Document number

Residential Solar Energy Storage Analysis

Prepared for NYSERDA

DNV KEMA
July 30, 2013

Scope

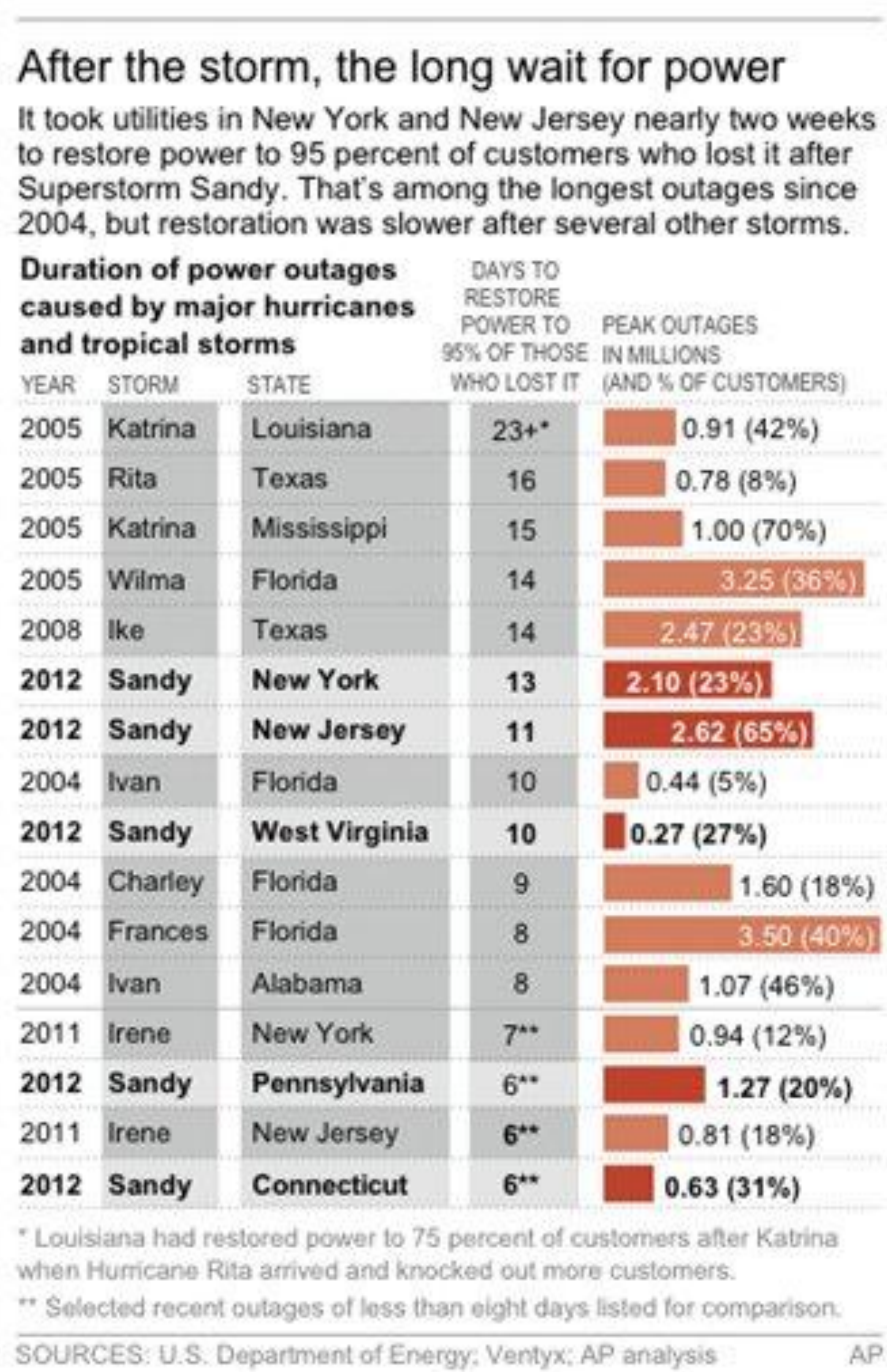
- In this study, the DNV KEMA team has examined the potential of storage applications to meet minimal electricity needs identified for residences, where grid failures prevented their distributed assets from operating during the outage
- Specifically, research has focused on the potential of solar–storage applications with the goal of:
  - Identifying lowest incremental cost to allow solar PV systems to island from the electric grid and provide a modest level of electricity for critical loads through these types of configurations
  - Identifying some niche applications close to commercialization for stationary energy storage in the commercial and industrial sector.

Disclaimer: This analysis is an initial expedited attempt to quantify the minimum system sizing to provide minimal electric backup for a residential PV system and should be used as a reference document for those purposes. In addition, the examples of energy storage applications for the Commercial and Industrial sector presented at the conclusion of the document are not intended to be all encompassing.

Contents

Motivations

- Recent natural disasters have increased visibility of electric power systems and their interdependence
- After Hurricane Sandy, New York utilities restored power to 95 percent of customers 13 days after peak outage reporting
- Extended outages result in economic, security, and consumer confidence problems:
  - Frozen water pipes
  - Dark nights (increased fire danger)
  - Spoiled food
  - No electric heat
  - No elevators for the infirm or elderly
  - No means to charge mobile communication devices



After the storm, the long wait for power

It took utilities in New York and New Jersey nearly two weeks to restore power to 95 percent of customers who lost it after Superstorm Sandy. That's among the longest outages since 2004, but restoration was slower after several other storms.

Duration of power outages caused by major hurricanes and tropical storms

YEAR	STORM	STATE	DAYS TO RESTORE POWER TO 95% OF THOSE WHO LOST IT	PEAK OUTAGES IN MILLIONS (AND % OF CUSTOMERS)
2005	Katrina	Louisiana	23+*	0.91 (42%)
2005	Rita	Texas	16	0.78 (8%)
2005	Katrina	Mississippi	15	1.00 (70%)
2005	Wilma	Florida	14	3.25 (36%)
2008	Ike	Texas	14	2.47 (23%)
2012	**Sandy**	**New York**	**13**	**2.10 (23%)**
2012	**Sandy**	**New Jersey**	**11**	**2.62 (65%)**
2004	Ivan	Florida	10	0.44 (5%)
2012	**Sandy**	**West Virginia**	**10**	**0.27 (27%)**
2004	Charley	Florida	9	1.60 (18%)
2004	Frances	Florida	8	3.50 (40%)
2004	Ivan	Alabama	8	1.07 (46%)
2011	Irene	New York	7**	0.94 (12%)
2012	**Sandy**	**Pennsylvania**	**6****	**1.27 (20%)**
2011	Irene	New Jersey	6**	0.81 (18%)
2012	**Sandy**	**Connecticut**	**6****	**0.63 (31%)**

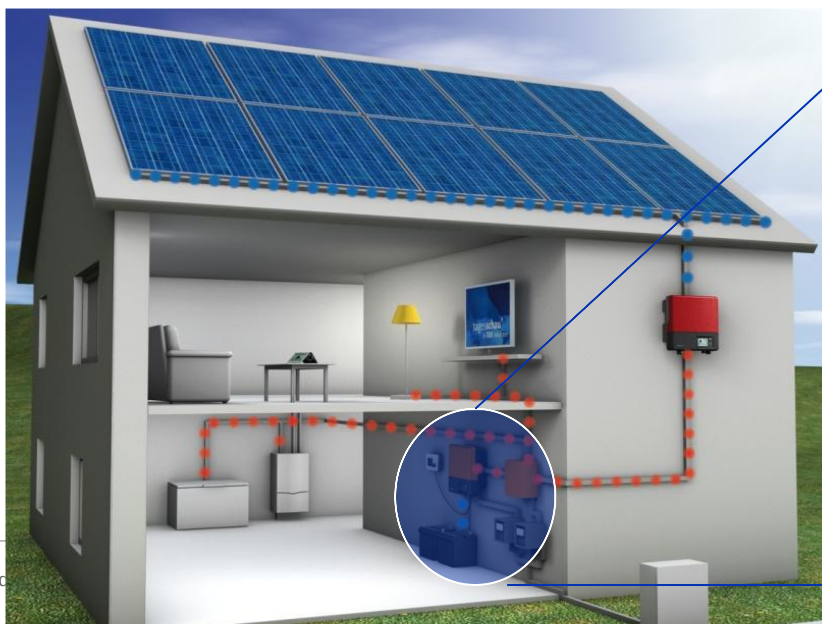
* Louisiana had restored power to 75 percent of customers after Katrina when Hurricane Rita arrived and knocked out more customers.

** Selected recent outages of less than eight days listed for comparison.

SOURCES: U.S. Department of Energy; Ventyx; AP analysis AP

Introduction

- These outages have exposed "gaps" in grid reliability
  - increased focus on utilization of distributed generation assets, notably photovoltaic generation to address these gaps
- An area of particular interest is allowing distributed generation assets to "island" from the grid during an outage
  - allows for continued power to critical systems such as health and safety, public safety, fuel distribution networks, telecommunication systems, and residences
- **This presentation will focus on "edge-of-grid" energy storage for residential backup and describes some near-term commercial and industrial applications**



Source: Sunny Backup by SMA

Source: Sunny Backup by SMA

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Critical Loads

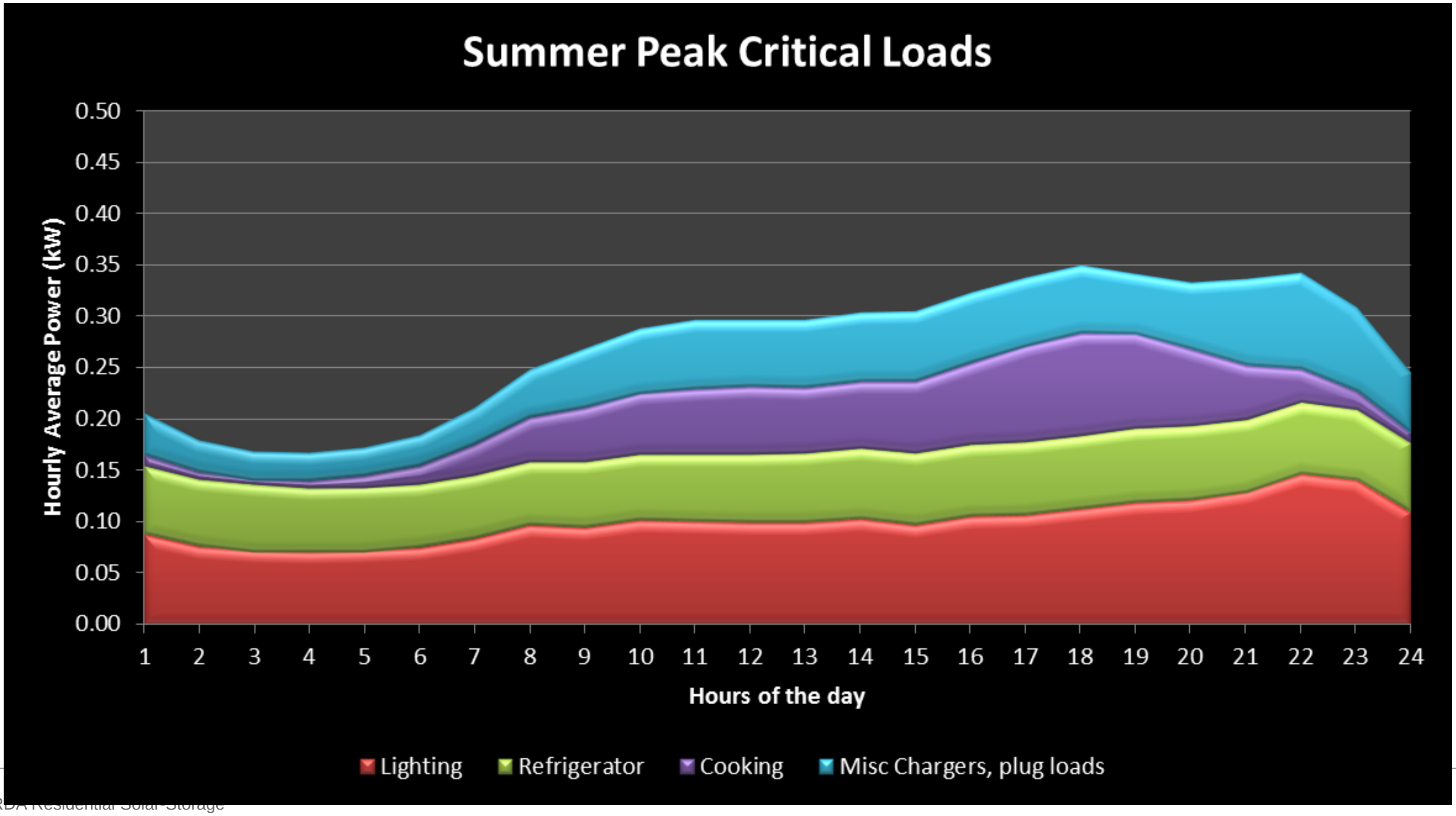
- It is not practical to design backup systems to support all electrical loads in a typical residence
- Customers and installers need to agree on which loads and circuits require backup during an outage
  - Power and energy requirements of critical load are the primary driving factors when sizing the storage device for back-up operation
- At a minimum, backed up loads may include communications equipment such as TVs or computers, select lighting, and a few outlets for charging mobile devices
- Additional desired backup may include fans and controllers for natural gas heating systems, water pumps, cooking, refrigerators and freezers

Establishing a Load Profile

- Capacity of the backup system is based on the power and energy requirements of the critical loads in relation to the duration of the grid failure
- Expected values of critical load can serve as a baseline to specify inverter and battery-capacity requirements
- The analysis here draws from Northeast residential load shapes for: heating, cooling, refrigeration, cooking, water heating, and misc. chargers and plug loads
- The data draws from the DNV KEMA load profile database for New York:
  - Electric Water Heater – DNV KEMA study for Northeast Energy Efficiency Partnership
  - Central A/C – DNV KEMA source
  - Electric Heating – DNV KEMA study for Northeast Energy Efficiency Partnerships
  - Non-electric Heating (pumps, fans) – DNV KEMA study for Northeast Energy Efficiency Partnerships
  - Lighting – DNV KEMA study for Northeast Energy Efficiency Partnerships
  - Refrigerator – Northwest Regional Technical Forum Data
  - Cooking – Northwest Regional Technical Forum Data
  - Misc Chargers, plug loads – DNV KEMA source
- *Tabulated data for each end use is shown at the end of the report*

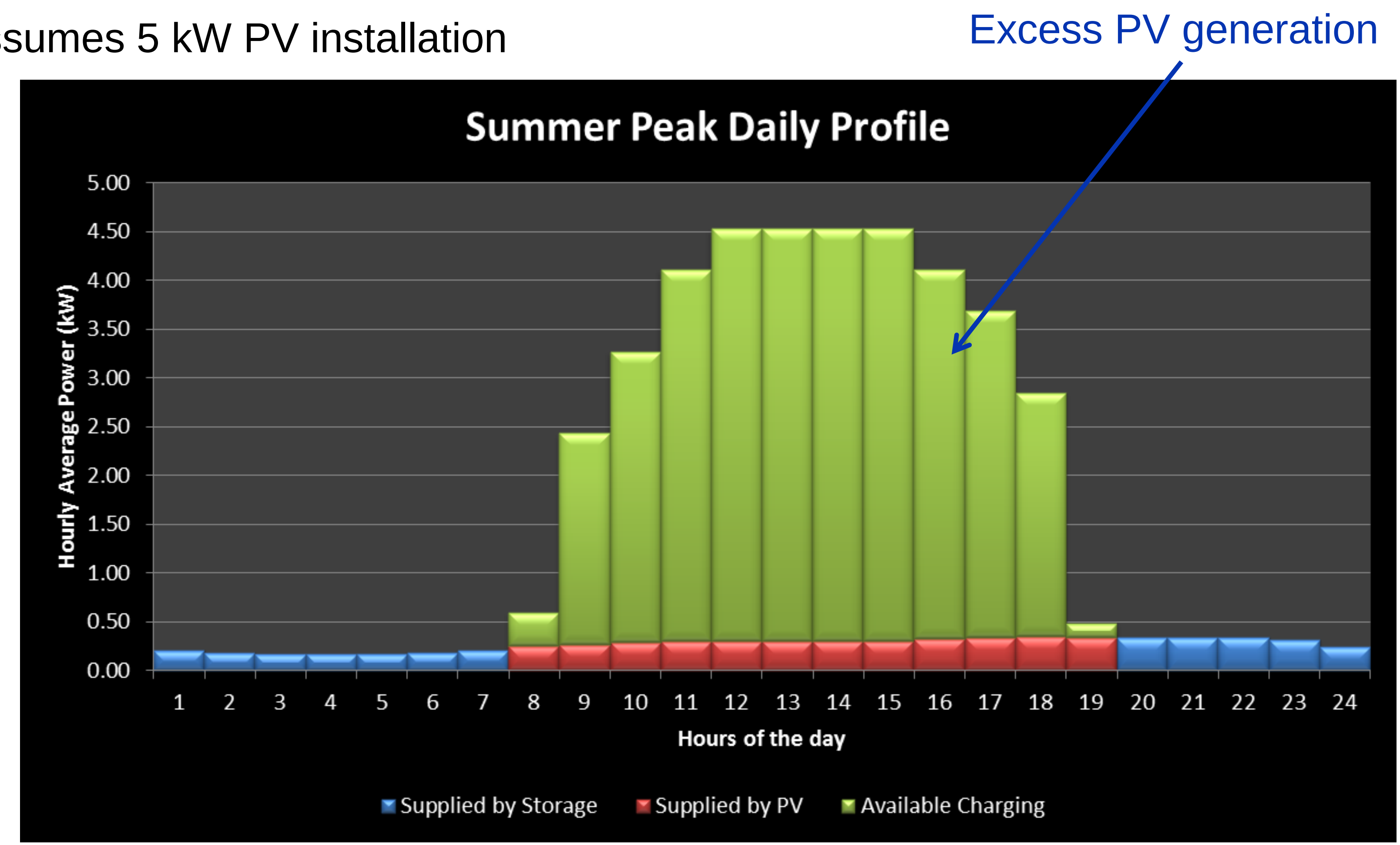
Summer Peak Residential Critical Load

- Graph shows hourly critical kW demand / kWh energy for a peak Summer day
- Central A/C and electric hot water heating were excluded from this minimal critical load analysis because their energy demands are so significant



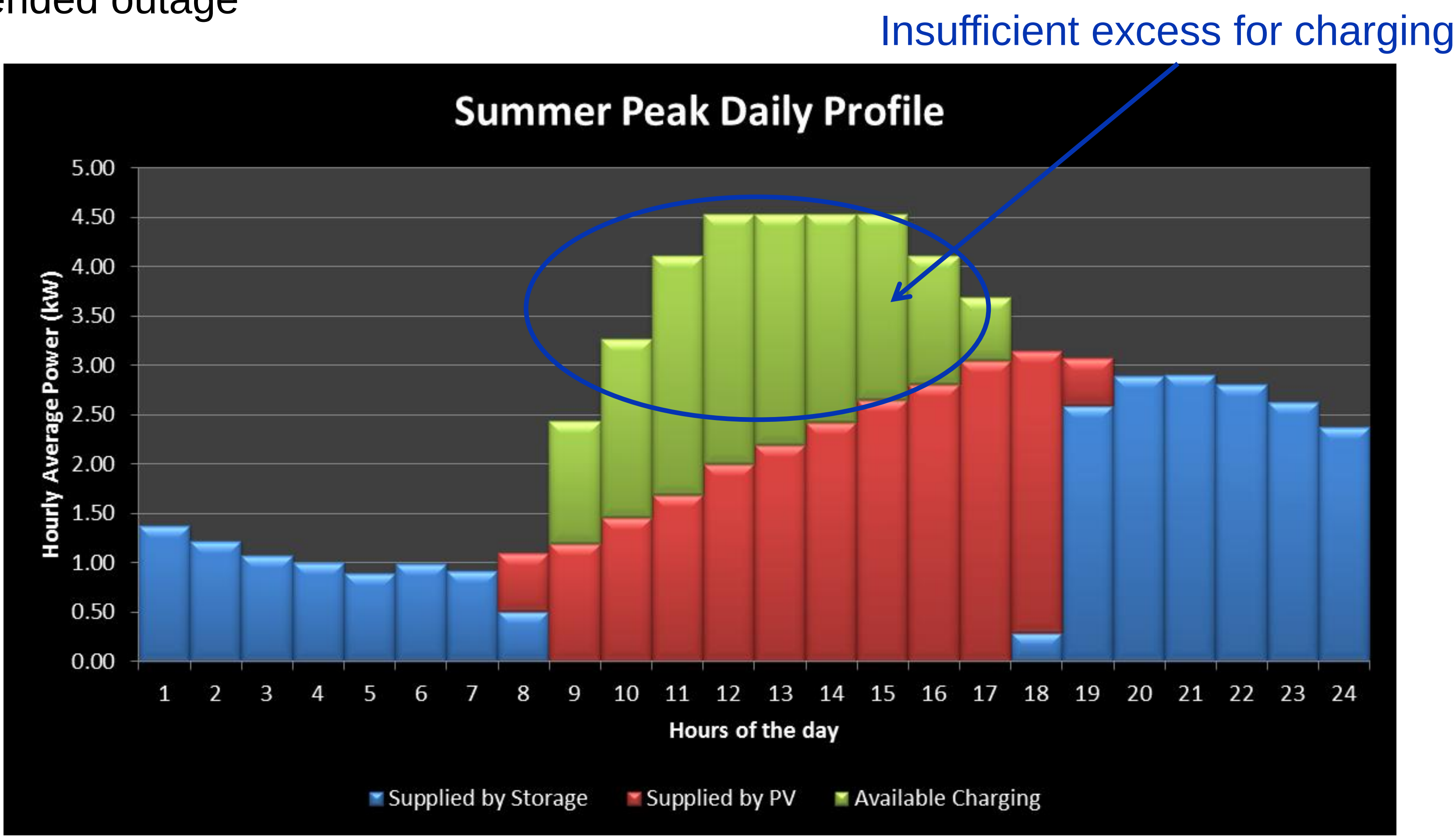
Summer Excess Generation

- Typical NY State Summer PV profile matched to critical load profile
- Assumes 5 kW PV installation



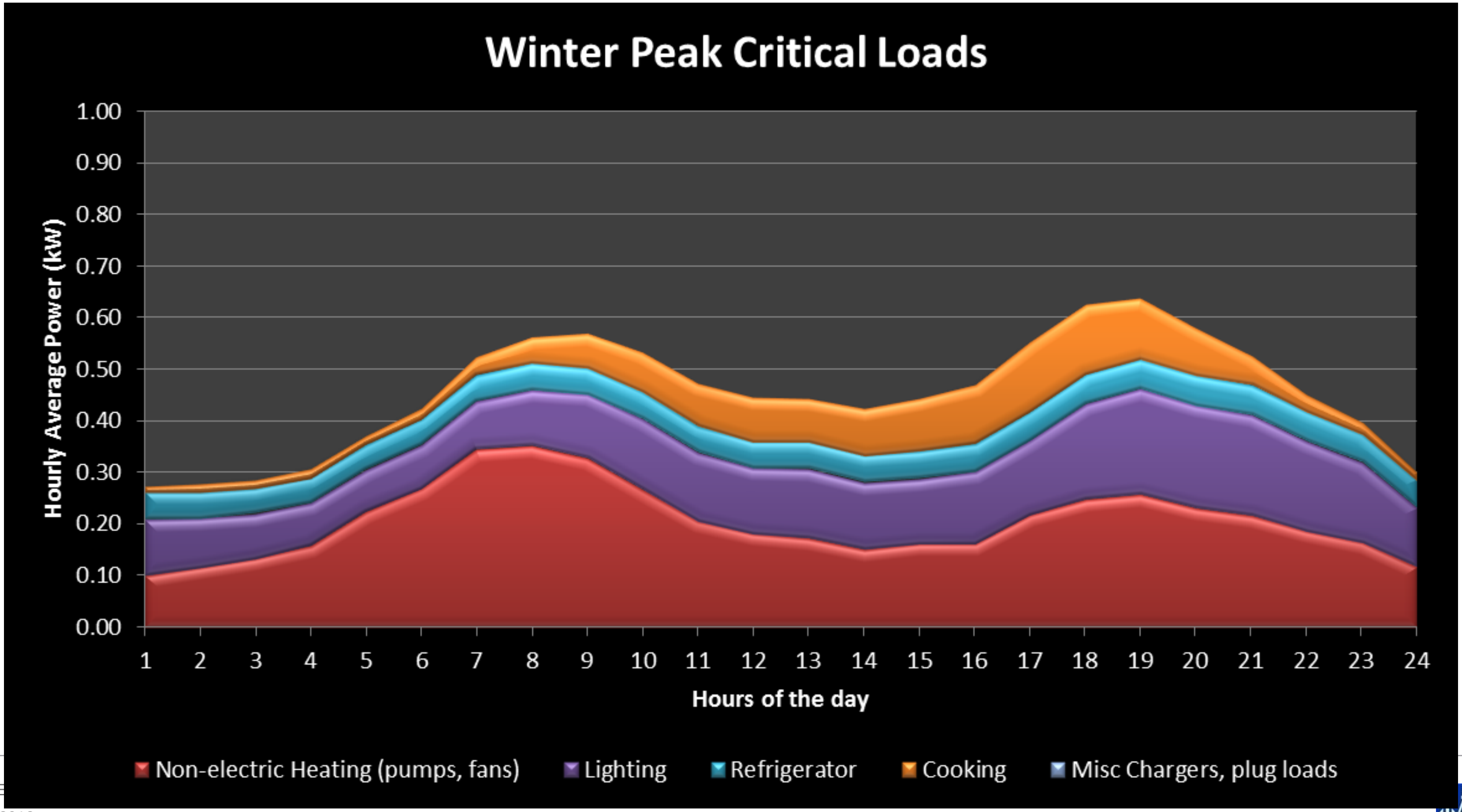
Summer Peak with Central A/C

- Backup solar-storage system cannot support air-conditioning load in the event of an extended outage



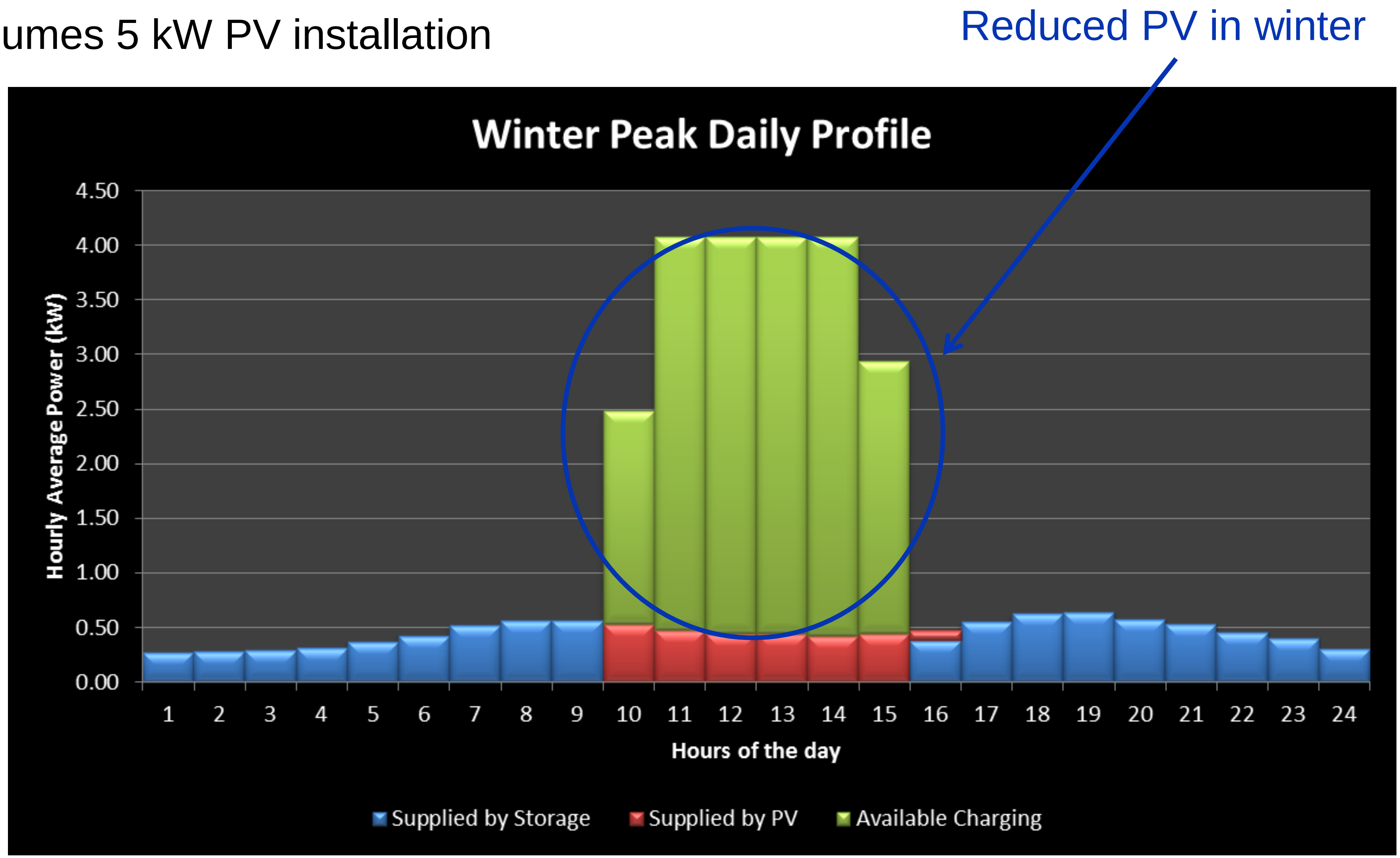
Winter Peak Residential Critical Load

- Graph shows hourly critical kW demand / kWh energy for a peak Winter day
- Electric heating and electric hot water heating not included because of their significant energy requirements



Winter Excess Generation

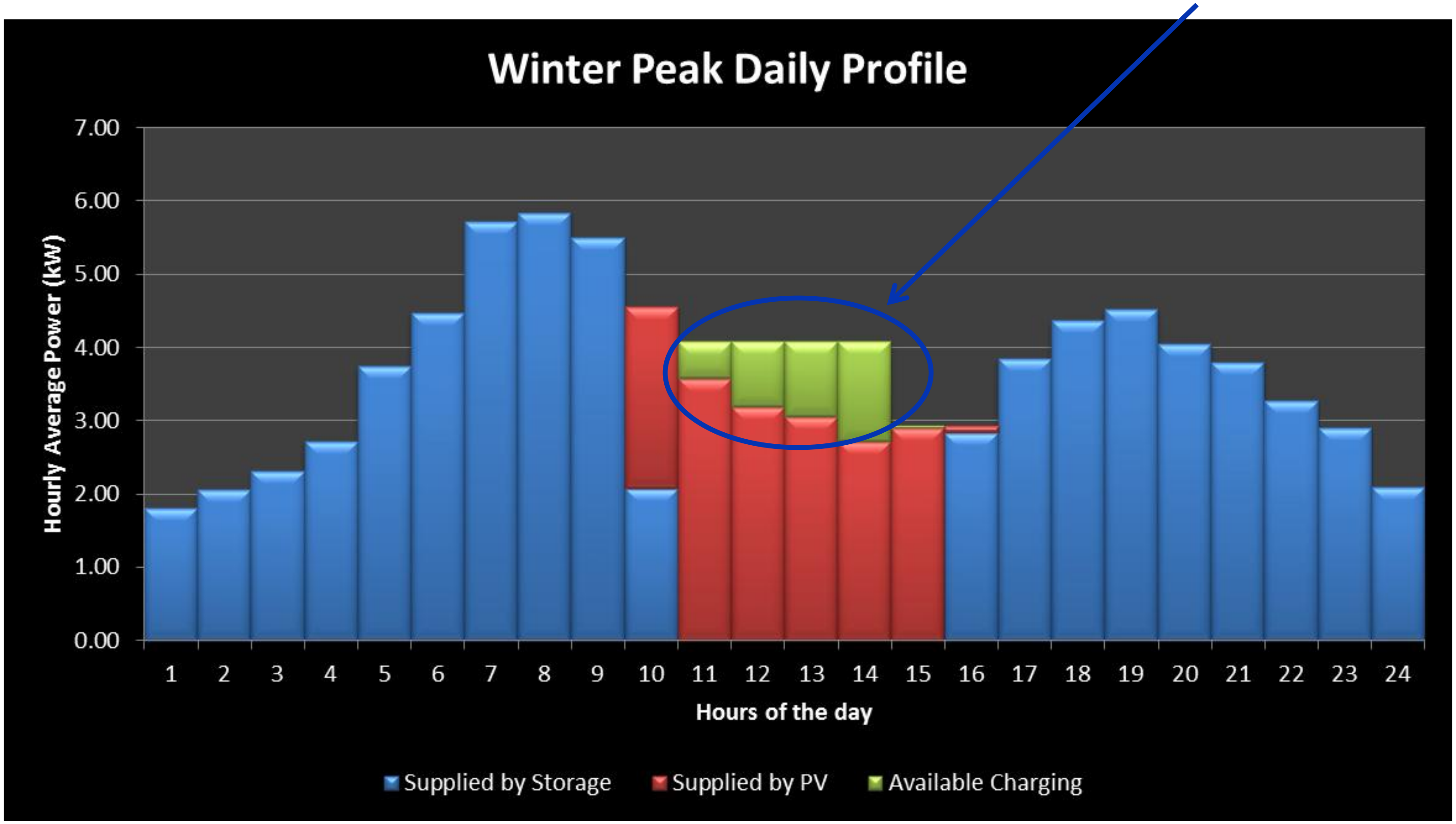
- Typical NY State Winter PV profile matched to critical load profile
- Assumes 5 kW PV installation



Winter Peak with Electric Heating

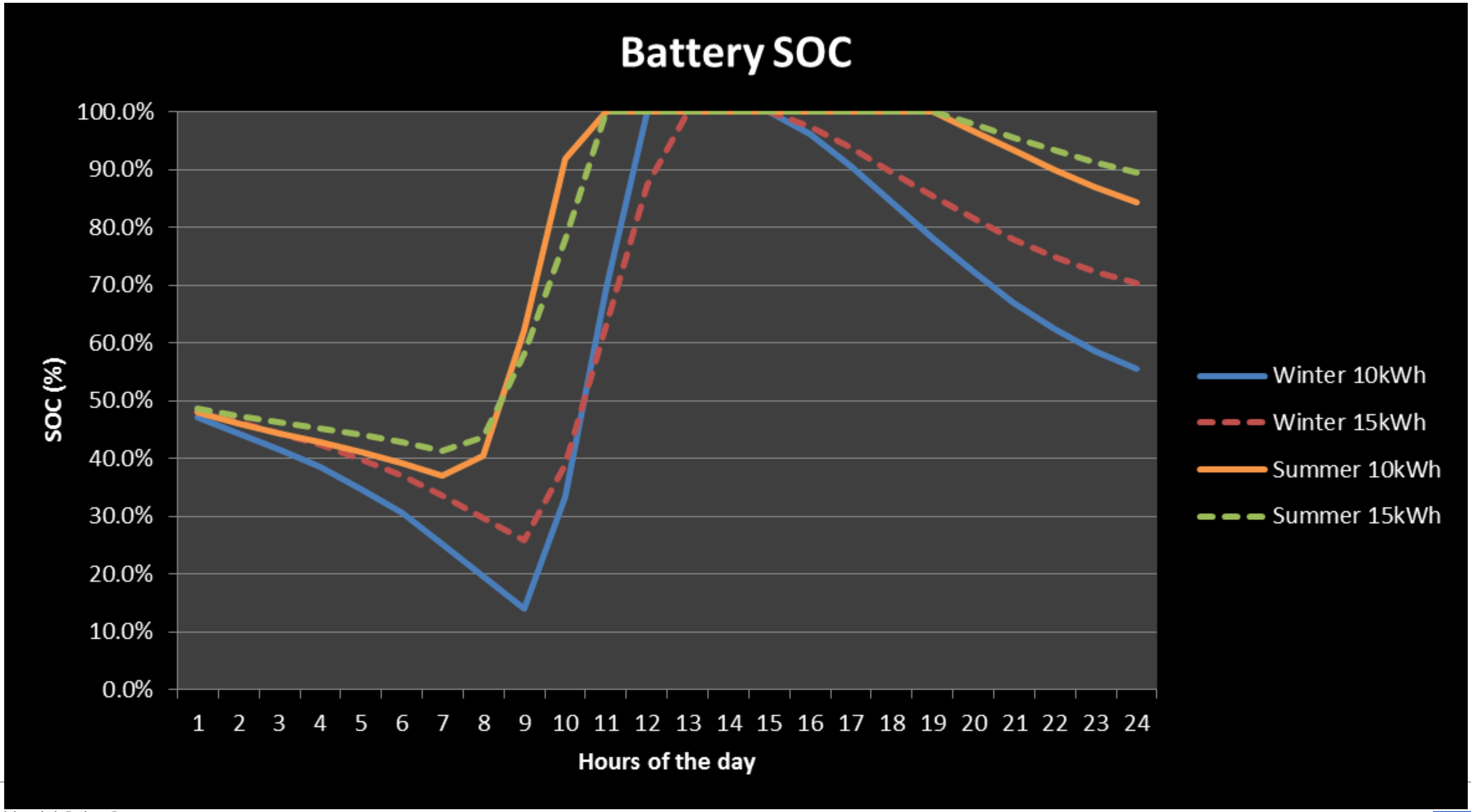
- Backup solar-storage system cannot support whole home electric heating load during an extended outage

Insufficient excess for charging



State-of-charge of Storage for Critical Load Support

- During Summer, excess PV generation is sufficient to levelize storage state-of-charge for 10kWh storage capacity
- Winter load may require larger capacity and greater critical load management



Sizing Storage for Solar-Storage Backup

- For peak Summer load days, assuming 5 kW PV installation, potential exists for up to 25 kWh of excess generation
  - For a properly sized storage device, this excess is sufficient to maintain storage SOC for long term outages
- Peak Winter days can have significantly higher demand
  - Combined with reduced PV output, excess power to charge storage is limited
- Central A/C in the Summer and electric heating in the Winter are not considered as critical load as the power/energy consumption is too large
- If storage capacity is limited, homeowner may reduce the magnitude of critical load e.g. reduce lighting, hot-water heating, and plug loads to survive prolonged outages.
- The instantaneous peak power demand from critical loads can be multiple times of the hourly average consumption

Storage Requirements and Recommendations

Sizing Recommendations

- DNV KEMA recommends sizing storage and required interconnection components at a minimum of 5kW for residential backup in New York
- DNV KEMA recommends a minimum of 10 kWh for residential back-up in New York,
  - energy rating of up to15 kWh may be necessary to survive prolonged outages during peak Winter days if electric hot water heating is installed, an alternative to larger storage capacity is a reduction in energy usage of critical loads during the outage

Balance of Plant and Control Recommendations

- To provide visibility and enable manual load management, DNV KEMA recommends solar-storage backup systems provide a means to monitor storage state-of-charge during backup operation
- In addition, advanced functionality such as automated and/or remote control of critical loads, through the system gateway or home EMS controller, may further improve survivability

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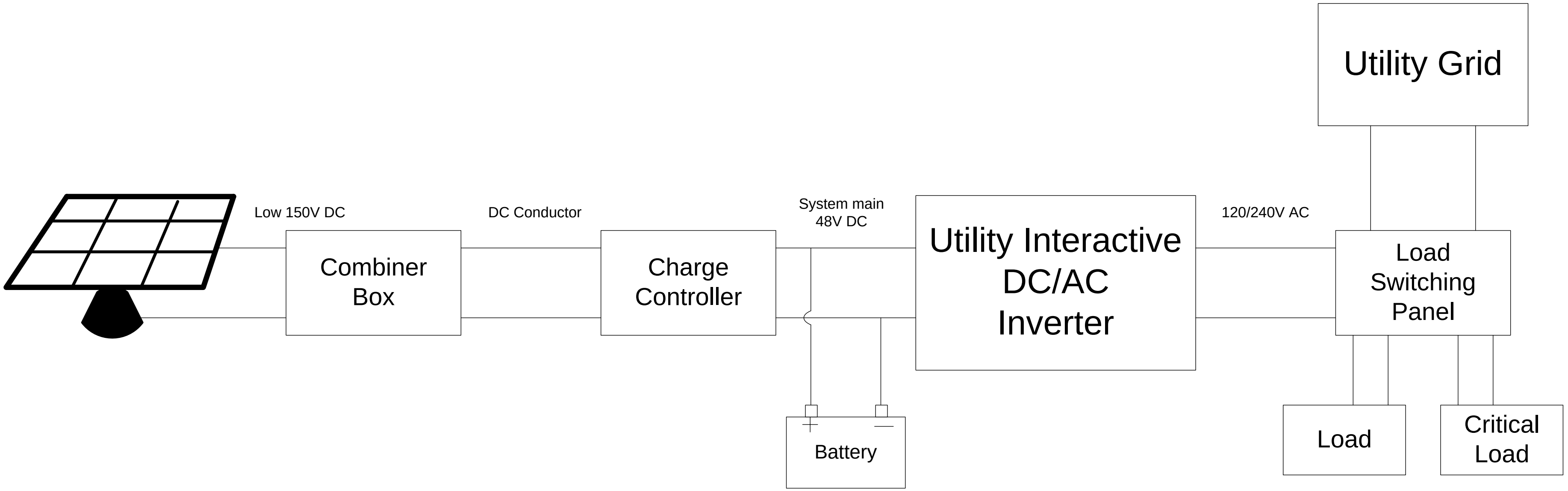
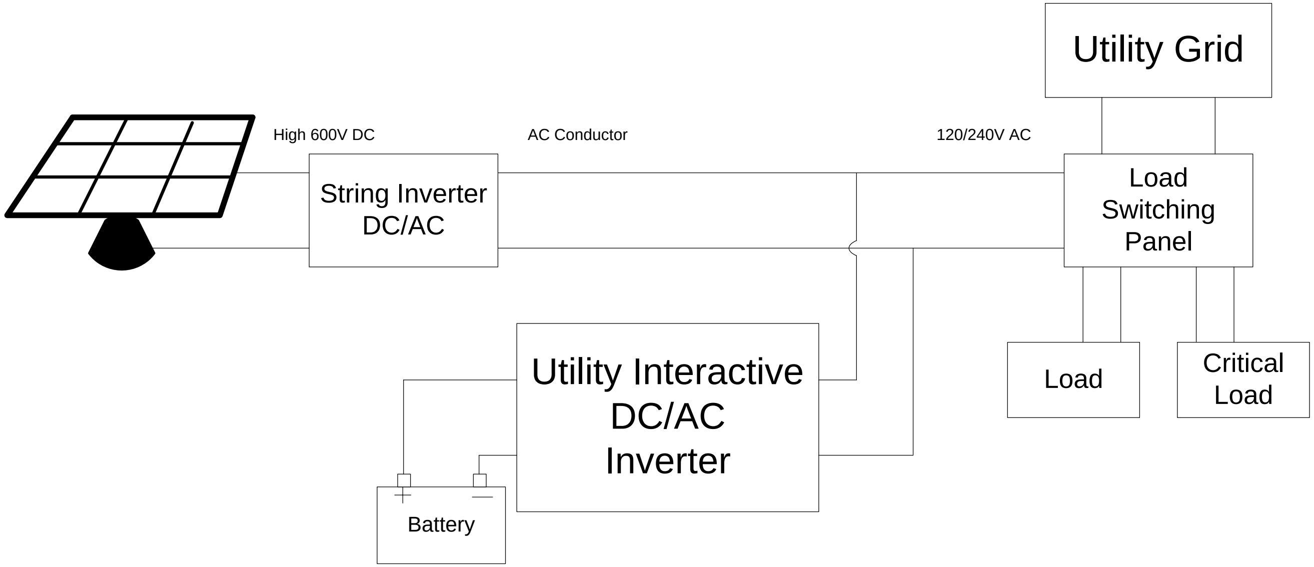
DC Coupling



- Traditionally, the majority of solar-storage systems have been DC coupled
- DC bus voltages typically operate at 150 - 600 V DC
  - higher voltages reduce losses and balance of plant costs
- Charge controller regulates DC current to prevent battery from overcharging

AC Coupling



- String inverters convert high DC voltage from PV array to 120/240V AC
- Similar overall cost to DC-coupled system
- Battery charge regulation techniques typically employ diversion loads and/or frequency phase-shift approaches to avoid overcharging storage
- AC coupling is seen by installers as the preferred approach for adding storage to existing PV systems

Inverters

- PV string inverters are *current-source* inverters
  - These convert power generated by a PV array from DC to AC, but rely upon an external AC source to operate as they cannot create an independent AC-voltage waveform
- Battery-based inverters do include *voltage-source* capable options.
  - These generate an AC voltage and frequency independent of an external AC power source
- Battery-based voltage-source inverters can provide a stable AC voltage and frequency reference that allows string inverters to operate when the grid is not present
  - In islanded mode, the AC power from string inverters is synchronized with the battery-based inverter output
- In a typical configuration, PV power can supply critical load first and the battery will be charged or discharged based on the mismatch between PV power and critical load
- The string inverter can be tripped off-line by a blackout relay, or by the frequency-phase shift function of the battery-based inverter

Diversion Load

- In a solar-storage charging systems, battery charging must be regulated to avoid over-charging
- The typical methods available for regulating the energy balance in AC-coupled systems are to either knock the string inverter off-line using a blackout relay or frequency-phase shift controller, or absorb excess generation using a diversion load
- If the PV array is much larger than necessary to charge the battery, excess power can be used to heat water, for example, by using a water heater as the diversion load
  - In operation, when battery voltage reaches the full charge setting in the charge control, it begins to divert power to the diversion load
  - The control uses pulse width modulation to turn the load on just enough to maintain battery voltage
- Using diversion loads to control excess generation provides more stable and reliable operation, as well as more sophisticated battery charging functionality

Some Additional Installation Considerations

- **Single manufacturer** – for installers, it can be advantageous to choose inverters, PV charge controllers and integration hardware from a single manufacturer for better compatibility
- **Battery enclosures** –enclosures must be designed to support the combined weight of the battery stack and provide adequate ventilation
- **Battery temperature sensing** – additional operational safety measurements should be employed to ensure optimal charging and prevent damage due to overcharging
- **AC bypass switch** – manually bypasses the inverters and connect the critical-loads panel to grid power during any required system maintenance
- **Dual AC inputs** – if the backup system design includes an engine generator, the design needs to specify inverters that have provisions for dual ac inputs, for example, grid and generator

SOURCE: https://solarprofessional.com/article/?file=SP5_5_pg74_Schwartz

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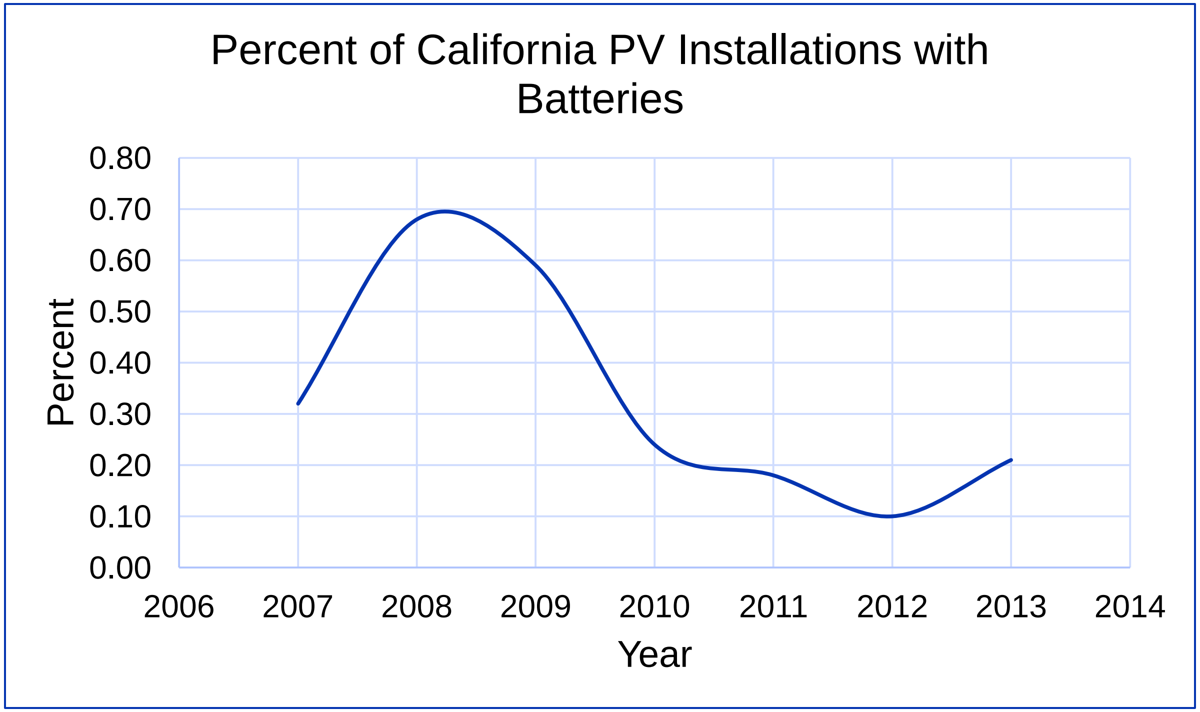
Case Study: California

- Comparison of the "installed cost" (before rebates or subsidies) of PV systems in California with and without energy storage over the last seven years is presented below
- It should be noted that these are "commercial" street costs excluding R&D and other overheads often included in many government-sponsored demo projects

	Res PV with batteries		Res PV (no battery) systems	
Year completed	# of systems	$/Watt	# of systems	$/Watt
2007	11	$ 11.61	3,420	$ 9.94
2008	52	$ 13.14	7,613	$ 9.90
2009	75	$ 12.30	12,628	$ 9.58
2010	38	$ 12.07	16,058	$ 8.49
2011	38	$ 10.26	21,411	$ 8.25
2012	29	$ 7.74	28,301	$ 7.06
2013	10	$ 7.88	4,729	$ 6.21

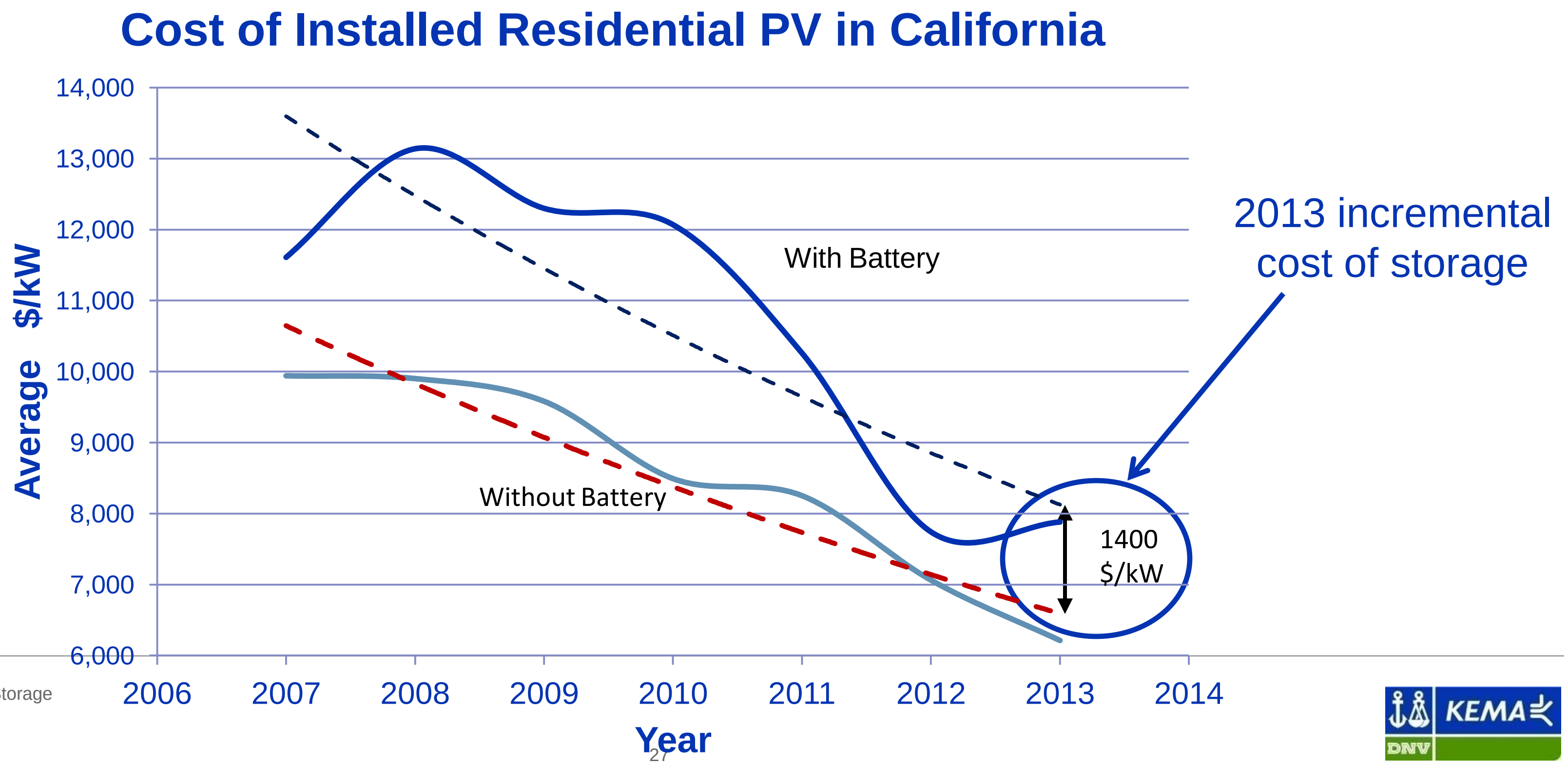
Case Study: California

- The PV installations with battery is about 0.4% of the total PV installations in California
- This ratio has been affected by the economic downturn that began in 2008



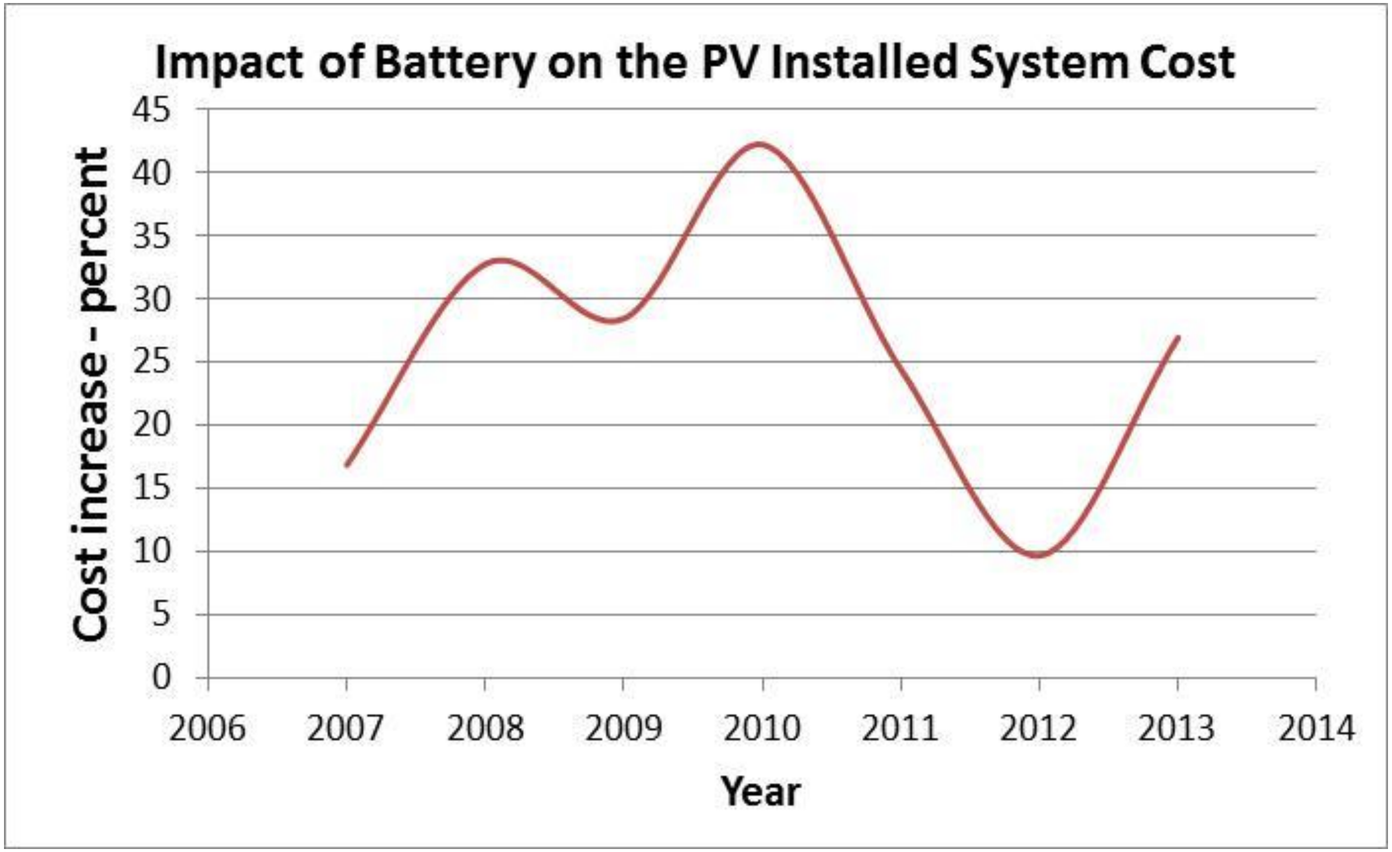
Case Study: California

- The cost of installed PV in California, with and without a battery, has been declining over the last several years at an average rate of 7% per year
- The incremental cost for having a battery added to a PV system has also been declining at an average rate of 11% per year
- Finding detailed data for each installation is difficult; our general belief is that these systems include supplying critical load



Case Study: California – Impact of Battery on installed cost

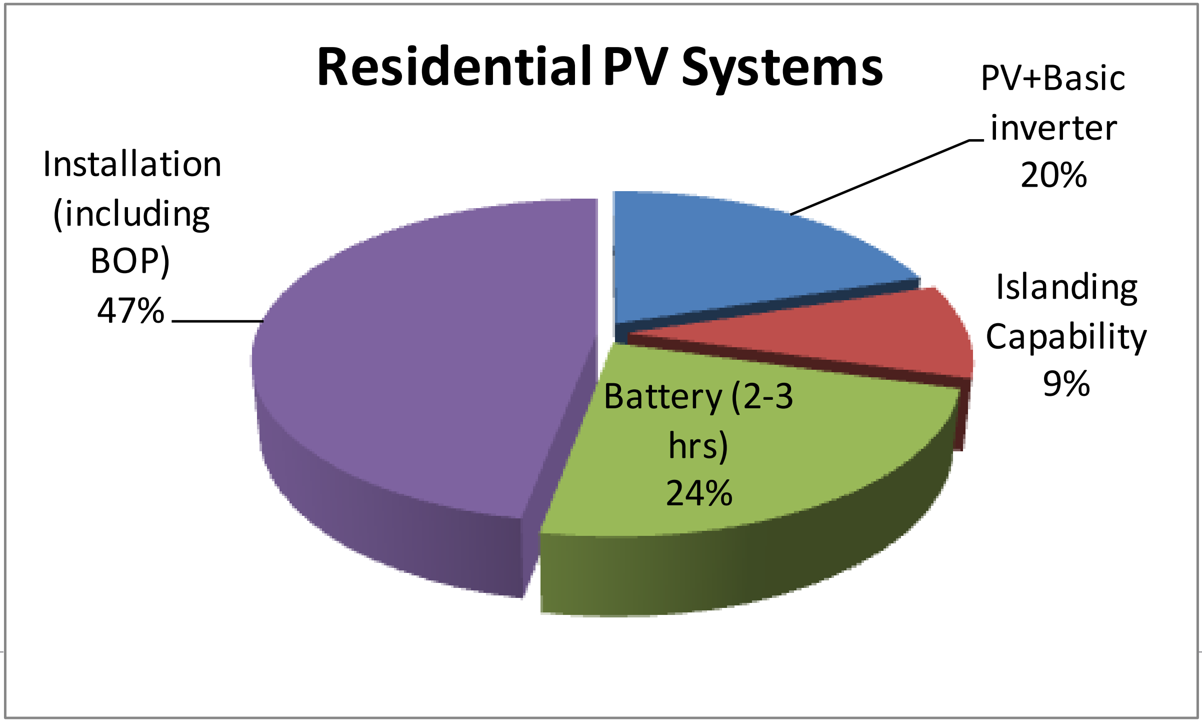
- Including a battery to PV increases the total installed cost by about 25%, depending on its capacity and capabilities



- Estimates put Li-ion replacement cost after 8 years to be 30-50% of complete system cost installed today. This is partly due to cost reduction and partly because certain BOP may be salvaged after 8 years.

Breakdown of Residential PV System Costs

- Depending on the type and size of the PV, inverter and the batteries used, the cost components vary but, on average, they may be generalized as follows:
  - Installation is about ½ the cost of an installed PV+ES system
  - Adding battery could double the PV hardware cost but its impact on the total installed cost is about 25 - 30%, depending on its capacity and capabilities.
  - Adding islanding capability to help PV system serve as a backup power could increase the installed cost by about 10%



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Examples of Existing Solutions

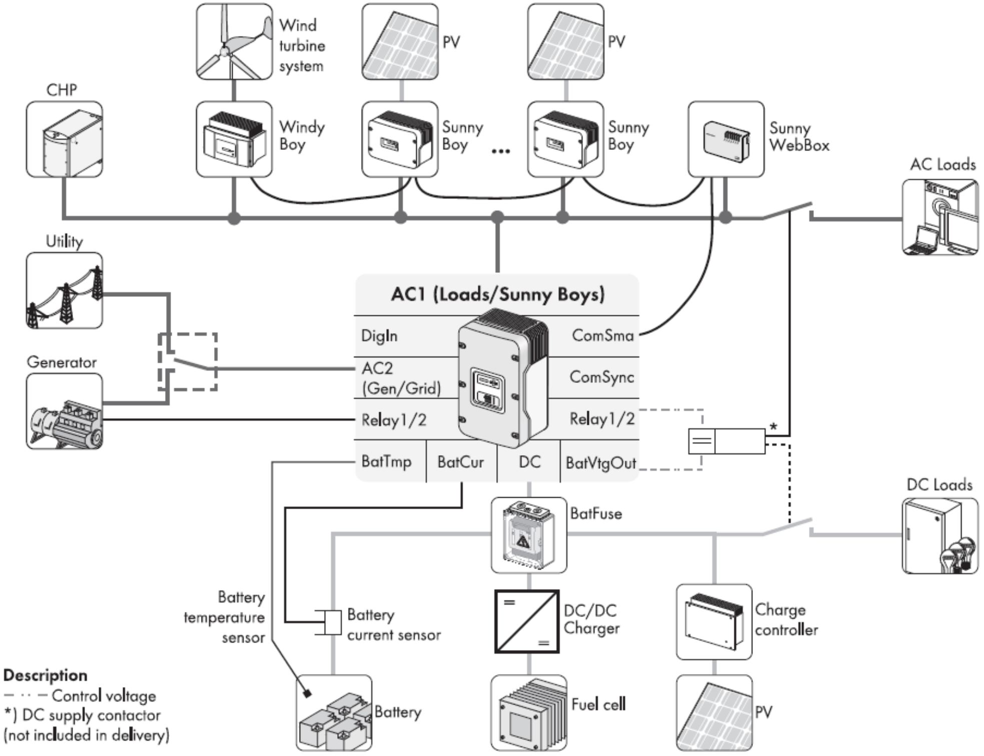
- Component Vendors
  - SMA America http://www.sma-america.com
  - Magnum Energy http://www.magnumenergy.com
  - OutBack Power Technologies http://www.outbackpower.com
  - Schneider Electric http://www.schneider-electric.com
  - RedFlow Battery http://www.redflow.com

- Integrators (packaged solutions)
  - Sunverge http://www.sunverge.com
  - SolarCity http://www.solarcity.com

- Demo projects
  - EcoCutie (Japan)

SMA America

- SMA has developed a high level of integration between its Sunny Island storage inverters and Sunny Boy string inverters in ac-coupled systems
- Functionality includes advanced frequency-shift battery charge regulation
  - capable of ramping up and down PV array charge current based on battery state of charge, a feature not available in AC-coupled systems using components from other manufacturers
- No diversion load is required since the charging current is regulated both on/off, and ramping up/down



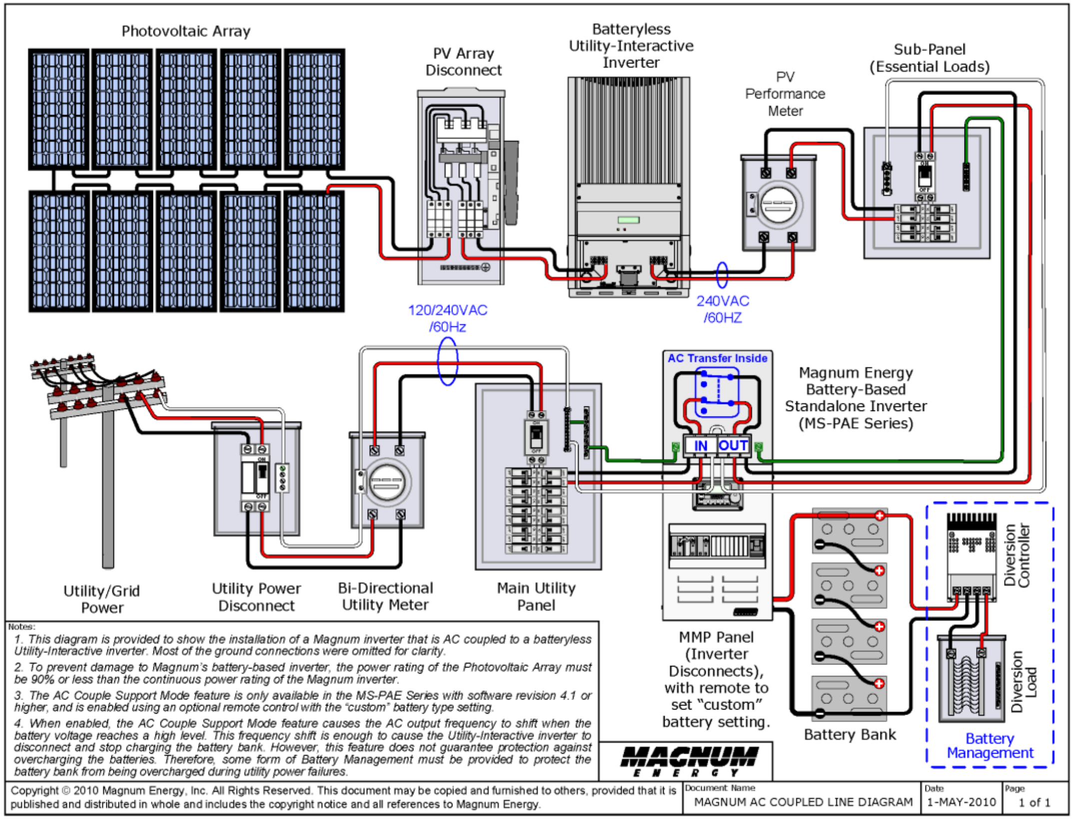
SOURCE: SMA America

SMA America

- SMA Sunny Island battery-based inverters and Sunny Boy grid-direct (string) inverters can be used in conjunction with one another and with backup generators to form a highly integrated stand-alone AC power grid
- As an add-on to the PV plant, the Sunny Island automatically switches to stand-alone power supply within approximately 20 milliseconds of a grid failure
- Both new and existing PV plants can be equipped with a Sunny Island System - with no effect on PV efficiency
- In addition to providing a backup system, the SMA Sunny Island enables storage of PV power produced during the day, for later use at night
- SMA sells batteries with their system: lead acid, flooded lead acid, and nickel cadmium battery, although other storage technologies may be integrated

Magnum Energy

- Magnum Energy designs and manufactures battery-based inverters for use in stand-alone applications and grid connected systems that require battery storage to provide uninterrupted power during utility-grid failures
- The Magnum Energy MS-PAE series inverter/charges can be used in AC-coupled applications



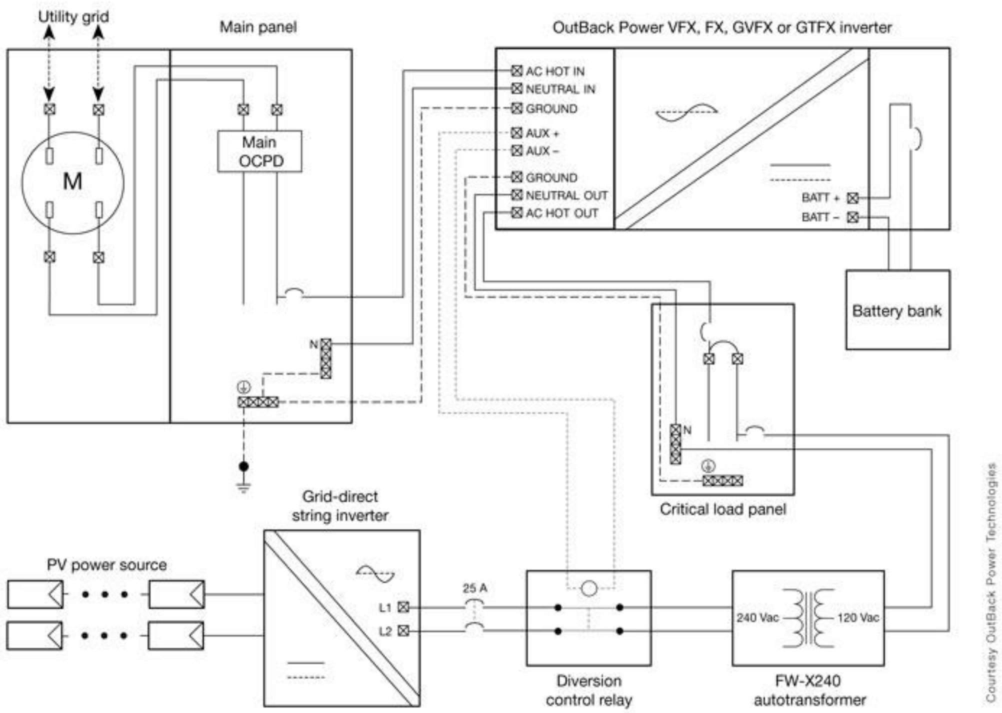
SOURCE: Magnum Energy

Magnum Energy

- Magnum Energy permits and supports AC-coupled system designs that synchronize the AC output of utility-interactive string inverters from various manufactures with its battery-based inverter/charges
- When the grid is operational, the Magnum battery-based inverter is in standby mode
  - Uses both utility grid and output of the string inverter to maintain charge on the battery bank
- When the grid goes down, the inverters disconnect from the grid and the battery bank begins supplying power to the critical loads; after 5-min, Grid-tie inverter will sync with Magnum inverter’s output and start supplying energy from the PV array
- Excess energy not consumed by the critical loads will return to the Magnum inverter and charge the battery bank
- Magnum recommends a diversion load, such as water heaters, as the primary battery charging protection approach, while using frequency-shifting as secondary approach

OutBack Power Technologies

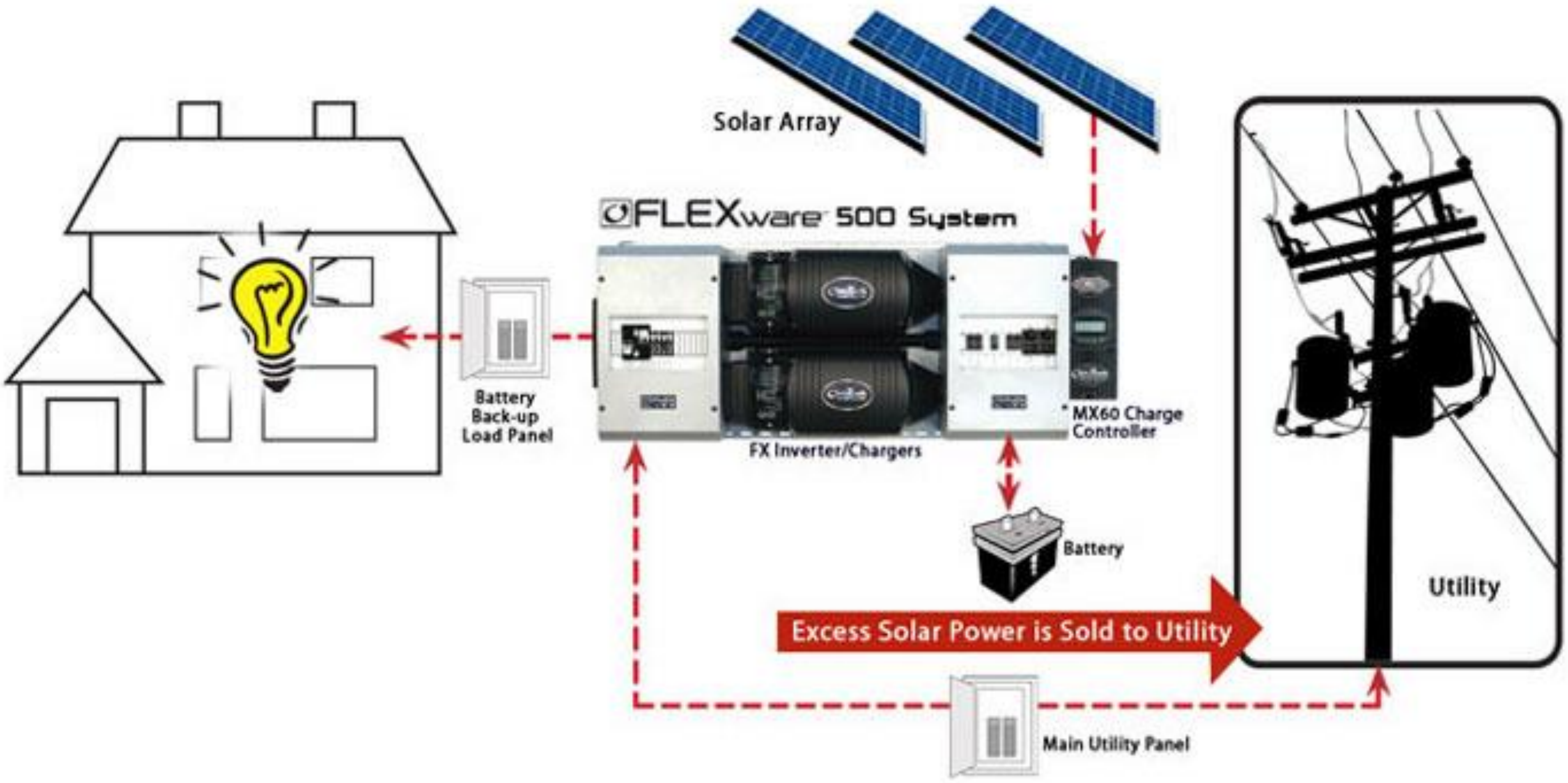
- OutBack Power Technologies designs and manufactures a full range of products, including stand-alone and utility-interactive battery-based inverters that can be utilized in both DC- and AC-coupled systems
- The OutBack FX (FX, VFX, GVFX or GTFX) single-phase inverter/charger series and Radian series support AC coupling



SOURCE: OutBack Power Technologeis

OutBack Power Technologies

- OutBack Power Technologies also offers power electronics and integration equipment that is primarily intended for use in DC-coupled systems



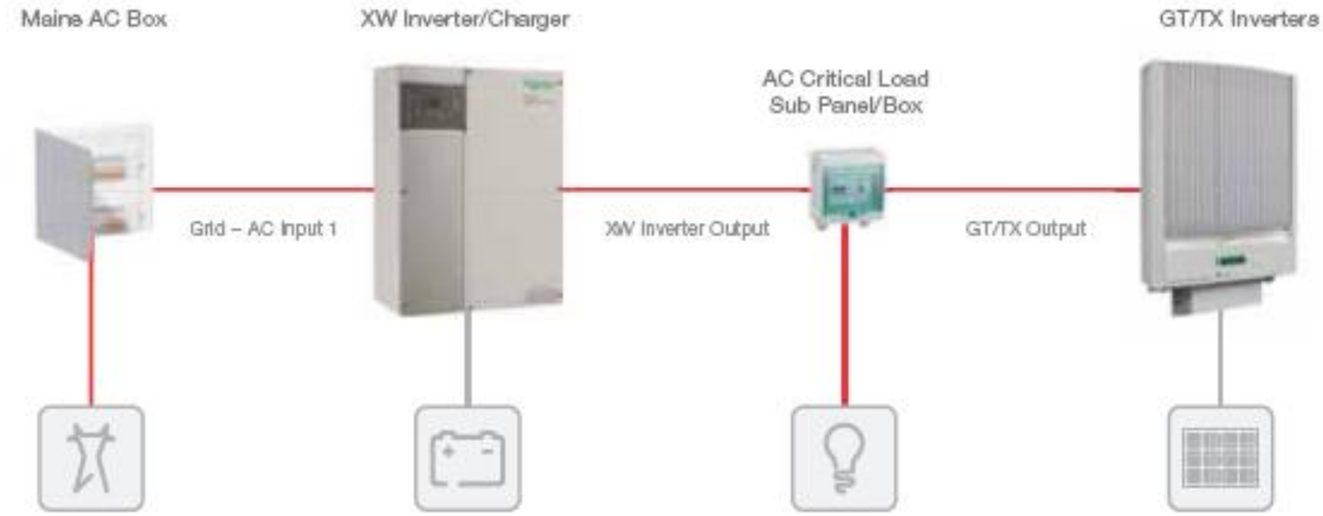
SOURCE: OutBack Power Technologeis

OutBack Power Technologies

- The FX series inverter/charges can be stacked in series and parallel in AC-coupled systems. When single FX inverter with a 120Vac output is coupled to a 240Vac string inverter, an OutBack autotransformer can be used.
- The Radian GS8048 is a utility-interactive inverter that can be stacked in parallel. It normally functions as battery-based inverter in AC-couple systems, but has capability of feeding excess power to the utility grid.
- Both OutBack Radian and FX inverters do not utilize frequency-shifting for battery management
  - Radian supports diversion loads and blackout relays, and the FX only supports blackout relays
- OutBack Power considers the battery-based inverter/charger must have enough capabilities to regulate voltage/frequency for PV string inverters and other backup generators in the case of utility grid is not present

Schneider Electric

- Schneider Electric designs and manufactures both utility-interactive inverters and battery-based inverter/chargers for the North American solar market
- The newest generation of Conext TX residential grid-direct inverters integrate with the Conext XW battery-based inverter/charger to create an AC-coupled system



AC-coupled

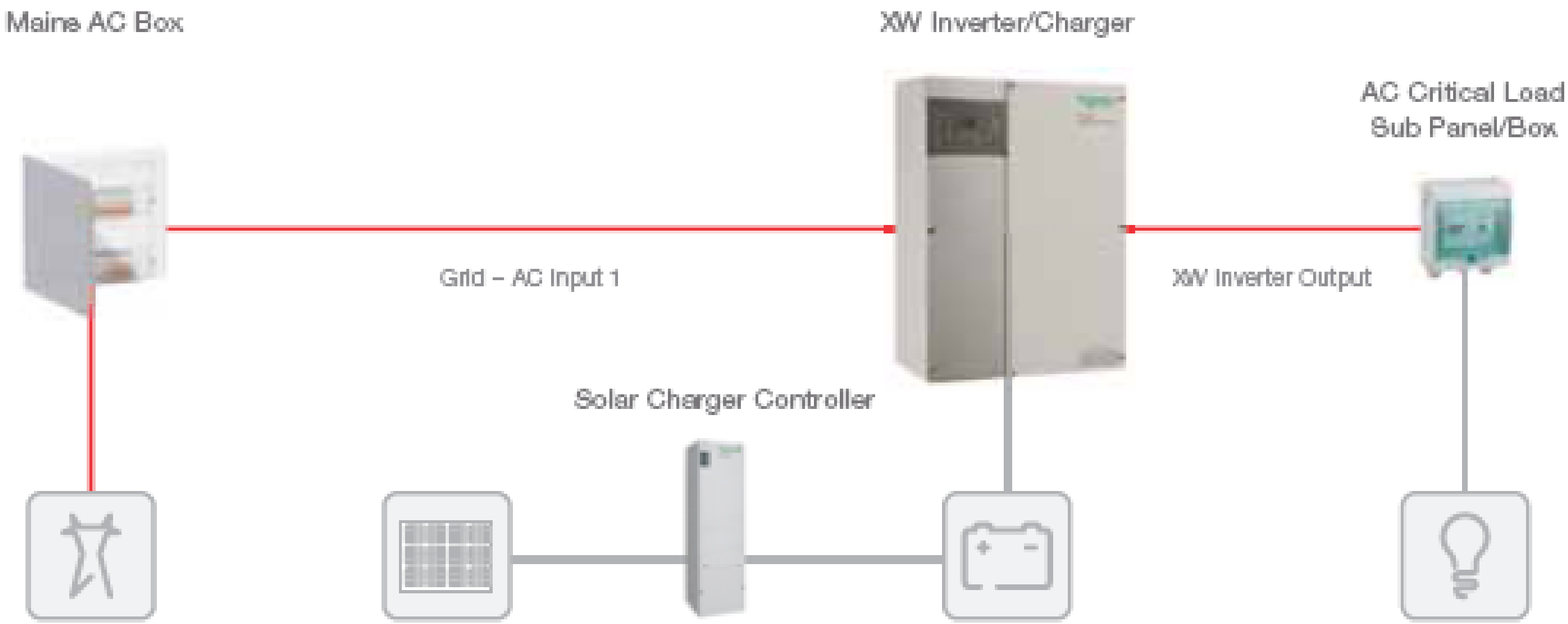
SOURCE: Schneider Electric

Schneider Electric

- Grid-present operation
  - When the AC source is qualified and is within the pre-set ranges, the XW inverter is connected to the source and behaves like a load charging battery
  - The TX grid-direct inverters synchronize with the utility-power reference and process power from the PV array
- Islanded operation
  - If the external AC source voltage or frequency deviates outside acceptable ranges, XW inverter is disconnected from the AC source by opening the input relays, and provides power to the critical loads
  - The TX grid-direct inverters detect temporary loss synchronization during transfer, and go off-line until detecting a stable AC output from XW for a minimum of 5 minutes
  - During utility failures, the XW serves as voltage source, and the TX inverters synchronize with the AC reference provided by XW inverter
- System regulation
  - The XW inverter uses frequency-shifting and on/off cycling to prevent overcharging

Schneider Electric

- Alternatives to AC coupling
  - If array-to-battery distance is the primary design driver for an AC-coupled system, user can weigh the potential cost and operational benefits of utilizing a DC-coupled system architecture with a higher voltage DC-charge controller
  - Schneider Electric manufactures charge controllers rated at 150Vdc and 600Vdc



DC-coupled

SOURCE: Schneider Electric

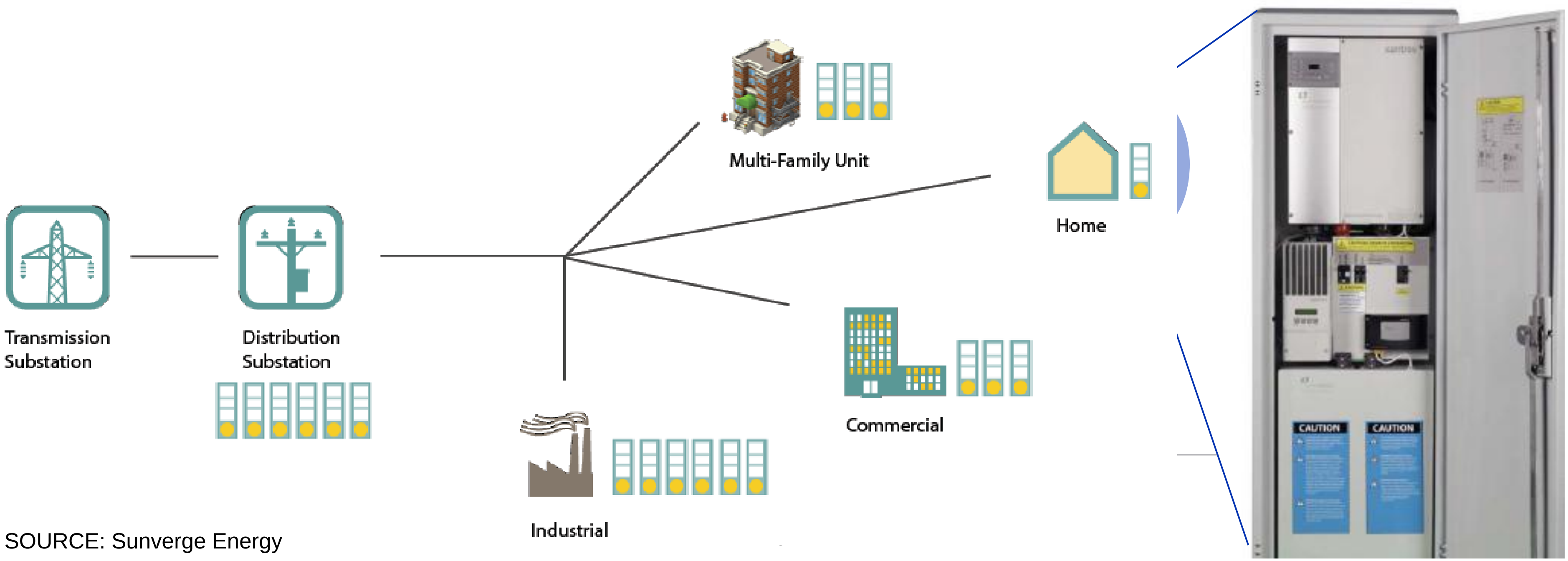
RedFlow Storage

- RedFlow offers a zinc-bromide module (ZBM) flow battery
- 61 energy storage systems were installed on Ausgrid network in 2011 and 2012 as part of a Smart Grid demonstration project
- R510 model rated at 5kW, 10kWh: comprised of one ZBM, SMA inverter, 3G modem for communications, battery management system (BMS), and remote terminal unit (RTU) housed in a metal enclosure

SOURCE: Redflow

Sunverge Energy

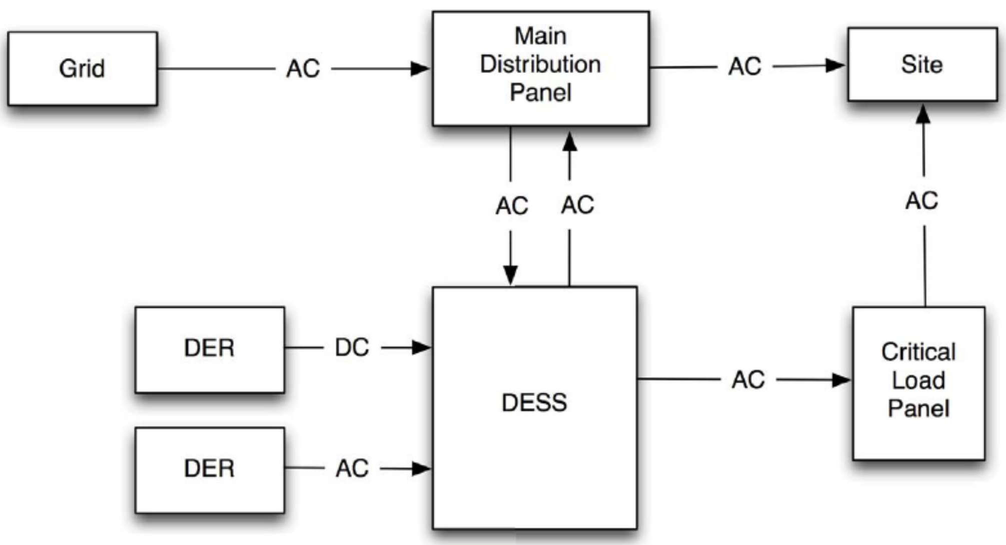
- Sunverge solar integration system consists of a 6 kW Schneider hybrid inverter and 10.77 kWh Li-Ion storage (capacity available up to 15.1 kWh)
  - unit is self-contained and sits behind the meter, NEMA 3 enclosure for indoor or outdoor installation
- Gateway used by the consumer to select loads that will operate in back-up mode
- Current system operates at 150 VDC, currently working on a model which can operate at both 150 V and 600 V



SOURCE: Sunverge Energy

Sunverge Energy

- Sunverge solar integration system
  - Intelligent communication platform through which utilities can send instructional demand response and load management messages to their customers
- Inclusion of storage allows for participation in utility demand response programs, even when not convenient for consumers
- UL 1741and IEEE 1547-- compliant anti-islanding
- Sunverge Home Area Network allows for in–home or remote wireless interfaces, homeowners can turn lights on and off loads and program run time of appliances
- Power Architecture:



SOURCE: Sunverge Energy

Sunverge Energy

- Currently 38 installations on-line, with 184 planned by 6/13 and 400 by end of 2013

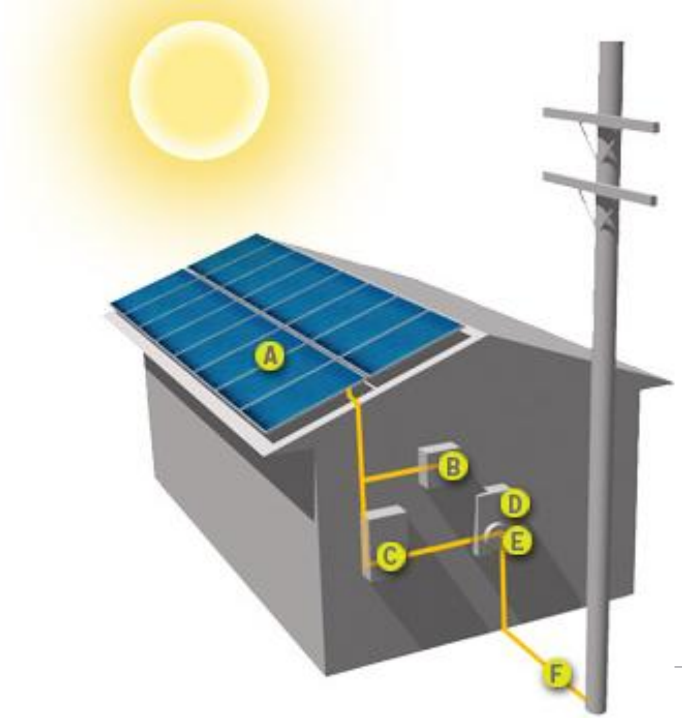
- Software application for remote monitoring of resources and storage state-of-charge

SOURCE: Sunverge Energy

SolarCity

- Developed a wall mounted residential storage product, selling residential product today
  - 5 kW, 10 kWh, primarily Li-Ion with some advanced lead acid installations
- Interconnection built around SMA Sunny Island platform
- Works with customers to select critical loads to be powered during an outage

  - A – Solar Panels
  - B – Battery Storage
  - C – Inverter
  - D – Electrical Panel
  - E – Utility Meter
  - F – Utility Grid



SOURCE: Solar City

SolarCity

- Close partnership with Tesla Motors
- Primarily selling in CA because of SGIP funding for energy storage
  - SGIP rebate has made system installation cost-effective
  - System operates in parallel with the grid but also provides battery back-up
  - Where allowed by tariffs, the system can perform market participation
- Over 70 SGIP applications for storage installations in 2012
- Solar lease program has signed on 21,000 customers in 2012
- Have not focused on Eastern US markets on residential, because of CA incentives

Eco-cutie System in Japan

- NEDO demonstration project from 2002-2008
- About 550 PV systems were installed on the roofs of houses in a single subdivision and connected to the utility in the demonstration research area in Ohta, Japan. The total nominal output power is more than 2 MW.
- The capacity of the PV systems was chosen to be 3 to 5 kW because this is the standard capacity of residential PV systems in Japan
- A lead-acid storage battery system was installed in all PV systems.
  - The lead-acid battery had a capacity of 9 kWh or 4,900 Ah, the upper bound regulated by the Fire Service Law in Japan.
- Both AC and DC configurations were tested for solar-storage systems

Eco-cutie System in Japan

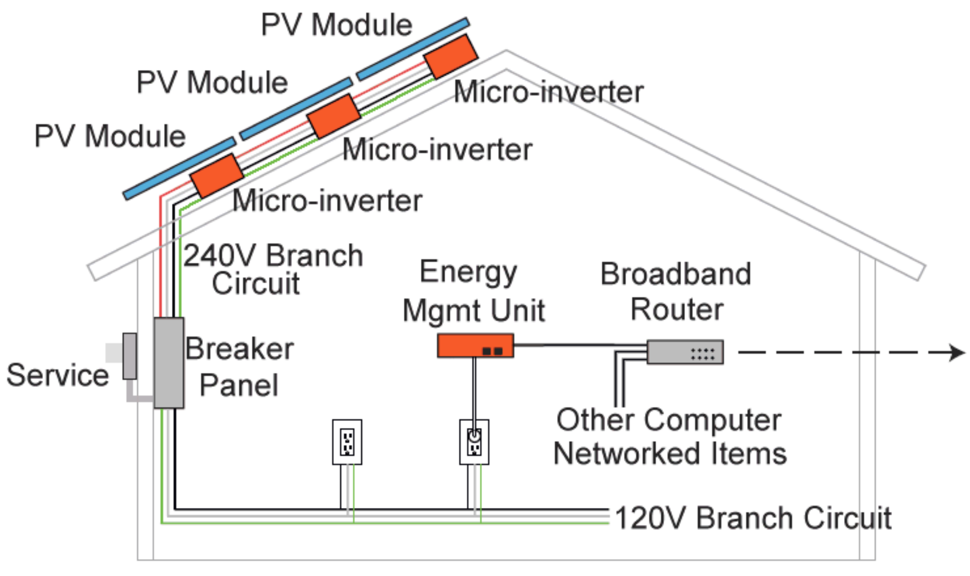
Contents

Micro-Inverters

- Established technology
  - Most common where array sizes are small, less impact from increased $/Watt for system
- Micro-inverters are attached to each solar module, versus at ground level for a typical centralized string inverter
  - up to 300 W per inverter
  - each inverter can operate in MPPT mode for its panel
- Main advantage is that shading, debris and/or snow lines on any one solar panel do not disproportionately reduce the output of the entire array
  - only the output of the affected modules are impacted
  - all the other modules will operate at their optimal efficiency
- Another key advantage is easier implementation of gradual deployment
- Disadvantages include high equipment and installation costs, higher likelihood of inverter failure
- Micro-inverters have not experienced the same sharp price decrease seen for panels and centralized inverters

EnPhase Micro-Inverters

- First commercially successful micro-inverter
- Over one million units shipped
- Software gateway allows for monitoring resolution to individual panel

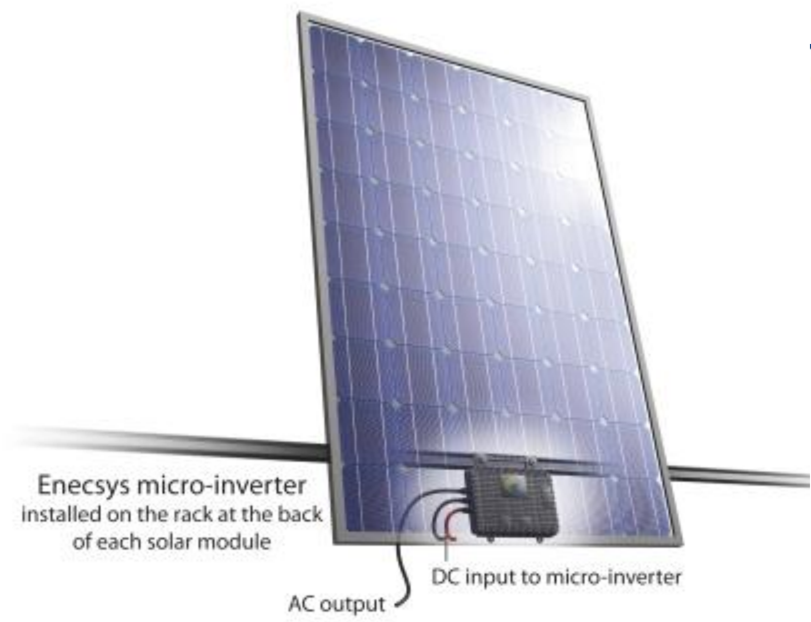


Typical Enphase Energy System

SOURCE: Enphase Energy

Enecsys Micro-Inverters

- U.K. Micro-inverter manufacturer
- First VDE AR-N 4105 compliant micro-inverter:
  - New German requirements on power quality, reactive power control and power phase balancing capabilities



SOURCE: Enecsys

Micro-Inverters – Integration with Battery Inverters and Cost

- Power-One's AURORA Micro 250 W and 300 W products (released 2012)
  - Not yet tested with battery-based inverters in ac-coupled applications
- SMA America has released a Sunny Boy 240 (240 W) micro-inverter
  - Designed to be compatible with SMA's Sunny Island system with special considerations
- Lux Research estimates that the cost of micro-inverters average between $0.50/watt and $1.00/watt, compared to string inverters which range between $0.25/watt and $0.50/watt
- The cost of power optimizers ranges widely, anywhere from $0.10/watt to $1.00/watt

SOURCE: http://www.solarserver.com/solar-magazine/solar-report/solar-report/microinverters-and-power-optimizers-perspectives-of-distributed-pv-system-architecture-in-the-residential-market.html

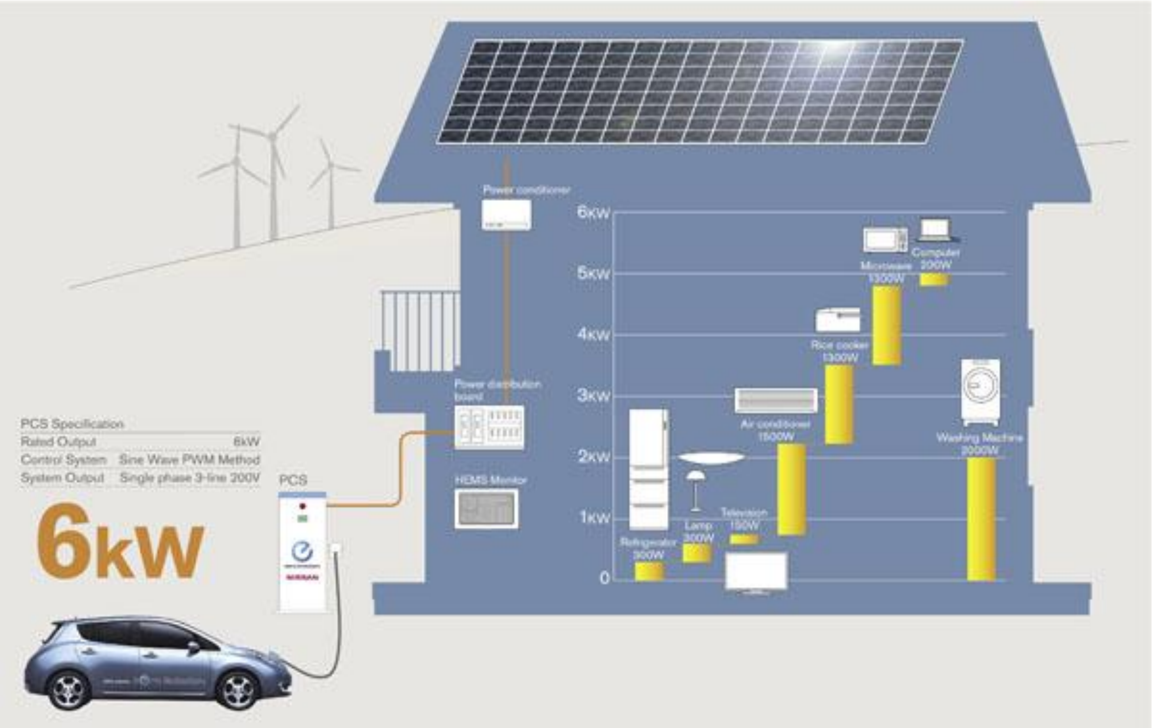
Backup Generator

- Low-cost stationary or mobile fossil fuel backup generation: gasoline, propane or natural gas
  - Stationary: 5,000 to 15,000 Watt ($5,000 to $10,000 for unit cost alone)
- Location constrained – not practical and/or safe for some locations
- No economic incentives to utilize generation for purposes other than back-up power

SOURCE: http://www.generac.com

EV Based Home Backup

- "LEAF to Home" power supply system
  - supply from batteries onboard Nissan LEAF electric vehicles (EV) to homes during an outage
  - used with the "EV Power Station" unit developed by Nichicon Corporation
- Industry first backup power supply system that can transmit the electricity stored in the large-capacity batteries of Nissan LEAF's to a residential home
- Available in Japan in 2013
- 6 kW, 24 kWh backup power
- $6,000 system on top of the cost of the vehicle



SOURCE: Nissan

Community Energy Storage (CES)

- Each unit provides ≥25 kW and 25-75 kWh at 240/120V AC
- Units are connected to secondary transformers

S&C Electric

SOURCE: S&C

Beckett Energy Systems

SOURCE: Beckett

GreenSmith

SOURCE: GreenSmith

Demand Energy

SOURCE: Demand Energy

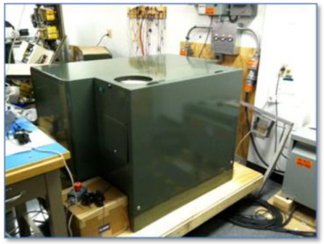
eCamion

SOURCE: Canada Newsline

ABB

SOURCE: ABB

GS Battery



SOURCE: GSB

PowerHub

SOURCE: PowerHub & SMUD

Community Energy Storage (CES)

- Competition in distributed energy storage continues to grow

Fiamm

SOURCE: Fiamm

RedFlow

SOURCE: RedFlow

One Cycle Control

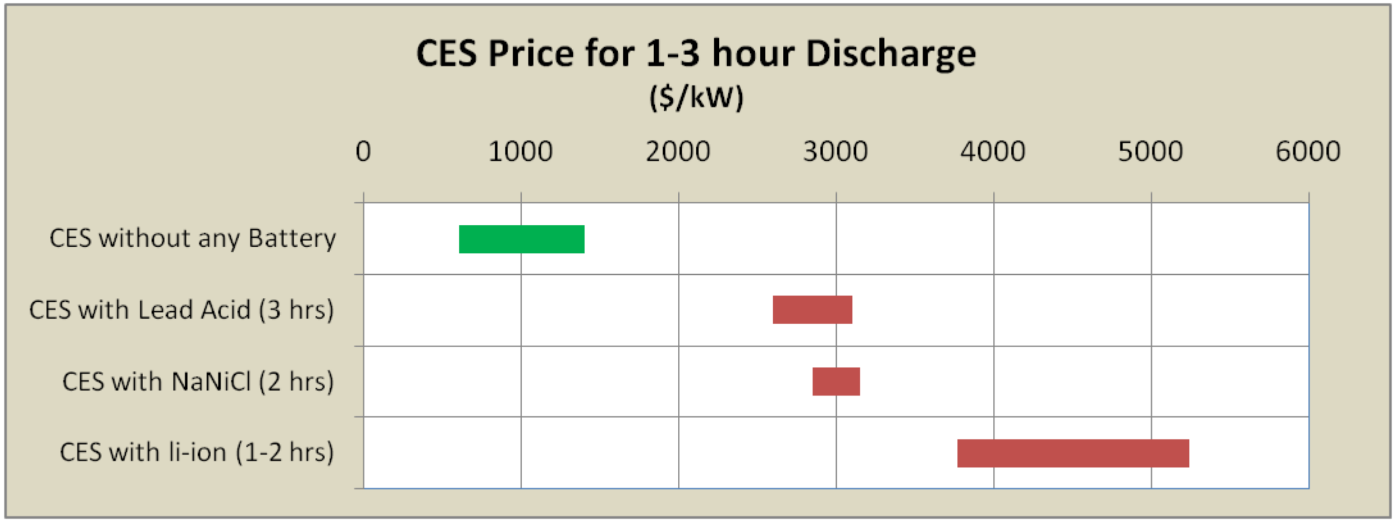
SOURCE: OCC

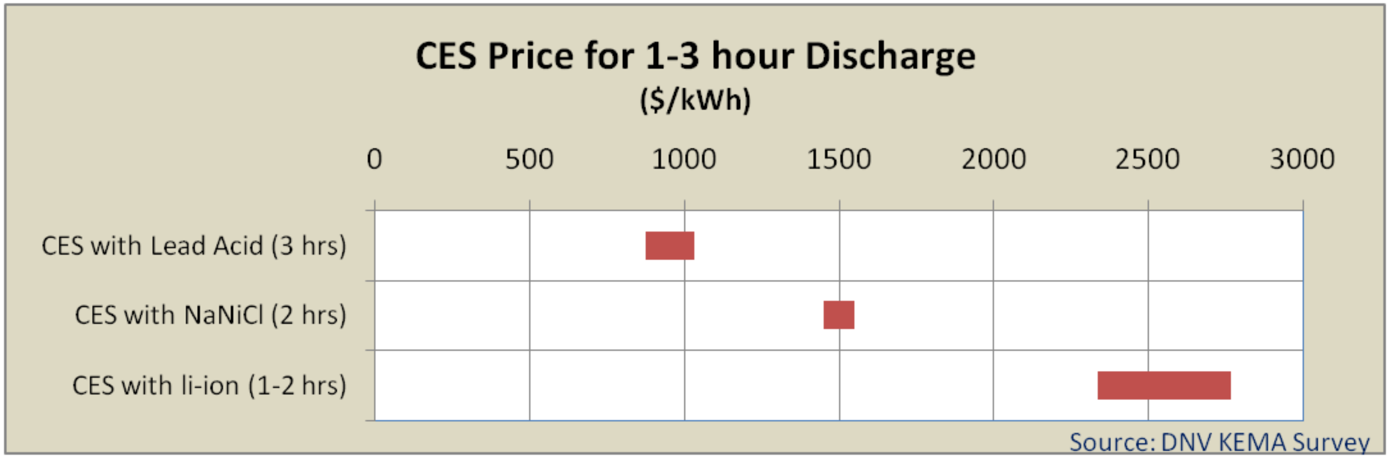
Silent Power

SOURCE: Silent Power

CES Price – 2012 and 2013 Surveys

25kW-100kW,
1-3 hours

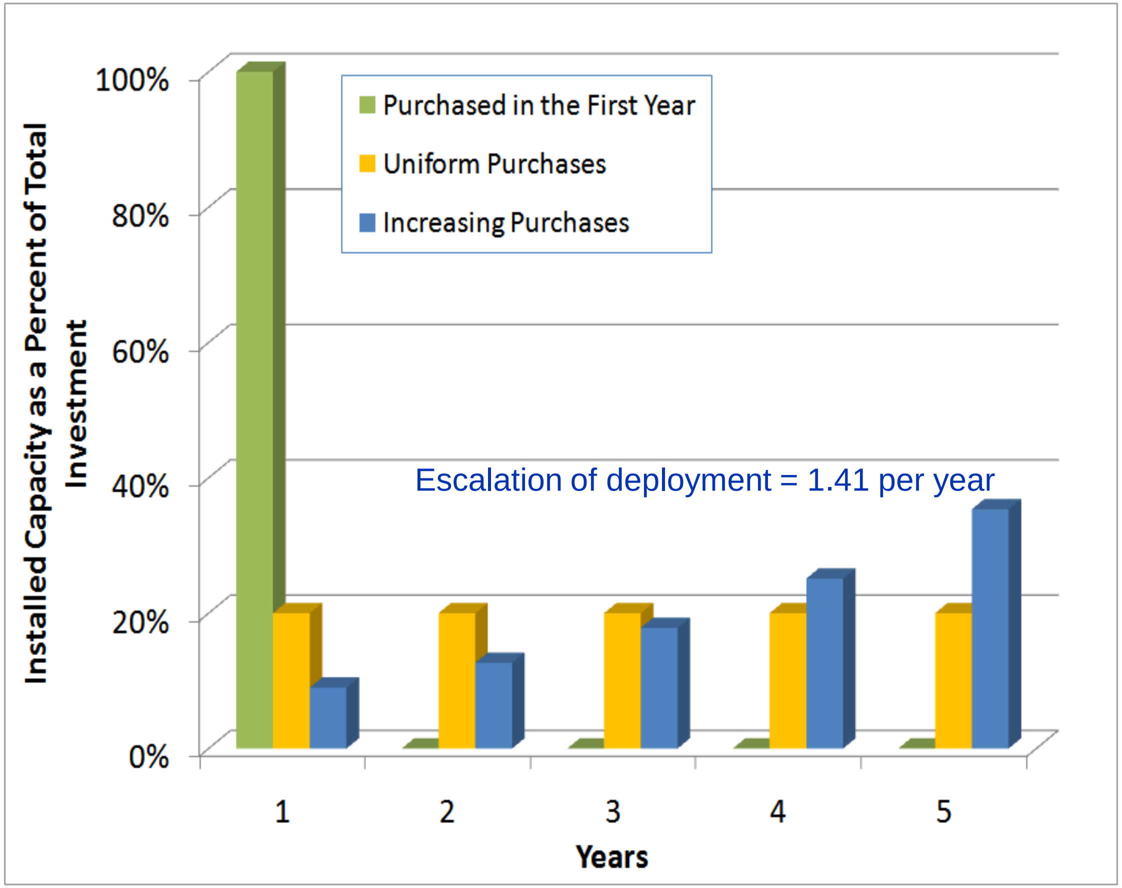




Gradual Deployment – Key to lowering the Storage Cost

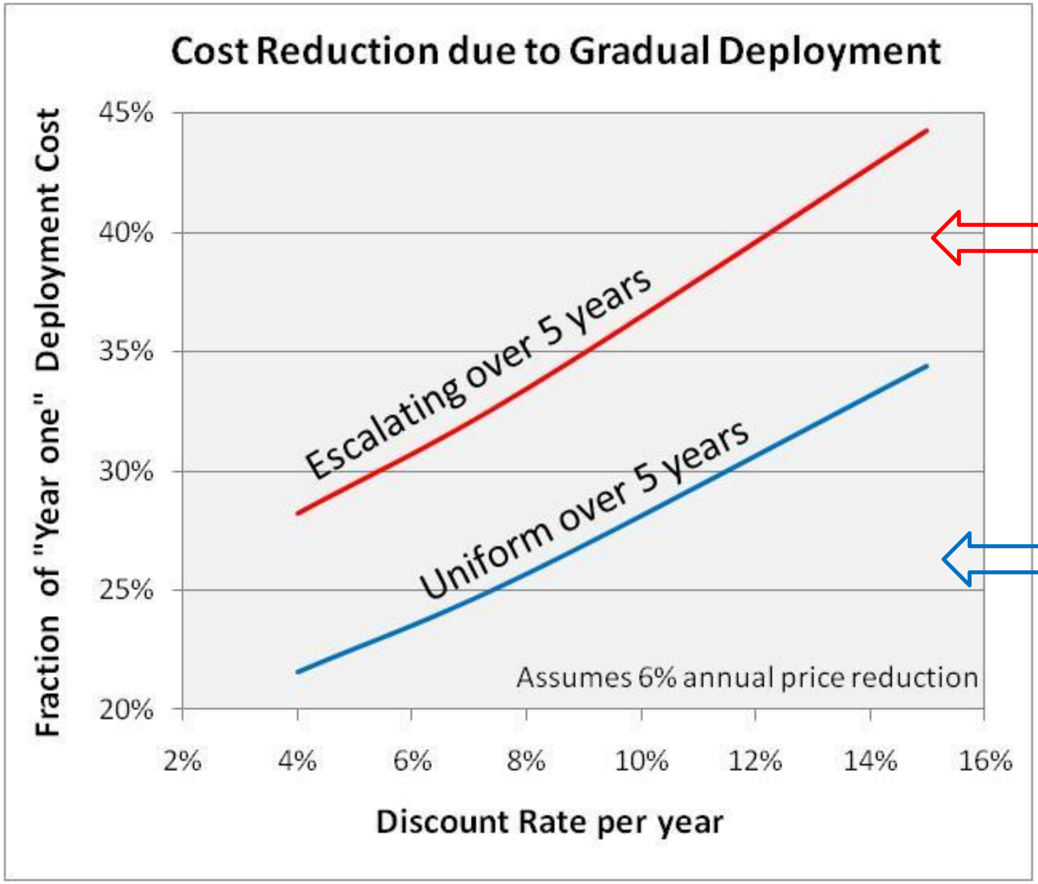
Key benefits of gradual deployment:

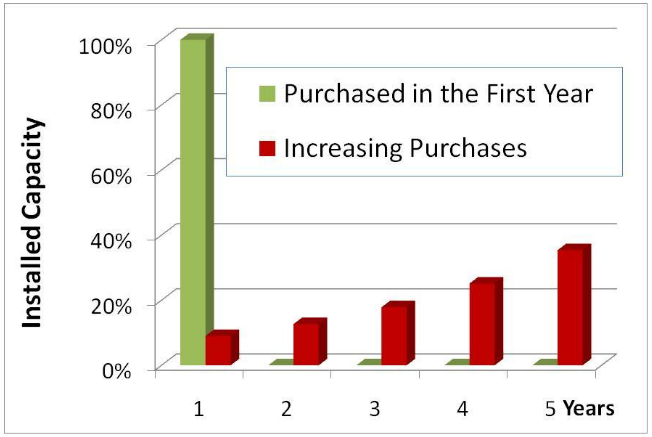
- Lower future expenditure
  - higher competition
  - commodity pricing
- Longer asset life
- Flexibility in matching
  - load growth
  - PV growth

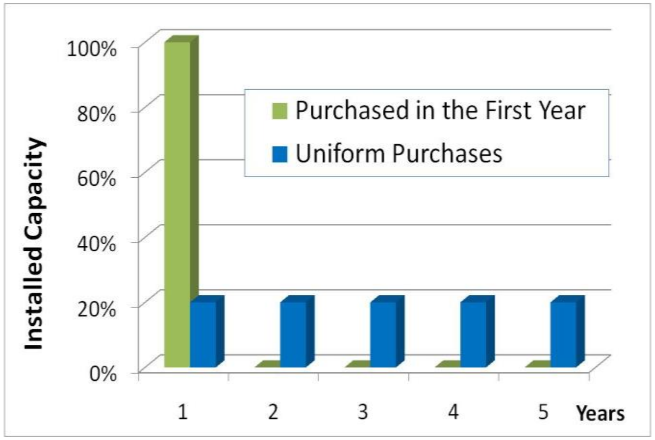


Gradual Deployment Saves 25% - 40%

Impact of Gradual Deployment on Present Value of Investment







Residential Fuel Cell

- Refrigerator sized fuel cell system hooks up to your natural gas supply
  - Fuel processor draws out hydrogen molecules
  - Electrochemical process combines hydrogen with oxygen to generate electricity
- ClearEdge Power produces a 5kW unit with heat byproduct capable of warming 750 gallons of water
  - High costs: $56,000 for fuel cell unit with installation for an existing home adding another $12,000 to $25,000
- Bloom Energy has stated future plans to develop a 1kW unit for residential market
  - Target price $3,000 with estimated 5-10 years of development required
- Panasonic's Ene-Farm 700 W home fuel cell, jointly developed with Tokyo Gas has sold over 21,000 units in Japan retails for $22,320 USD

SOURCE: ClearEdge Power

Contents

Standards Relevant to Customer-Cited PV-Energy Storage Systems

Standard	Description	Application
IEC 61850-90-7	Object Models for Photovoltaic,Storage and other DER inverters	Identifies the standard pieces of information necessary for the control of PV and Energy Storage systems. These pieces (object models) can be mapped to any communications protocol such as DNP 3.0
IEC 61850-7-420	Communications systems for Distributed Energy Resources (DER) - Logical nodes	Development of one international standard that defines the communication and control interfaces for all DER devices.[1]
IEEE 1547.8	Draft Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Standard 1547	Better understanding of the interactions of DR (Distributed Resource) and the grid Guidance for the increased use of DR Guidance for the use of 'smart' inverters Guidance for the integration of DR with the 'smart grid'[2]
AN2013-001	Application Note created by the DNP 3.0 Users Group Describes a standard data point configuration, set of protocol services and settings (also known as a profile) for communicating with photovoltaic (PV) generation and storage systems using the DNP3 standard3	Provides inverter manufacturers, utilities, and system integrators with standard-based methods for integration of inverter-based photovoltaic and battery storage systems with utility communication and control systems and enables the use of DNP3 to implement the full slate of common smart inverter functions identified in IEC/TR 61850-90-7.

[1] Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, 2008 IEEE
Date of Conference: 20-24 July 2008
Author(s): Cleveland, Frances M.
Xanthus Consulting Int., Boulder Creek, CA

[2] Update of the Status of IEEE 1547.8, Expanding on IEEE Standard 1547
D. L. Bassett PE, Consultant,
Senior Member, IEEE
Co-Chair IEEE 1547.8

[3] http://www.remotemagazine.com/main/news/dnp-users-group-releases-new-application-note/

Recent Standards Activities

- The NIST has created Priority Action Plan (PAP) 7 with several tasks related to the development of communication standards for PV and Energy Storage control.
  - Task 1 – define Use Cases for Distributed Energy Storage devices and applications.
  - Task 2 & 3 – development of a series of IEEE 1547 Standards revisions and extensions.
  - Task 4 – extend and harmonize object models for ES-DER devices including energy storage devices, power electronics interconnection of generation sources, and combined generation-storage devices across transmission, distribution, and consumer domains
  - Task 5 – Develop codes and test methods to ensure safe and reliable implantation of ES with the residential and commercial-building consumer domains.
- NIST PAP 12 is also underway to map IEC 61850 object models to the DNP 3.0 protocol. However, DNP3.0 is also recognized as lacking some of the capabilities necessary to carry out the entire functionality of IEC 61850 object models.
- IEC TC57 WG17 has developed the standard IEC 61850-7-420, consisting of abstract object models for four types of generators and one type of storage:
  - Diesel generators
  - Fuel cells
  - Photovoltaic systems
  - Combined heat and power (CHP)
  - Batteries

Recent Standards Activities

- The IEEE 1547.8 working group met in February, 2013. The working group is looking at a number of ways to enhance IEEE 1547 in response to new technologies and higher penetrations of distributed energy resources. A new section 4.1.7 Monitoring Provisions has been added that addresses:
  - Types of communication
  - Analog and status monitoring
  - Emergency actions
  - Autonomous modes
  - Direct management
  - Default actions or operation

Contents

C/I Customer-Sited ES, for Electric Bill Demand Charge and VAR Charge Reduction

- Commercial and Industrial (C/I) rate class tariffs typically have additional electric bill charges that residential tariffs don't: Demand charges and Power Factor (PF) penalties
- Demand charges are typically calculated on the measured peak power consumption (kW) per meter period (15-30 minutes) per billing period (month)
  - Example from ConEd's general service tariff for large C/I:

Demand Delivery Charges, per kW of maximum demand

Charges applicable for the months of June, July, August, and September	Low Tension Service		High Tension Service	
first 5 kW (or less)	$135.85	per month	$105.05	per month
next 95 kW	$22.34	per kW	$16.99	per kW
over 100 kW	$22.07	per kW	$16.72	per kW

- PF penalties apply when a customer's PF (a measure of relative VAR vs WATT components of customer demand) are outside of allowed limits.
  - Example from ConEd's charges, if C/I customer's PF is out of limits (0.95)

.   (4) Charge per kVar

$1.10 per kVar   applicable to Customers specified in paragraph (1)(a), (b), (c), or (d) above for billable reactive power demand. Billable reactive power demand, in kVar, shall be equal to the kVar at the time of the kW maximum demand (as defined in

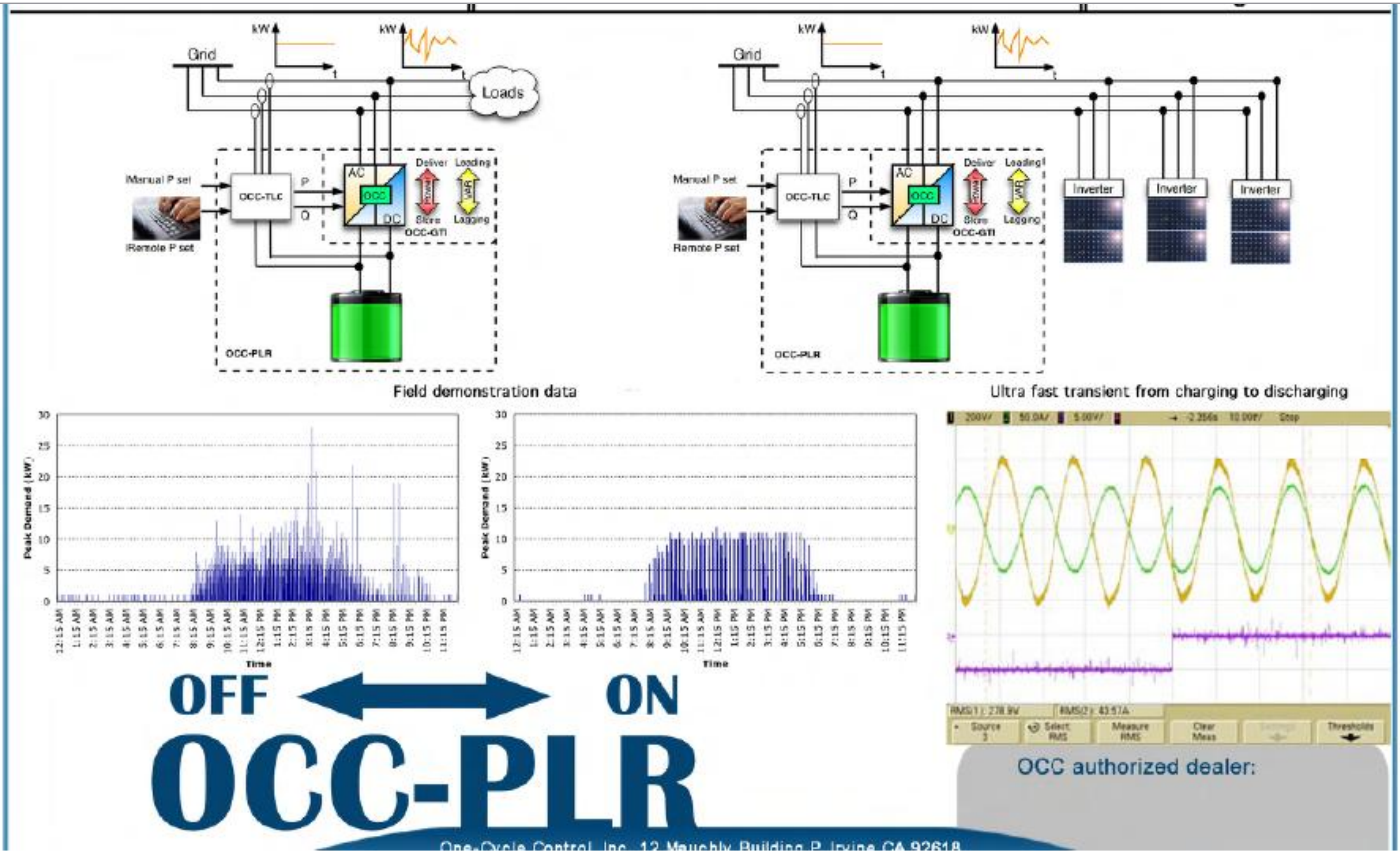
Demand Charges, ConEd's 'Plan Language' Description

understanding demand billing

What Is Demand?

The term "demand' refers to the demand made by the customer upon the Company for the reserve of certain capacity. Whatever the energy requirements may be, we must maintain facilities with sufficient capacity to meet the maximum requirements of our customers. Even though these facilities may not always be used at full capacity, they are nonetheless required so that the electricity is available to customers whenever they want it. The demand charge reflects these capacity-related costs.

Example of ES Product for Demand Charge Reduction



www.onecyclecontrol.com/**OCC-PLR**-product.html

Example of ES System for Demand Charge Reduction

Examples of potential customer bill-savings benefit, for a California GS C/I rate:

One-Cycle Control, Inc. 7/13

OCC-PLR Motivation

	< 20 kWp	20-200 kWp		
	GS-1	GS-2	GS-2 Option A	GS-2 Option B
Winter ($/kWp)	-	$12	$12	$12
Summer ($/kWp)	-	$31	$12	$29 ($17 mid peak)

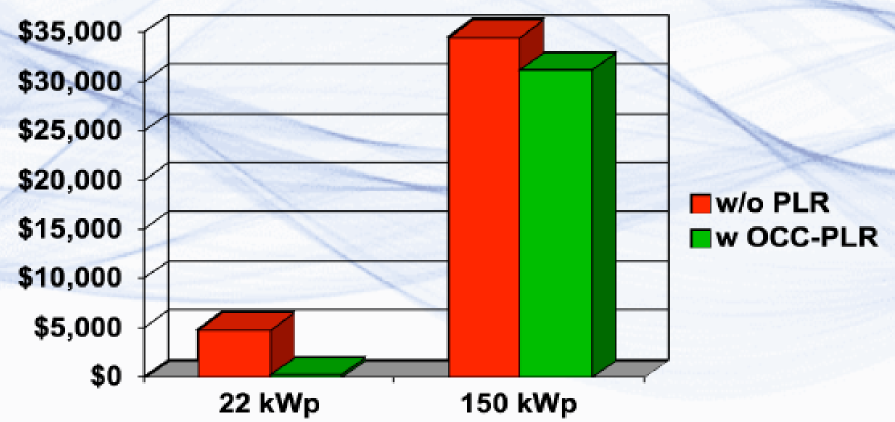
- SCE Rate Schedules & Peak Charges

gsmedley@onecyclecontrol.com 2010 © One-Cycle Control, Inc.

One-Cycle Control, Inc. 8/13

Annual Cost with / without 15kW OCC-PLR

- Customer A: 22 kWp (OCC-PLR enables GS-2 ==> GS-1)
- Customer B: 150 kWp (GS-2)



Annual Savings: $4800 $3300
(Peak kW Costs only)

gsmedley@onecyclecontrol.com 2010 © One-Cycle Control, Inc. Greg Smedley

From OCC demo and presentation to the CA Energy Comm., March 2011

Example of ES System for Demand Charge Reduction

ARISTA
PoD

Reduce electric utility demand charges with Arista's Power on Demand "Peak-Shaving" system.

WHAT IS PoD?

Arista's Power on Demand (PoD) solution is designed to reduce demand charges that can significantly increase utility bills for large users of electricity.

HOW DOES PoD WORK?

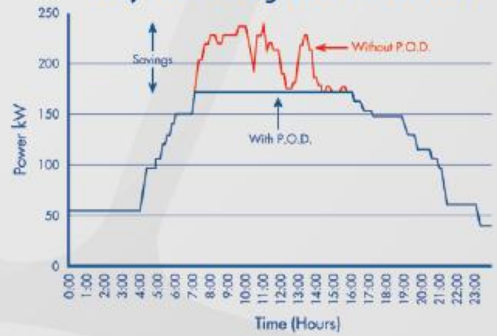
This innovative, patent-pending system is designed to utilize energy generated by wind turbines and/or solar arrays and energy stored from the grid itself to reduce peak electricity demand at consumer levels.

WHY PoD?

Dramatically lower your utility bills and benefit from a Return on Investment (or payback period) that no stand-alone renewable energy system can match.

WHAT IS A DEMAND CHARGE?

Large users of electricity often bear disproportionately high energy costs because they not only pay for the energy they actually use, but they are also required to pay for the right to have energy capacity available to them (whether or not they are using that capacity) at all times. This is called a "demand charge."



The chart above represents a customer's peak usage day that was used to determine their "demand charge." Arista's PoD system stores the energy captured from the WindTamer turbine and then releases the power during peak demand hours. This results in lower demand charges and utility bills for the customer. Use of the PoD system resulted in the following savings:

	Before System	Power-on-Demand
Monthly Demand Charges	$3,625	$2,360
Monthly Total	$5,967	$4,607
Annual Utility Costs	$71,607	$55,284
Annual Savings		$16,323

For a 1-4 hour duration energy storage system, the Demand Charge savings will typically exceed Energy time-shift savings

http://aristapower.com/power-od/our-systems/

KEMA DNV

Example of Demand Charge Reduction Savings Potential

Small C/I Customer with 100kW Monthly Peak Adding 'CES' BESS for 20kW Peak Demand Reduction												
ConEd Service Class 9 Rate I Demand Charge used												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Demand Charge >5kW-100kW, $/kW	17.69	17.69	17.69	17.69	17.69	23.34	23.34	23.34	23.34	17.69	17.69	17.69
Monthly peak demand reduction, kW	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20
Monthly savings, $	$ (354)	$ (354)	$ (354)	$ (354)	$ (354)	$ (467)	$ (467)	$ (467)	$ (467)	$ (354)	$ (354)	$ (354)
Annual savings, $	$ **(4,698)**											
'CES' Cost 25KVA 2Hr's $2500/kW	$ 62,500											
Annual cost at 12% carrying charge, $	$ 7,500											
Years for simple payback, years	13											
'CES' Cost 25KVA 2Hr's $1500/kW	$ 37,500											
Annual cost at 12% carrying charge, $	$ **4,500**											
Years for simple payback, years	8											
'CES' Cost 25KVA 2Hr's $1000/kW	$ 25,000											
Annual cost at 12% carrying charge, $	$ 3,000											
Years for simple payback, years	5.3											

Passes simple financial/financing screen with CES at $1,500/kW cost, w/ 12% financing

Passes simple investment/payback screen with CES at $1,000/kW cost

C/I Customer Sited ES VAR Charge Reduction Example

- ConEd example of savings from bringing customer's PF into the no-penalty zone:

.

The New Reactive-Power Charge and Mandatory Hourly Pricing

What You Need to Know Now, and Why

Reactive Power Information for Con Edison Bills

Reactive Power billing determinants to be presented on bill

Demand (kW)	3000
Power Factor	92.00%
Actual Reactive Power Demand (kVar)	1,200
Allowable Reactive Power Demand (kVar) at 95% Power Factor	1,000
Billable Reactive Power Demand (kVar)	200
Reactive Power Demand Charge @ $1.10 per billable kVar	$220.00

Reactive Power billing determinants to be presented on bill (no charge)

Demand (kW)	3000
Power Factor	97.00%
Actual Reactive Power Demand (kVar)	800
Allowable Reactive Power Demand (kVar) at 95% Power Factor	1,000
Billable Reactive Power Demand (kVar)	0
Reactive Power Demand Charge @ $1.10 per billable kVar	$0.00

- Providing VAR-support for customer-load PF correction does not consume battery capacity. It is a coincident service enabled via appropriate BESS inverter.

www.dnvkema.com

www.dnv.com

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Appendix

A	Raw Load Data

Summer Average Residential Load

- Hourly kW demand / kWh energy

Load / Hour	Electric Water Heater	Central A/C	Electric Heating	Non-electric Heating (pumps, fans)	Lighting	Refrigerator	Cooking	Misc Chargers, plug loads
1	0.1896	0.7629	-	-	0.0863	0.0642	0.0063	0.0418
2	0.1402	0.6746	-	-	0.0765	0.0627	0.0045	0.0322
3	0.1078	0.5805	-	-	0.0731	0.0615	0.0043	0.0272
4	0.1209	0.5087	-	-	0.0712	0.0605	0.0059	0.0272
5	0.1307	0.4641	-	-	0.0725	0.0601	0.0109	0.0276
6	0.2244	0.4706	-	-	0.0778	0.0603	0.0172	0.0301
7	0.4925	0.4236	-	-	0.0881	0.0609	0.0232	0.0359
8	0.6116	0.5043	-	-	0.0997	0.0617	0.0285	0.0469
9	0.5763	0.5793	-	-	0.0988	0.0624	0.0323	0.0581
10	0.5870	0.7161	-	-	0.0994	0.0631	0.0365	0.0640
11	0.5328	0.8440	-	-	0.0977	0.0640	0.0406	0.0673
12	0.4590	0.9613	-	-	0.0948	0.0649	0.0428	0.0661
13	0.3793	1.0775	-	-	0.0985	0.0658	0.0431	0.0665
14	0.3584	1.2117	-	-	0.0978	0.0666	0.0438	0.0669
15	0.3113	1.3252	-	-	0.0956	0.0675	0.0517	0.0682
16	0.2756	1.4537	-	-	0.0988	0.0685	0.0689	0.0686
17	0.2941	1.5821	-	-	0.1039	0.0697	0.0876	0.0669
18	0.3529	1.5813	-	-	0.1115	0.0707	0.0983	0.0665
19	0.4291	1.5533	-	-	0.1165	0.0711	0.0941	0.0590
20	0.4365	1.4521	-	-	0.1198	0.0708	0.0766	0.0648
21	0.4134	1.3451	-	-	0.1282	0.0700	0.0538	0.0836
22	0.4518	1.2816	-	-	0.1488	0.0687	0.0339	0.0936
23	0.4243	1.1486	-	-	0.1438	0.0672	0.0202	0.0820
24	0.3196	0.9992	-	-	0.1104	0.0657	0.0114	0.0590
Daily Total:	8.6190	23.5012	-	-	2.4095	1.5687	0.9363	1.3699

Summer Peak Residential Load

- Hourly kW demand / kWh energy

Load / Hour	Electric Water Heater	Central A/C	Electric Heating	Non-electric Heating (pumps, fans)	Lighting	Refrigerator	Cooking	Misc Chargers, plug loads
1	0.2210	1.1689	-	-	0.0882	0.0656	0.0110	0.0418
2	0.1482	1.0376	-	-	0.0763	0.0643	0.0075	0.0322
3	0.1439	0.9007	-	-	0.0726	0.0631	0.0064	0.0272
4	0.1187	0.8312	-	-	0.0709	0.0622	0.0073	0.0272
5	0.1294	0.7177	-	-	0.0723	0.0616	0.0107	0.0276
6	0.1670	0.8089	-	-	0.0747	0.0615	0.0185	0.0301
7	0.2297	0.7088	-	-	0.0833	0.0618	0.0300	0.0359
8	0.3728	0.8487	-	-	0.0959	0.0625	0.0429	0.0469
9	0.5829	0.9263	-	-	0.0939	0.0633	0.0536	0.0581
10	0.7274	1.1747	-	-	0.1009	0.0642	0.0595	0.0640
11	0.7440	1.3895	-	-	0.1001	0.0652	0.0639	0.0673
12	0.6451	1.7024	-	-	0.0988	0.0664	0.0658	0.0661
13	0.5408	1.9013	-	-	0.0984	0.0674	0.0641	0.0665
14	0.4668	2.1228	-	-	0.1023	0.0683	0.0656	0.0669
15	0.3849	2.3490	-	-	0.0970	0.0691	0.0701	0.0682
16	0.3545	2.4808	-	-	0.1047	0.0699	0.0799	0.0686
17	0.3312	2.7115	-	-	0.1057	0.0708	0.0941	0.0669
18	0.3953	2.7913	-	-	0.1120	0.0716	0.0993	0.0665
19	0.4188	2.7325	-	-	0.1184	0.0718	0.0922	0.0590
20	0.4629	2.5596	-	-	0.1207	0.0716	0.0754	0.0648
21	0.5088	2.5702	-	-	0.1284	0.0709	0.0527	0.0836
22	0.4862	2.4678	-	-	0.1457	0.0698	0.0326	0.0936
23	0.3956	2.3139	-	-	0.1393	0.0686	0.0188	0.0820
24	0.2956	2.1315	-	-	0.1089	0.0674	0.0100	0.0590
Daily Total:	9.2715	41.3476	-	-	2.4095	1.5989	1.1321	1.3699

Winter Average Residential Load

- Hourly kW demand / kWh energy

Load / Hour	Electric Water Heater	Central A/C	Electric Heating	Non-electric Heating (pumps, fans)	Lighting	Refrigerator	Cooking	Misc Chargers, plug loads
1	0.1890	-	1.1305	0.0707	0.0966	0.0505	0.0100	0.0418
2	0.1443	-	1.2599	0.0787	0.0886	0.0492	0.0088	0.0322
3	0.1173	-	1.3724	0.0858	0.0846	0.0486	0.0094	0.0272
4	0.0903	-	1.6124	0.1008	0.0829	0.0484	0.0113	0.0272
5	0.1483	-	2.2526	0.1408	0.0849	0.0486	0.0162	0.0276
6	0.2979	-	2.8510	0.1782	0.0971	0.0495	0.0236	0.0301
7	0.6609	-	3.9911	0.2494	0.1257	0.0506	0.0299	0.0359
8	0.9366	-	4.1386	0.2587	0.1556	0.0513	0.0345	0.0469
9	0.8030	-	3.5866	0.2242	0.1375	0.0517	0.0360	0.0581
10	0.6965	-	2.9332	0.1833	0.1230	0.0514	0.0360	0.0640
11	0.5751	-	2.1672	0.1355	0.1146	0.0511	0.0381	0.0673
12	0.4976	-	1.8618	0.1164	0.1094	0.0513	0.0413	0.0661
13	0.4319	-	1.7914	0.1120	0.1089	0.0516	0.0455	0.0665
14	0.3832	-	1.6191	0.1012	0.1048	0.0520	0.0525	0.0669
15	0.3353	-	1.7216	0.1076	0.1045	0.0527	0.0656	0.0682
16	0.3062	-	1.7858	0.1116	0.1141	0.0537	0.0884	0.0686
17	0.3554	-	2.7075	0.1692	0.1368	0.0551	0.1148	0.0669
18	0.4867	-	2.7847	0.1740	0.1828	0.0567	0.1276	0.0665
19	0.6131	-	2.9045	0.1815	0.2100	0.0578	0.1213	0.0590
20	0.6188	-	2.5649	0.1603	0.2062	0.0583	0.0988	0.0648
21	0.5160	-	2.4305	0.1519	0.2037	0.0578	0.0664	0.0836
22	0.4849	-	2.0836	0.1302	0.1888	0.0566	0.0404	0.0936
23	0.4291	-	1.6074	0.1005	0.1570	0.0548	0.0241	0.0820
24	0.2927	-	1.2059	0.0754	0.1188	0.0527	0.0133	0.0590
Daily Total:	10.4103	-	54.3643	3.3978	3.1371	1.2618	1.1539	1.3699

Winter Peak Residential Load

- Hourly kW demand / kWh energy

Load / Hour	Electric Water Heater	Central A/C	Electric Heating	Non-electric Heating (pumps, fans)	Lighting	Refrigerator	Cooking	Misc Chargers, plug loads
1	0.2225	-	1.6273	0.1017	0.1090	0.0518	0.0135	0.0418
2	0.1595	-	1.8954	0.1185	0.0951	0.0503	0.0161	0.0322
3	0.1169	-	2.1659	0.1354	0.0859	0.0495	0.0177	0.0272
4	0.0895	-	2.5581	0.1599	0.0823	0.0494	0.0185	0.0272
5	0.1151	-	3.5937	0.2246	0.0806	0.0496	0.0173	0.0276
6	0.1297	-	4.3168	0.2698	0.0832	0.0506	0.0220	0.0301
7	0.1789	-	5.5379	0.3461	0.0919	0.0518	0.0341	0.0359
8	0.3058	-	5.6362	0.3523	0.1076	0.0525	0.0495	0.0469
9	0.5173	-	5.2515	0.3282	0.1224	0.0528	0.0659	0.0581
10	0.7655	-	4.2955	0.2685	0.1354	0.0524	0.0768	0.0640
11	0.9335	-	3.3096	0.2068	0.1323	0.0519	0.0825	0.0673
12	0.8661	-	2.9292	0.1831	0.1265	0.0521	0.0845	0.0661
13	0.7936	-	2.7900	0.1744	0.1335	0.0526	0.0848	0.0665
14	0.6675	-	2.4433	0.1527	0.1287	0.0532	0.0913	0.0669
15	0.6085	-	2.6214	0.1638	0.1252	0.0540	0.1006	0.0682
16	0.4896	-	2.6211	0.1638	0.1382	0.0552	0.1149	0.0686
17	0.5074	-	3.5100	0.2194	0.1431	0.0566	0.1328	0.0669
18	0.5794	-	3.9873	0.2492	0.1835	0.0578	0.1335	0.0665
19	0.6068	-	4.1400	0.2588	0.2027	0.0587	0.1170	0.0590
20	0.5647	-	3.7107	0.2319	0.1974	0.0589	0.0901	0.0648
21	0.4862	-	3.4934	0.2183	0.1933	0.0585	0.0565	0.0836
22	0.4195	-	3.0016	0.1876	0.1729	0.0576	0.0329	0.0936
23	0.3676	-	2.6668	0.1667	0.1530	0.0560	0.0221	0.0820
24	0.2815	-	1.9002	0.1188	0.1135	0.0538	0.0174	0.0590
Daily Total:	10.7728	-	80.0028	5.0002	3.1371	1.2876	1.4925	1.3699