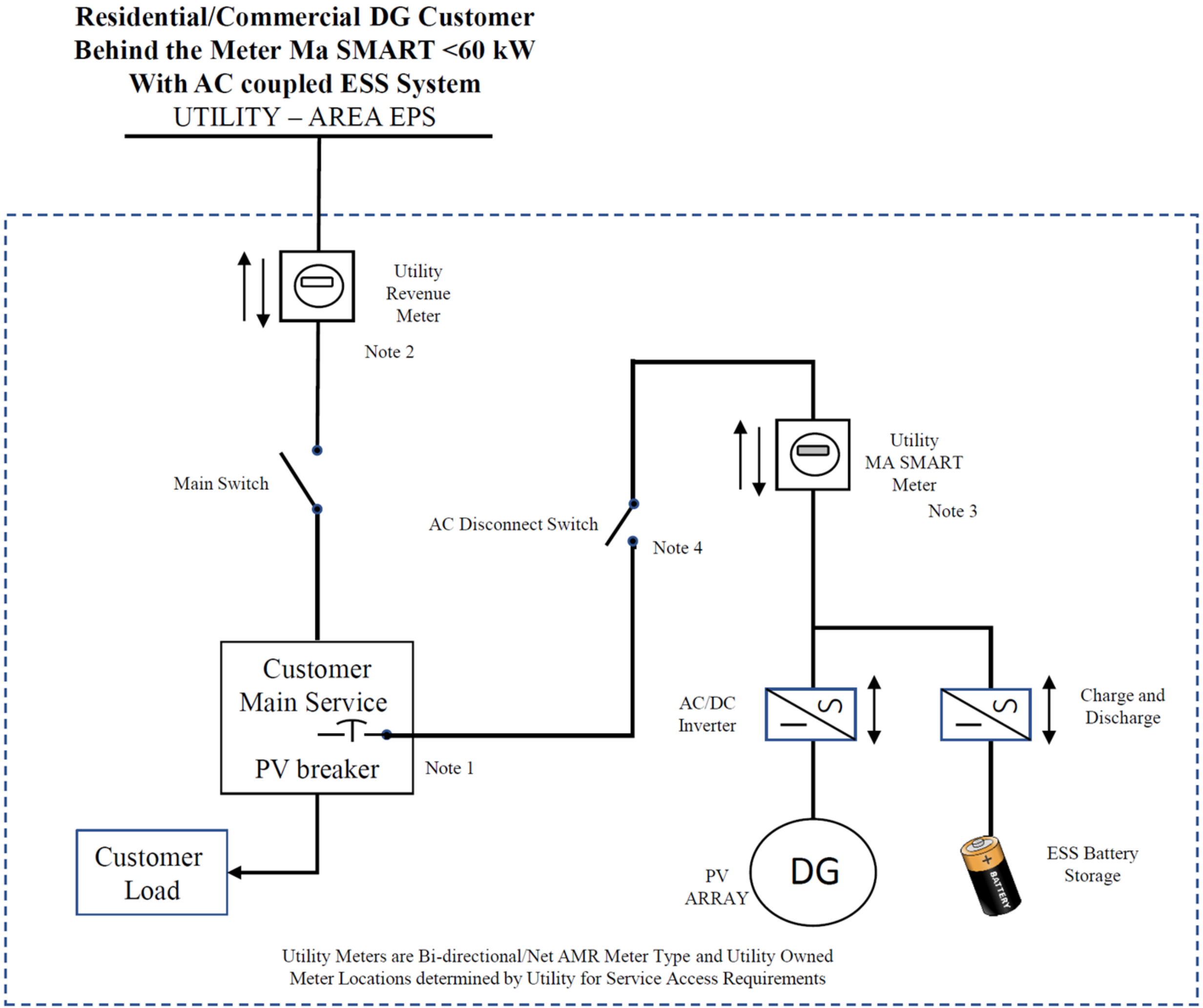
Types of Systems: DC coupled

DC coupling

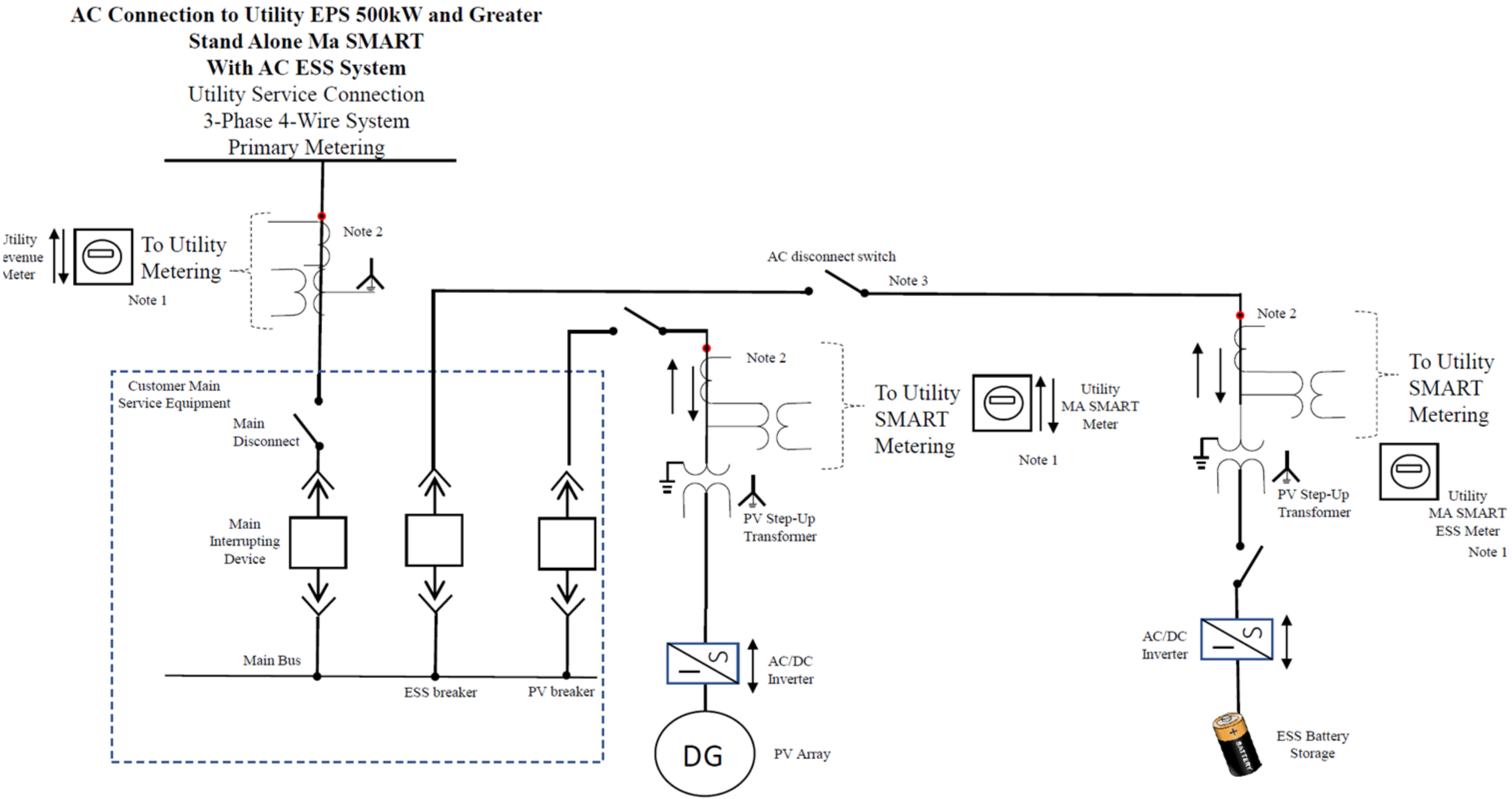
DC coupled systems employ a charge controller to directly charge the battery with the PV source. Then a battery-based inverter is employed to to power home loads and transfer extra power to the utility grid.



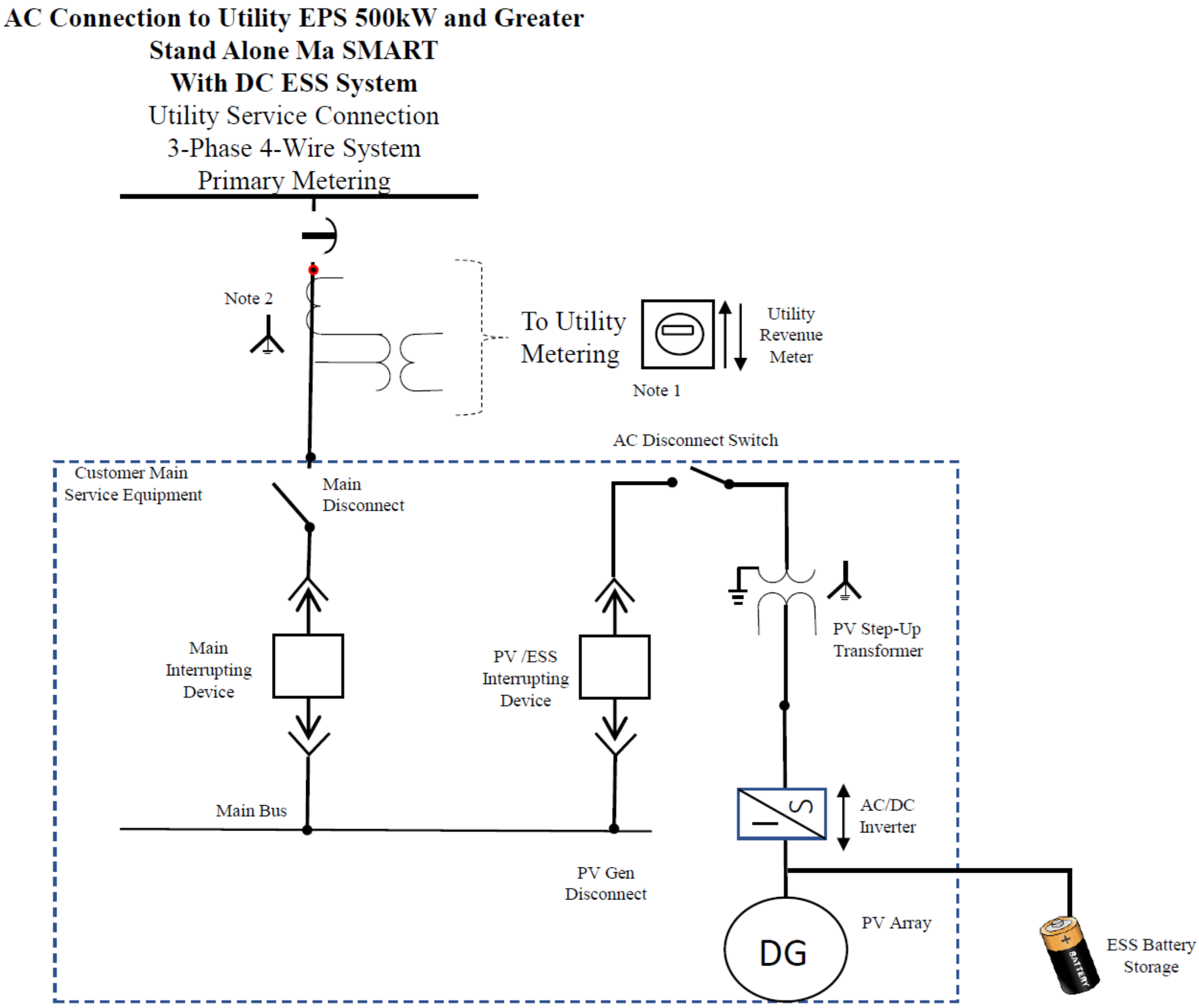
Diagramming systems:
Behind the Meter (BTM)



Diagramming systems: In Front of the Meter (IFM) AC coupled



Diagramming systems: In Front of the Meter (IFM) DC coupled



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:

Utility Scale -

- Transmission
- Peaker replacement
- Frequency regulation
- Distribution

Commercial scale -

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

Residential Scale -

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

How to judge systems:

Services Provided

Cost Per Service

System Efficiency

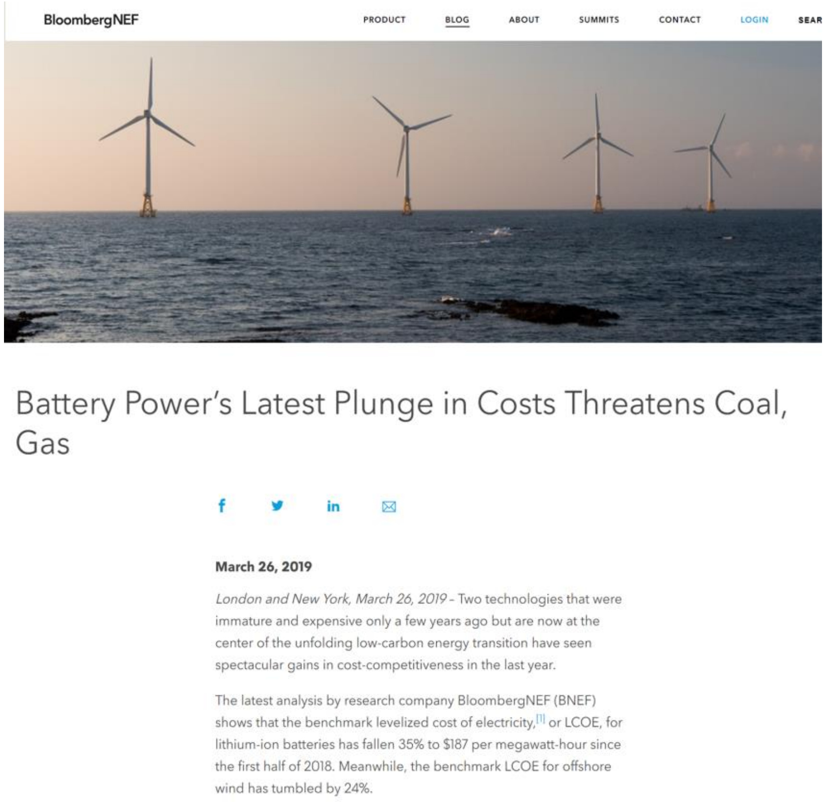
Flexibility over the life of the system

Cost:

Solar + storage costs in USA : This changes every day!

Project Costs - ESS

- Bloomberg, March 2019: “Battery Power’s Latest Plunge in Costs Threatens Coal, Gas”
- LCOE for lithium-ion batteries has fallen 35% to $187 per MWh
- Lithium-ion battery costs have fallen 76% since 2012
- LCOE measures the all-in expense of producing a MWh of electricity from a new project, taking into account the costs of development, construction and equipment, financing, feedstock, operation and maintenance.



Battery Power’s Latest Plunge in Costs Threatens Coal, Gas

March 26, 2019

London and New York, March 26, 2019 - Two technologies that were immature and expensive only a few years ago but are now at the center of the unfolding low-carbon energy transition have seen spectacular gains in cost-competitiveness in the last year.

The latest analysis by research company BloombergNEF (BNEF) shows that the benchmark levelized cost of electricity,[1] or LCOE, for lithium-ion batteries has fallen 35% to $187 per megawatt-hour since the first half of 2018. Meanwhile, the benchmark LCOE for offshore wind has tumbled by 24%.

Solar + Storage Costs - Rough Estimate of LCOE (*indicative*)

(Calculations run for July 2019 Singapore seminar)

1MW PV	$1.92/W	$	1,920,000
1MW / 2MWh ESS	$590/kWh	$	1,180,000
Project Total		**$**	**3,100,000**
kWh/year			1,211
Degradation			0.05%
20y kWh			23,111,679
LCOE S+S		**$**	**0.13**

100MW PV	$1.05/W	$	105,000,000
100MW / 200MWh ESS	$350/kWh	$	70,000,000
Project Total		**$**	**175,000,000**
kWh/kWp/year			1,211
Degradation			0.05%
20y kWh			2,311,167,900
LCOE S+S		**$**	**0.08**

- “Simple Calculation”
- Doesn’t include:
  - Cost of capital
  - Cost of land
  - Inverter replacement
  - Battery refresh
  - Additional revenue from ESS
  - Local incentives
  - More

Micro-Grids Highlight the potential for strong resiliency with the use of ESS systems...

A Micro Grid consists of group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.

Microgrids are electricity distribution systems containing loads and distributed energy resources, (such as distributed generators, storage devices, or controllable loads) that can be operated in a controlled, coordinated way either while connected to the main power network or while is landed.

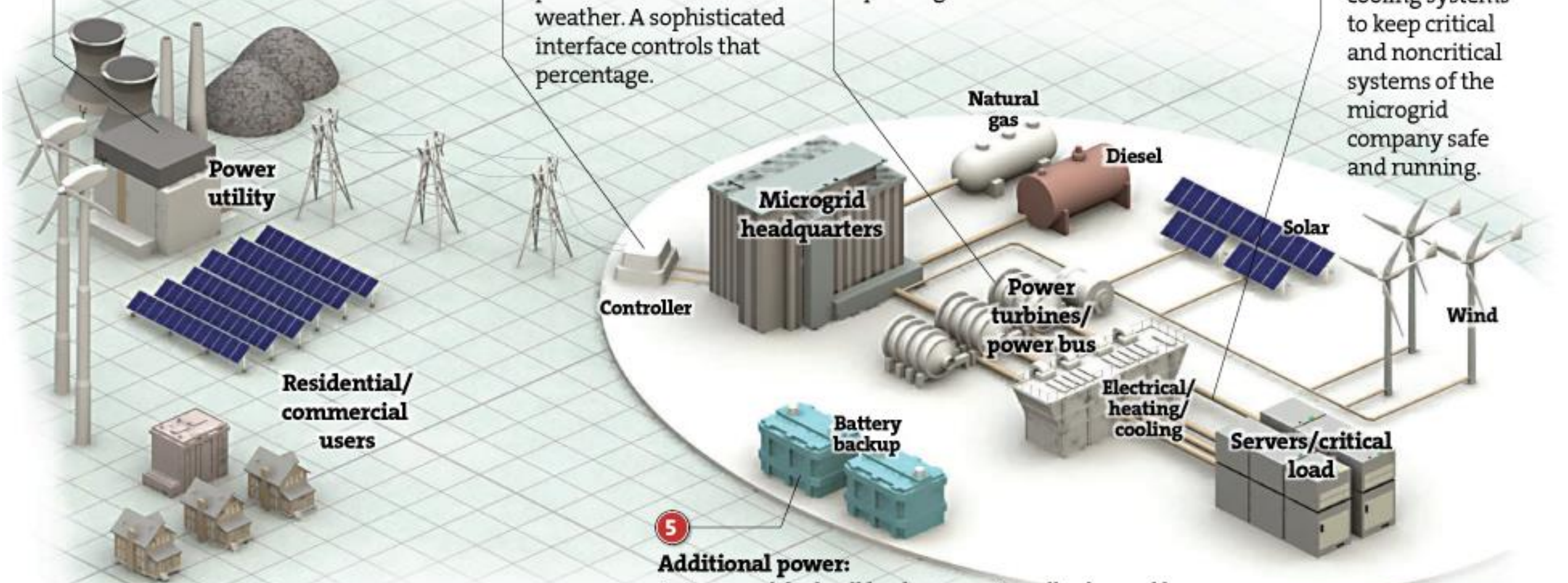
HOW A MICROGRID 'ISLAND' WORKS

1 **The national grid:** The electrical grid is powered by a major utility. Coal, nuclear, wind and solar sources combine to provide power to commercial and residential users.

2 **Connection:** The utility grid powers the microgrid system, but only a percentage of the power, dependent on time of day, power load or even weather. A sophisticated interface controls that percentage.

3 **The microgrid:** Electrical power is produced in the microgrid by a mix of sources: gas or diesel power generators, wind and solar. The microgrid can "island" itself or run independently from the power grid.

4 **Distribution:** The turbine system powers electrical, heating and cooling systems to keep critical and noncritical systems of the microgrid company safe and running.



5 **Additional power:** Battery and fuel-cell backups continually charged by the system are available for additional redundancy.

Source: OATI

MARK BOSWELL • Star Tribune

Micro Grids...

Oati in Minneapolis MN

The building is powered by:

- **Solar:** 150 kw rooftop solar array, with additional expansion array planned
- **Wind:** 24kW of vertical axis wind turbines
- **Electricity storage:** 231 kWh, at 125kW Ensync battery rated power and energy
- **Natural gas turbines:** 600kW Capstone C600 natural gas burning microturbine. Paired with absorption chiller and heat exchanger for CCHP
- **Generator:** 1500kW of diesel backup generator
- **Utility connection:** Connected to local utility Xcel Energy

Questions?

Thank you for your interest in Renewable Energy and Energy Storage Systems!