NATIONAL RENEWABLE ENERGY LABORATORY

Battery Energy Storage Market:

Commercial Scale, Lithium-ion Projects in the U.S.

Joyce McLaren, Pieter Gagnon, Kate Anderson, Emma Elgqvist, Ran Fu, Tim Remo

October, 2016

Funded by the DOE Solar Energy Technologies Office under the SuNLaMP Project 30379-1614
Solar-plus-Storage: Cost Reduction through Optimization and Market Characterization (FY16-17)

Table of Contents

This slide deck presents the results of data collection on the commercial-scale li-ion battery energy storage market (current as of Autumn 2016).

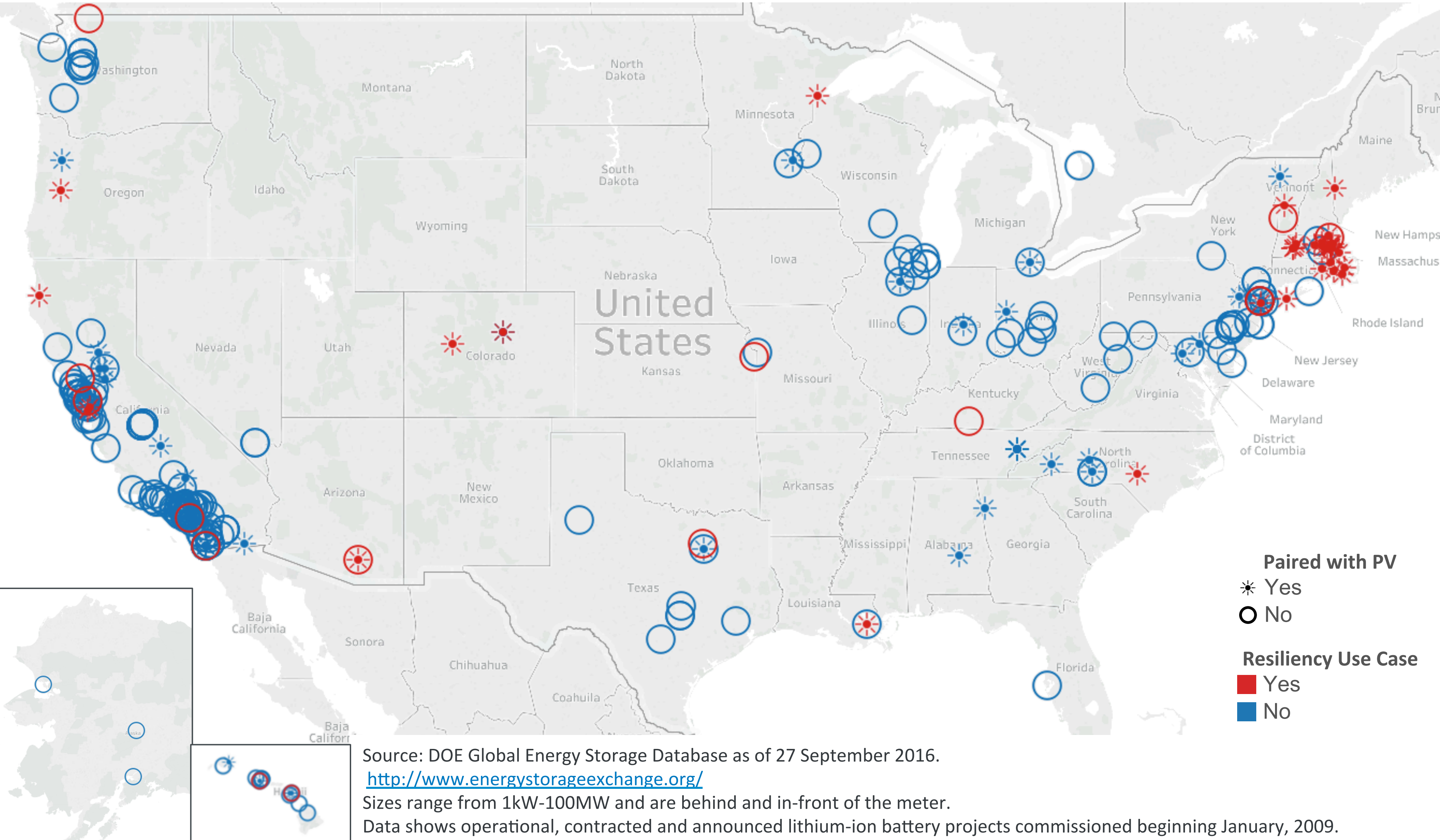
It includes:

- **map of existing U.S. project locations**
- **li-ion energy storage project cost data (on a kW and kWh basis), based on developer quotes**
- **project cost breakout and list of elements typically included in project cost estimates**
- **common use-cases and value streams for battery energy storage projects**
- **map of electric utility demand charges (which impact battery energy storage economics)**
- **how the Federal Investment Tax Credit (ITC) and Modified Accelerated Cost Recovery System (MACRS) apply to energy storage projects**
- **summary of NREL's FY16-17 solar + storage optimization modeling project**

The information presented in these slides was collected to inform the inputs and assumptions for NREL's solar + storage optimization modeling in FY17. The number of project quotes made available was limited and the energy storage market is rapidly changing. Therefore, this information should be seen only as a compliment to market data from other sources.

Li-ion Energy Storage Project Locations

This map indicates the locations of all li-ion battery projects listed on the Department of Energy (DOE) Energy Storage Database. **Projects paired with solar photovoltaics (PV) are show as a sun.** Projects listed as having a resiliency use case are shown in red. Projects are currently clustered on the west and east coasts, due to favorable electricity markets and incentives.

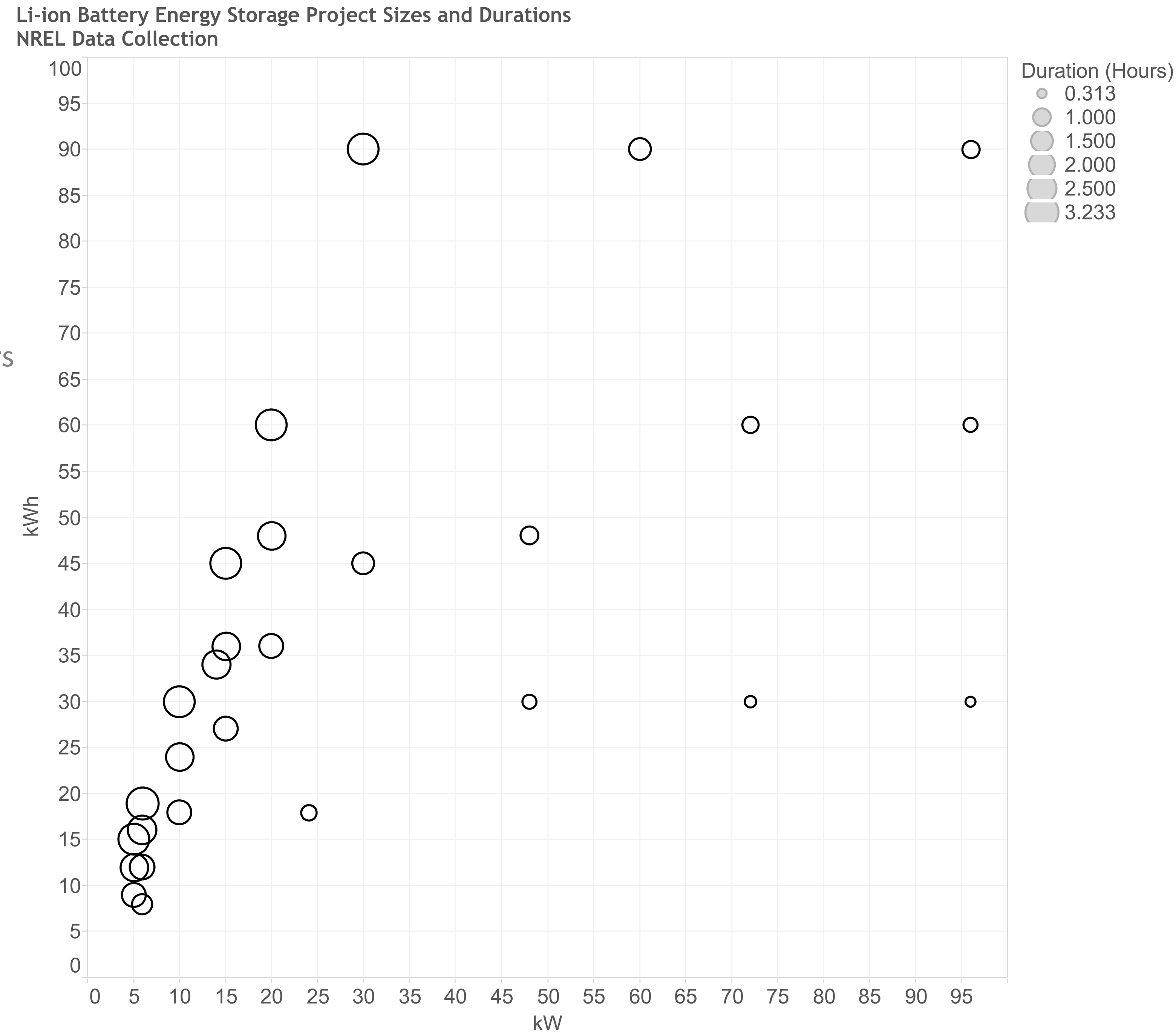


Source: DOE Global Energy Storage Database as of 27 September 2016.
http://www.energystorageexchange.org/
Sizes range from 1kW-100MW and are behind and in-front of the meter.
Data shows operational, contracted and announced lithium-ion battery projects commissioned beginning January, 2009.

NREL Data Collection

The following slides present current market baseline data for behind-the-meter, commercial-scale battery (li-ion) energy storage. The information is based on project quotes that were shared with NREL by industry participants between April – May 2016.

Project Sizes (NREL Data Collection)



Project Count: 28

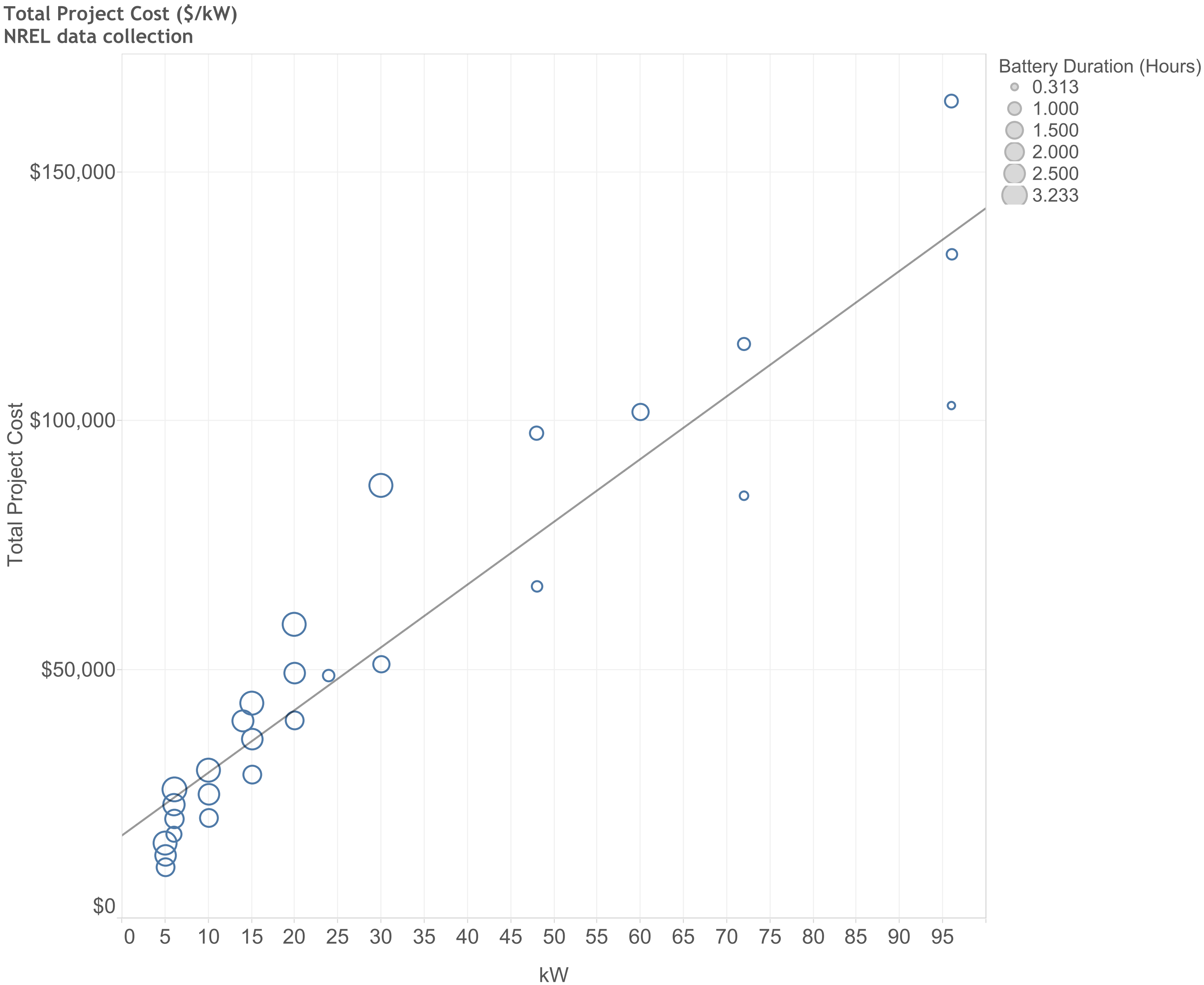
Battery Duration Hours
Average: 1.9
Minimum: 0.3
Maximum: 3.2

kW
Average: 30.7
Minimum: 5
Maximum: 96

kWh
Average: 37.1
Minimum: 8
Maximum: 90

Total Project Cost per kW (NREL Data Collection)

For the 28 projects for which data was collected, the average cost of the projects is $55k. The average duration of the battery projects is just under 2 hours. The average power rating of the projects is 30kW.



Count: 28

Total Project Cost
Average: $55,282
Minimum: $10,200
Maximum: $164,131

Battery Duration (Hours)
Average: 1.9
Minimum: 0.3
Maximum: 3.2

kW
Average: 30.7
Minimum: 5
Maximum: 96

Total Project Cost per kWh (NREL Data Collection)

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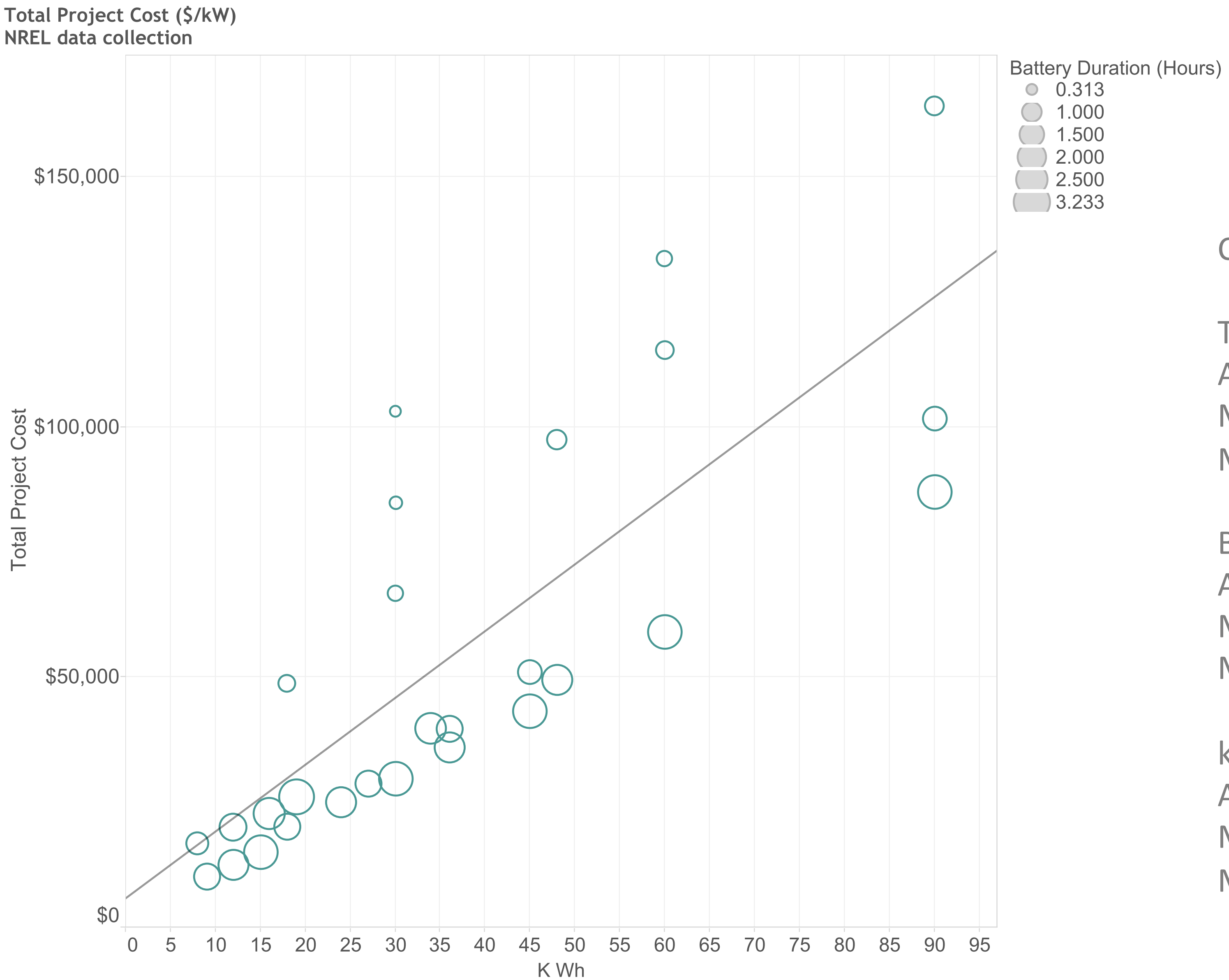


Count: 28

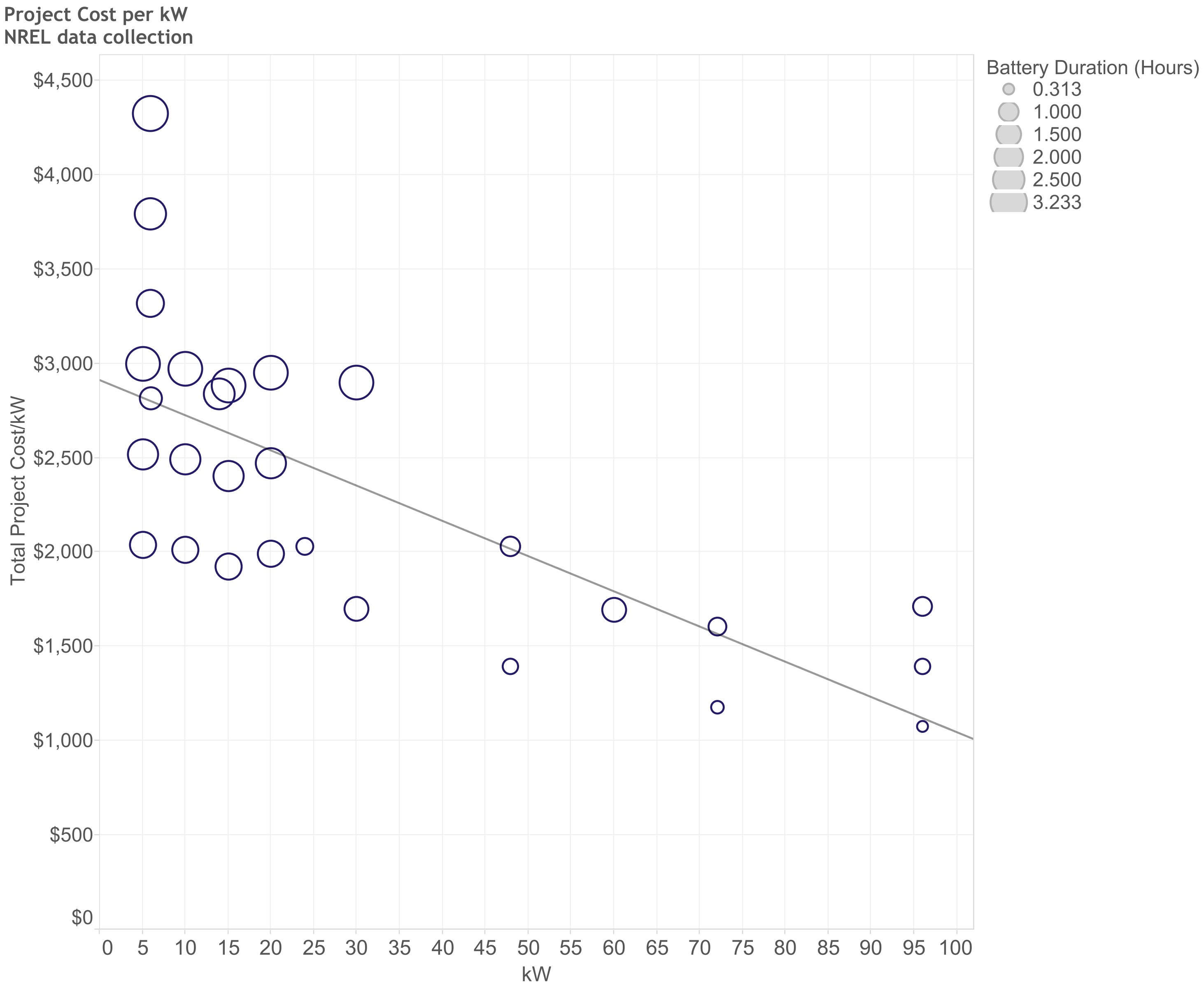
Total Project Cost
Average: $55,282
Minimum: $10,200
Maximum: $164,131

Battery Duration (Hours)
Average: 1.9
Minimum: 0.3
Maximum: 3.2

kWh
Average: 37.1
Minimum: 8
Maximum: 90

Total Project Cost –Normalized (NREL Data Collection)

Normalizing the data points by the kW rating shows the decrease in cost per kW with increase in the system power. The average cost per kW is $2,338. The wide range of costs is indicative of the fact that displaying the data in this way does not depict any information about the kWh rating of the battery, which can vary greatly across any given kW rating.



Count: 28

Battery Duration (Hours)
Average: 1.9
Minimum: 0.3
Maximum: 3.2

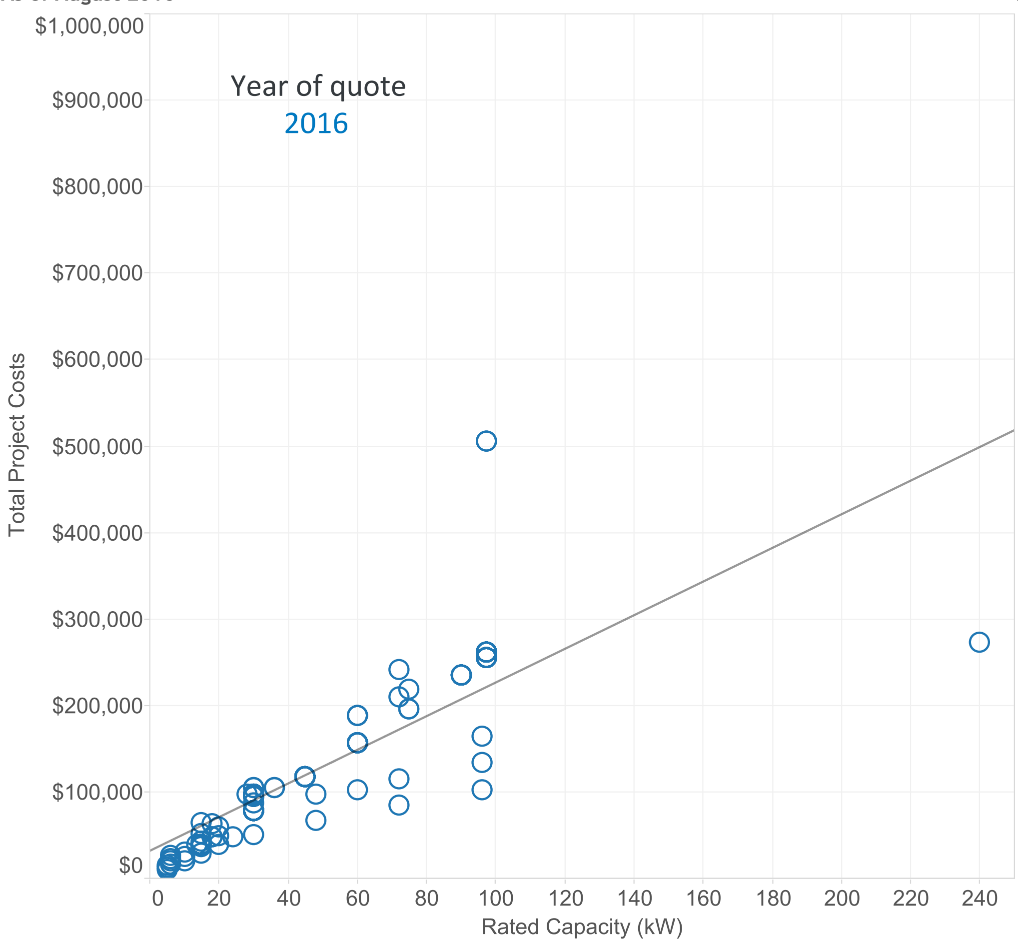
kW
Average: 30.7
Minimum: 5
Maximum: 96

Total Project Cost/kW
Average: $2,338
Minimum: $1,073
Maximum: $4,323

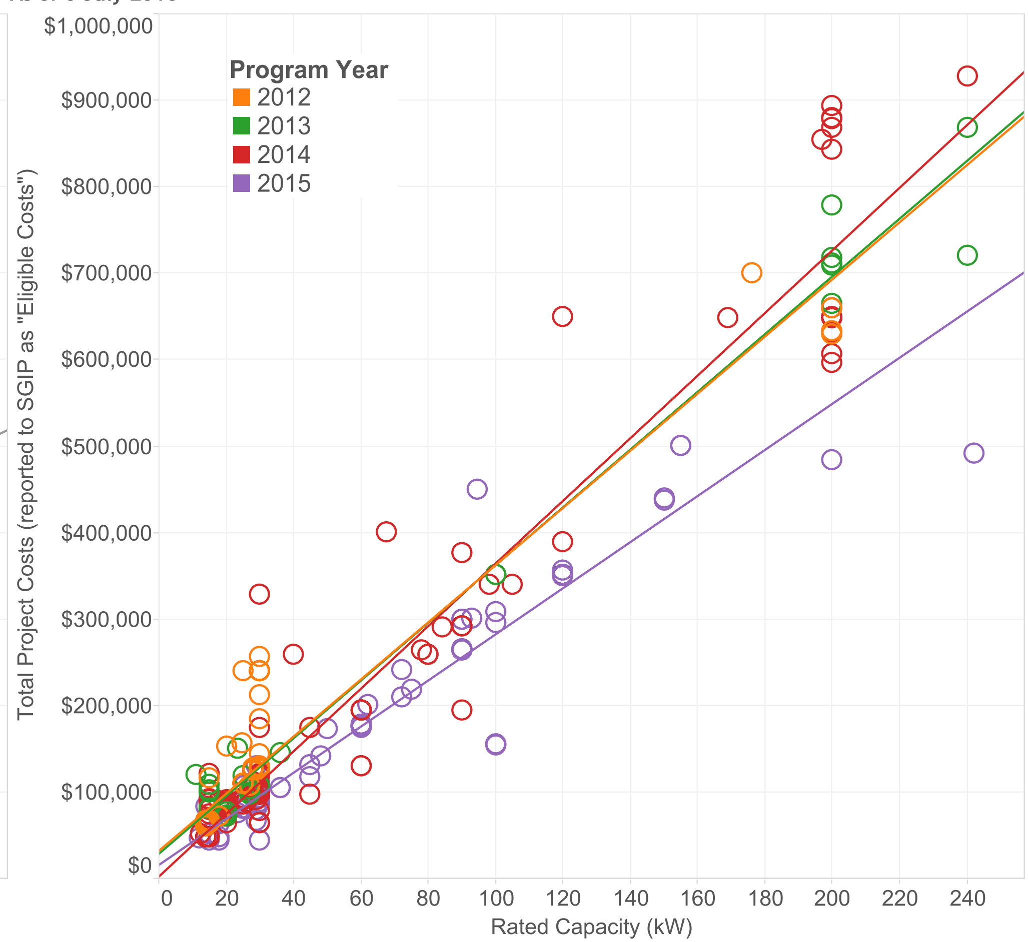
Comparison of NREL storage cost data vs. project costs reported to California Self-Generation Incentive Program

System quotes provided to NREL, while slightly lower, do not differ significantly from those reported to the California SGIP and may reflect reductions in system costs in the last year. The trends shown in these plots are dependent on the energy rating of the batteries. All things being equal, a portfolio with larger energy rating would show a higher $/kW trend. Since the energy ratings in the data points are not identical, these graphs should not be interpreted as a comparison of project costs, but simply as a depiction of the trend of one metric across two different portfolios.

NREL Data Collection
System quotes provided to NREL by industry
As of August 2016



California Self-generation Incentive Program
Paid, PBI in Progress, and Reserved
As of 6 July 2016



Storage Project Cost Breakdown

Battery

Hardware

- Inverter - Power Conversion
- Container or Housing
- Container extras (insulation/walls)
- Electrical Conduit (inside of container)
- Communication Device
- HVAC
- Meter (revenue grade)
- Fire Detection
- Fire Suppression
- Labor
- AC Main Panel
- DC disconnect
- Isolation Transformer
- AUX Power (lighting)

Engineering, Procurement, Construction (EPC)

- Control System/SCADA
- Site Preparation
- Loading & Drive from OEM site
- Lifting & Hoisting (by crane on site)
- PE stamped calculations/ drawings
- OEM testing and commissioning
- Electrical BOS outside of container (conduit, wiring, DC cable)
- Electrical Labor
- Structural BOS (fencing)
- EPC Overhead & Profit

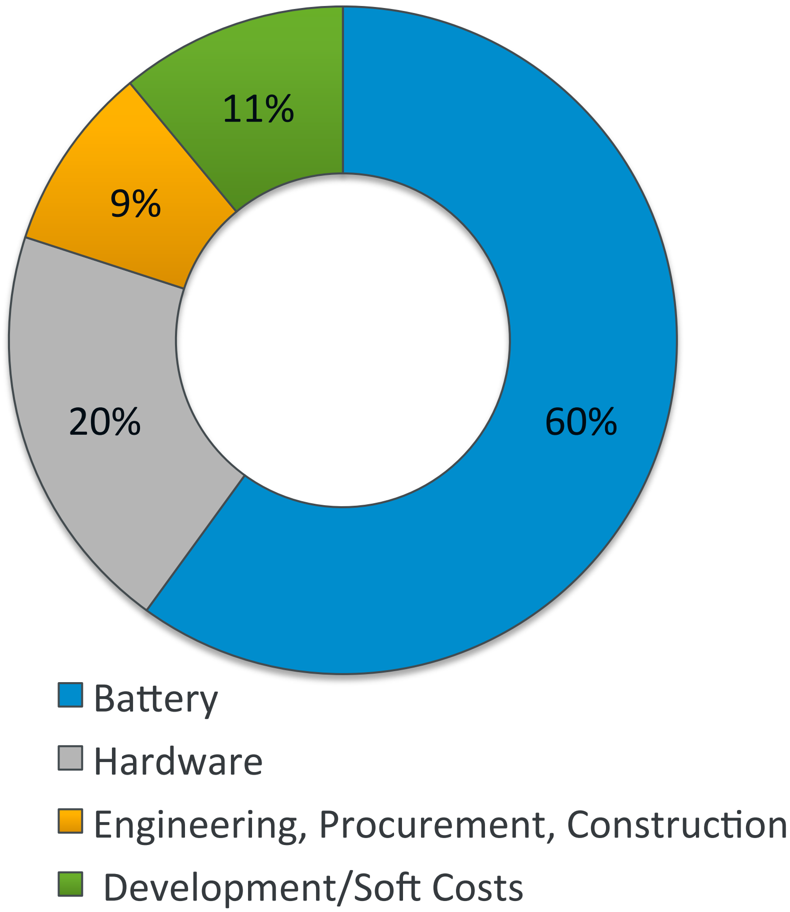
Development / Soft Costs

- Customer Acquisition
- Developer Overhead & Profit
- Interconnection

Project Cost Breakout

500kW/1000kWh commercial scale containerized li-ion battery system

Total Project Cost = $883,427



Developed by Ran Fu & Timothy Remo
Data as of 09/30/2016 as part of NREL's Bottom-up Cost Model under DOE SuNLaMP agreement number 29839.

Use-cases & Value Streams

The following slides summarize :

- common use cases and value streams for energy storage
- utility demand charges across the US
- how the federal ITC and MACRS apply to energy storage

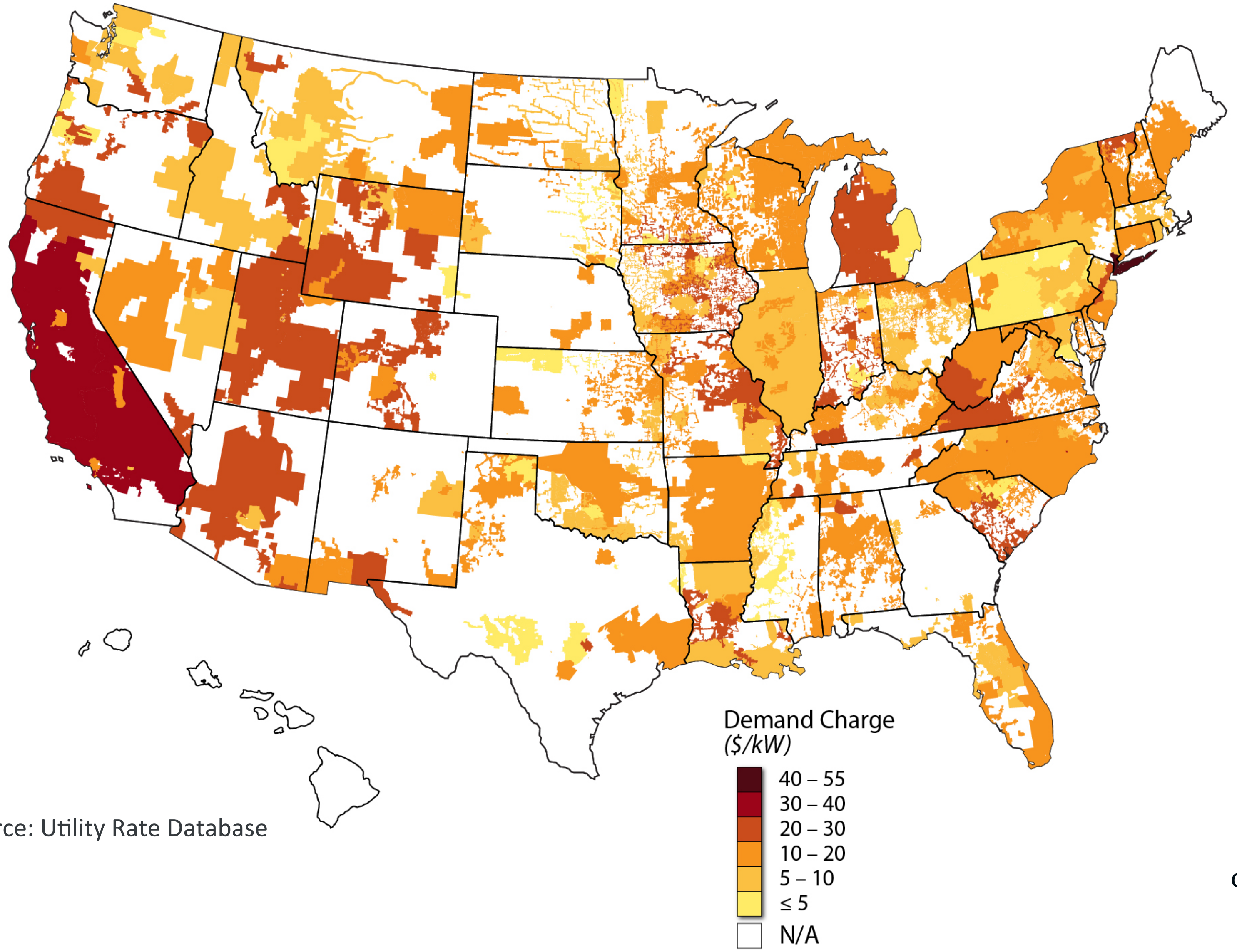
Battery Storage Use-cases & Value Streams

Battery system design and dispatch strategies differ depending on the use-case and the value streams that are being tapped. While the kWh dispatched may be the same in the case of two different projects (or even by the same project at different times), the monetary value ($/kWh) gained from that dispatch may be very different. Depending on the market structure in a particular location, commercial-scale, behind-the-meter battery projects may tap into one or more of the value streams below.

Value Stream	Reason for dispatch	Value
Demand Charge Reduction	Reduce on-site load to shave peaks in usage	Lower retail electricity bill via lower demand charge
Time-of-Use/Energy Arbitrage	Battery dispatched to meet on-site load during times of day when retail energy prices are high	Lower retail electricity bill via lower energy charge
Capacity/Demand Response	Dispatch power to grid in response to events defined by the utility/Independent System Operator	Payment for capacity service
Frequency Regulation	Battery injects/absorbs power to follow regulation signal	Payment for regulation services
Energy Sales	Dispatch power to grid during times that locational marginal prices (LMP) are high	LMP price for energy
Resiliency	Battery dispatched to provide power to critical facilities during outages.	Avoided cost of interruption.

Current Commercial/Industrial Utility Demand Charges

This map shows the highest demand charge observed in each utility territory. In regions where utility demand charges are high, behind-the-meter storage may yield electricity bill savings to the consumer by shaving load during peaks. The sheer number of utility rate structures across the U.S. has posed a challenge to identifying opportunities for deploying storage for demand charge savings.

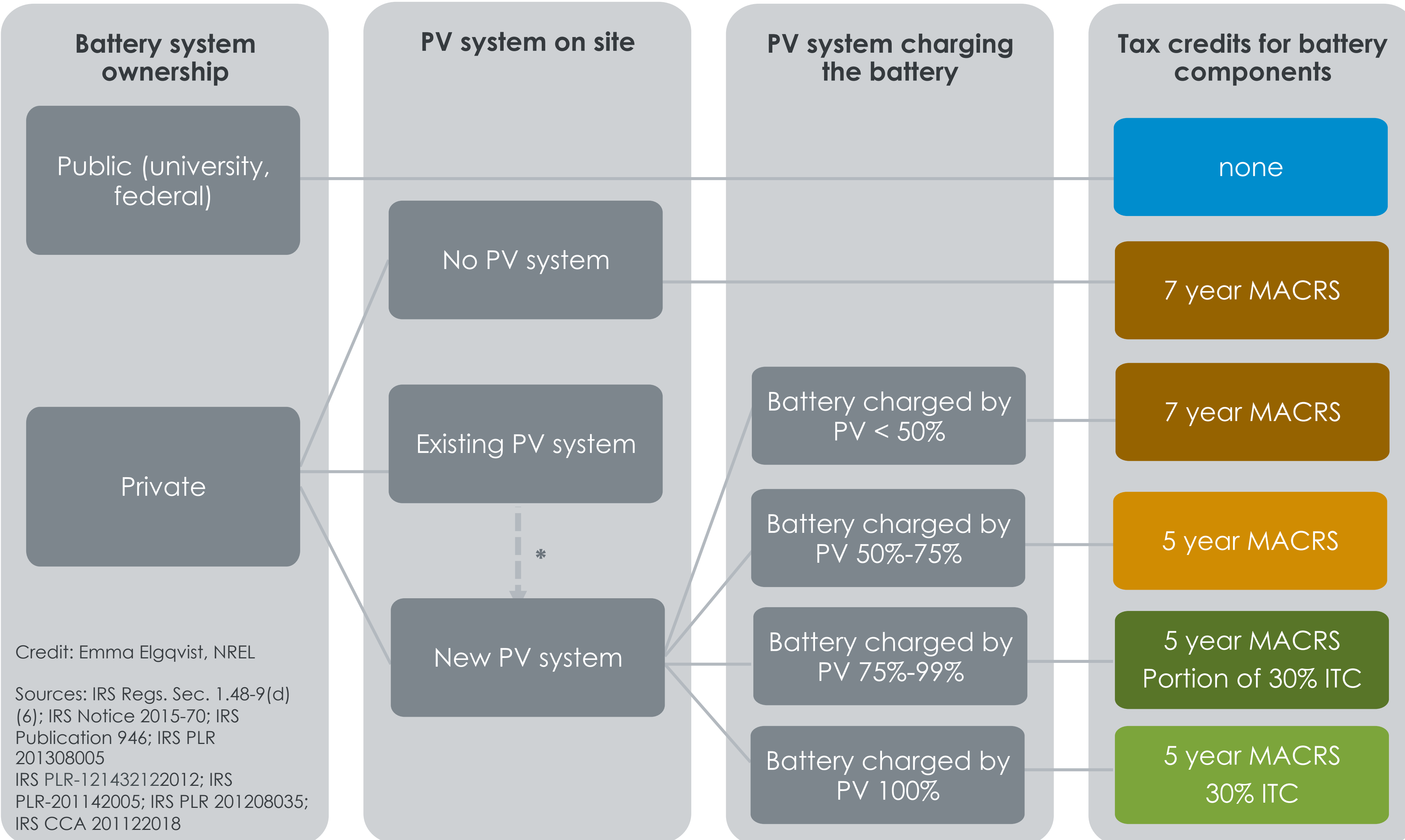


Source: Utility Rate Database

Data shown are based on commercial utility tariffs from the Utility Rate Database, as of August 2016. The database was updated between Sept 2015 and Sept 2016. Tariffs that are available only to specific customer types – such as schools or agricultural pumping – are excluded.

ITC & MACRS for solar and storage projects

The Investment Tax Credit (ITC) and Modified Accelerated Cost Recovery System (MACRS) are national level incentives that can improve battery energy storage project economics.



*We assume energy storage can be added to an existing PV system based on a IRS Private Letter Ruling that allowed owner of a wind turbine to add energy storage to existing facility and claim the tax benefit. We believe that the PV and energy storage would need to be in close proximity and under common ownership (same taxpayer). We believe a replacement battery (e.g. at 10 years) does not qualify for the ITC, but does qualify for 5 year MACRS.

Solar-plus-Storage: Cost Reductions through Optimization and Market Characterization

PROJECT SUMMARY

Through data collection, innovative modeling and analysis this project:

- Develops project cost baselines to refine modeling inputs based on current market data
- Identifies cost-optimal technology combinations of solar and storage for a variety of building types and market conditions
- Explores methods to value the contribution of solar-plus-storage to electric system resiliency
- Characterizes market potential for multiple technology and policy trajectories
- Supports identification of policy and regulatory options to support solar-plus-storage deployment

Final results available autumn 2017.

Project Website: http://www.cleanegroup.org/ceg-projects/solar-storage-optimization/

QUESTIONS ADDRESSED

- *At what technology costs are projects economical?*
- *What policy changes would encourage the formation of new markets?*
- *How can system owners capture multiple value streams?*
- *How can we value energy resiliency in economic calculations?*
- *Where will solar with storage be cost-effective in the near-term? Longer-term?*

Methodology considers different:

- Building Types
- Ownership Models
- End-Use Cases
- Utility Rate Tariffs
- Technology Costs
- Electricity Markets
- Incentives/Policies
- Climate Zones

VALUE STREAMS CONSIDERED

- ✧ Demand charge reduction
- ✧ Energy arbitrage
- ✧ Regulation/Capacity
- ✧ Demand Response
- ✧ Resiliency

Principal Investigator: Joyce McLaren
joyce.mclaren@nrel.gov

Funded by the DOE Solar Energy Technologies Office (SETO) as SuNLaMP Project 30379-1614 (FY16-17)

Appreciation to the organizations that provided information and peer reviews, including:

- Alpha Energy
- CAIRN
- Center for Sustainable Energy
- Clean Energy Group
- Connecticut Green Bank
- CUNY
- Fosterra Clean Energy Consulting
- Geli
- NYSERDA
- Sonnen
- STEM
- Sunverge

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