

# After-Market Applications for Depreciated EV Batteries in the NY Metro Region

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*A Feasibility and Market Research Study*



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## **LIST OF ACRONYMS**

BBU	battery backup unit
BEV	battery electric vehicle
BQDMP	Brooklyn Queens Demand Management Program
DADRP	Day Ahead Demand Response Program
DCAS	Department of Citywide Administrative Services
DEC	NYS Department of Environmental Conservation
DEP	NYC Department of Environmental Protection
DOE	U.S. Department of Energy
DSASP	Demand Side Ancillary Services Program
DSPP	Distributed Service Platform Providers
ECC	Empire Clean Cities
EDRP	Emergency Demand Response Program
EPRI	Electric Power Research Institute
ESS	energy storage system
ESVT	energy storage valuation tool
EV	electric vehicle
EVSE	electric vehicle supply equipment
FDNY	Fire Department of New York
FERC	Federal Energy Regulatory Commission
FY	fiscal year
HEV	hybrid electric vehicle
HOV	high occupancy vehicle
IBEW	International Brotherhood of Electrical Workers
ICAP	installed capacity
ICE	internal combustion engine
IEA	International Energy Agency
KW	kilowatt
kWh	kilowatt-hour
Li ion	lithium ion
MTA	Metropolitan Transportation Authority
MW	megawatt
NiMH	nickel-metal-hydride
NEV	neighborhood electric vehicle
NPV	net present value
NREL	National Renewable Energy Laboratory
NYCEDC	New York City Economic Development Corporation
NYISO	New York Independent System Operator

NYPA	New York Power Authority
NYS	New York State
NYSERDA	New York State Energy and Research Authority
O&M	operation and maintenance
OEM	original equipment manufacturer
OLTPS	Office of Long-Term Planning and Sustainability
PEV	plug-in electric vehicle
PHEV	plug-in hybrid electric vehicle
PUC	Public Utilities Commission
PV	photovoltaic
R&D	research and development
RE	renewable energy
RPS	renewable energy portfolio standards
SCR	special case resources
SLA	sealed lead-acid
TCI	Transportation and Climate Initiative
TOU	time of use
UPS	uninterruptible power supply
USABC	U.S. Advanced Battery Consortium
ZEV	zero emission vehicle

## ***Table of Contents***

<b>LIST OF INFORMANTS .....</b>	<b>1</b>
<b>EXECUTIVE SUMMARY .....</b>	<b>3</b>
<b>INTRODUCTION.....</b>	<b>7</b>
Study Approach.....	7
Study Tasks.....	9
<b>OPTIONS FOR REUSE OF USED EV BATTERIES.....</b>	<b>10</b>
Behind-the-Meter Secondary Market Opportunities .....	12
Demand Response .....	12
Peak Shift .....	12
Front-of-the-Meter Secondary Market Opportunities.....	13
Frequency Regulation .....	13
Transmission and Distribution Deferral .....	15
Ramp Rate Support.....	15
Renewables Integration .....	16
Time of Use Arbitrage.....	17
Repurposing for Behind-the-Meter Use: Pros and Cons.....	17
Re-Purposing for Front-of-the-Meter Use: Pros and Cons .....	17
Conclusions .....	18
<b>SECONDARY USE EV BATTERY STORAGE FINANCIAL MODEL DESCRIPTION.....</b>	<b>19</b>

Introduction and Approach .....	19
Model Description and Assumptions .....	21
General Approach and Precedents .....	21
Chemistry .....	22
Costs and Pricing .....	22
Operation and Valuation .....	24
Results and Conclusion .....	25
Next Steps.....	26
Mature Market and Improved Data .....	26
Alternative Implementation for Secondary Use Batteries .....	26

## **BATTERY REMANUFACTURING FOR SECONDARY MARKETS: CHALLENGES AND REQUIREMENTS..... 28**

Testing & Validation.....	28
Safety & Materials Handling Concerns .....	31
The Warranty Challenge .....	32
Space and Size Constraints.....	32
Climate-Controlled Warehousing.....	33
Market Preferences & Cultural Concerns .....	33
Price of New Batteries vs. Repurposed Batteries .....	34

## **WHY NEW YORK METRO REGION MAKES SENSE FOR BATTERY STORAGE..... 35**

Supply of EV Batteries in the New York Metro Region is Expanding Rapidly .35	35
The Number of EVs on the Road is Increasing.....	35
Fleets: Private and Governmental .....	35
New York State and City Policies that Will Encourage EV Adoption .....	36
New York in the Multi-State Zero Emission Vehicle Program .....	36

New York City is Developing Infrastructure to Further Increase EV Usage .....	37
New Yorkers and EVs.....	38
Opportunities for Reusing NYC Fleet EV Batteries.....	38
NYC Fleet Pipeline and Scale of Opportunity .....	38
NYC Fleet Salvage Policy and Typical Depreciation Patterns .....	39
Alternative Retirement Scenarios .....	39
Emerging Regulatory Reform and Policy Challenges and Opportunities .....	40
REV and New York's Energy Grid.....	40
Other Emerging Energy Challenges in New York State .....	41

## **POTENTIAL PARTNERS ..... 43**

Prospective Aggregators, Re-manufacturers and Distributors .....	43
Renewables Developers .....	43
System Integrators .....	43
Auto Salvage Distributors.....	43
Battery Re-manufacturers .....	44
Case Studies .....	46
Case Study 1: BAE Systems HDS .....	46
Case Study 2: Green Charge Networks .....	47
Case Study 3: BMWi.....	49

## **POTENTIAL PROJECTS ..... 53**

The Demand Management Opportunity .....	53
Dual-Purposing Second Life Packs: UPS & Demand Management for Data Centers .....	53
MTA NYC Transit Hybrid Bus Battery Stationary Deployments .....	54
Other "Closed-Loop" Pilots .....	56
Developing World Deployments .....	56

## **CONCLUSIONS AND POLICY RECOMMENDATIONS.... 58**

## **BIBLIOGRAPHY ..... 61**

## **FIGURES**

Figure 1. Toyota Battery Re-Purposing Pilot .....	29
Figure 2. Profile: DNV GL's Battery XT Platform .....	30
Figure 3. The Private Fleet Opportunity: DHL .....	39
Figure 4. Utility Fleets and Battery Re-Purposing .....	40
Figure 5. Global Battery Solutions Remanufacturing Li-ion Battery Cells .....	44
Figure 6. Global Battery System Has a Process That Quickly Diagnoses Battery Packs, Repairs Them, and Thoroughly Tests Them to Meet Top- Quality Standards .....	45
Figure 7. GBS Remanufacturing Includes Disassembly and Recovery, Replacing Worn Out or Obsolete Cells and Electronics and Upgrading the Module to the More Current Revision .....	45
Figure 8. Sumitomo's Frequency Regulation Modules Use 16 Depreciated Nissan Leaf Batteries and Serve Nearby Hikari-no-Mori Solar Array .....	48
Figure 9. Second Life Batteries Alliance: BMW, Bosch & Vattenfall .....	52
Figure 10. MTA Hybrid Bus .....	55
Figure 11 MTA Hybrid Bus, One of 1,600 in Service in NYC <b>Error! Bookmark not defined.</b>	

## **TABLES**

Table 1. Lower Hudson Valley TOU Rates Availability.....	13
Table 2. Con Edison TOU Rates for New York City as of July 2014.....	13
Table 3. Grid Service Pricing .....	23

Table 4. Residual (Breakeven) Value of Secondary Use Batteries .....26

## **Annex I Literature Review**

## List of Informants

This report would not have been possible without the generous assistance of the following informants who provided valuable insights for the study.

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## **Executive Summary**

The number of electric vehicles in New York State has been steadily increasing, with 40,000 EVs anticipated on state roadways by 2018. An EV battery is considered to have reached its end of life for vehicular use and need to be retired when it has no less than 70% of its original storage capacity, yet this retired pack is still capable of satisfying the energy use of a less-demanding, lower-power application. How New York State and its neighbors choose to grapple with retired battery packs in end-of-life vehicles is looming - both as a significant public policy challenge as well as a meaningful private sector opportunity within the state and beyond.

This feasibility *and market research study* seeks to identify and study after-market applications for depreciated EV traction battery packs from passenger vehicles as well as light and medium-duty EVs used in fleet applications. Establishing the usefulness of these packs in secondary markets is critical to establishing a residual value for what is the single most expensive component in an EV. This study considers several prospective business models for the lifecycle optimization of the lithium ion (or "Li ion") automotive battery, all of which will ultimately hinge on a better understanding of the battery's residual value. The implications of a viable battery lifecycle optimization model are manifold and re-use holds the promise of strengthening the power grid, reducing reliance on fossil fuels for power generation, and hedging risk while potentially lowering upfront costs to the EV operator, possibly through scenarios such as battery leasing.

The secondary market opportunities for EV batteries appear in both behind-the-meter (customer sited) and front-of-the-meter (utility) applications in seven primary clusters: Demand Response, Peak Shift, Frequency Regulation, Transmission and Distribution Deferral, Ramp Rate Support, Renewables Integration, and Time-of-Use Arbitrage.

### **Economic Model**

This consultant team prepared a financial model to calculate the NPV of an emergent use in New York State, the provision of grid services for a utility user, by an average supplier. In the utility-use model the grid services provided by the storage application include demand response, frequency regulation, peak shift, transmission and distribution deferral, renewables integration, time of use arbitrage, and ramp rate support. In this model, retired vehicle batteries are remanufactured into stationary storage systems that provide stacked grid services as a percentage of available power and energy. In the traditional utility-centric energy storage approach, the power

producing utility purchases energy storage systems from technology companies to address required grid services.

The study's financial model leads to the conclusion that under a strict regulatory regime that favors renewables and energy storage, and with advanced battery technology, there is a viable market for secondary use EV batteries. The best situation for capturing residual value of the secondary use batteries exists under an optimistic pricing regime, which becomes financially infeasible under a conservative pricing scheme. Of course, the impact on initial cost of EVs diminishes as the value per kWh decreases. An additional factor to consider in the viability of the secondary use battery market is the market price of new batteries. As manufacturing capacity increases worldwide, and costs to manufacture batteries decreases, the price per kWh of new batteries decreases as well. This puts pressure on the feasibility of using secondary use batteries in novel applications as described in this study. Although this outcome may be advantageous for reducing the direct cost of EVs, it also exacerbates the problem of battery waste as the financially viable secondary uses for batteries diminish.

### **Core Challenges to Secondary Use**

The Study specifically addresses business concerns about battery degradation, early battery obsolescence, and dynamism in the battery market through determination of the appetite for risk among prospective secondary market players. These core challenges may require new investment, protocols, or further study to address. In the near term, concerns about length of warranty may prove decisive in establishing the viability of a meaningful secondary market and future discussions with battery manufacturers on warranty length extension for after-market applications uses could create the conditions for a robust replacement market. Secondary concerns regarded movement, handling, storage, and siting of retired packs. Longer term, the steadily falling price of new Li-ion batteries will in all likelihood prove the strongest challenge to creation of a vibrant secondary market.

### **Potential Partners for Secondary Use Projects**

There exists a huge array of players in the automotive industry and energy services sector that each offer crucial skill sets, market knowledge, relationships, and core capacities necessary to activate a vibrant secondary market for automotive battery packs. These include OEMs, salvage/automotive recycling companies, auto auction companies, electronics recyclers, after-market auto parts distributors, the battery manufacturers

themselves, grid storage companies, utilities, and niche tech start-ups like Green Charge, Stem, Demand Energy, and Innovari.

The study provides an in-depth look at three potential partners through case studies:

1. BAE Systems HDS
2. Green Charge Networks
3. BMWi

Other potential New York State players poised to play leading roles in the second life marketplace include Rochester's DNV-GL, UTS in Smithtown, and Albany's NY-BEST Consortium.

Potential battery 2<sup>nd</sup> use projects identified by the study partners include:

1. Demand Management
2. Dual-Purposing Second Life Packs: UPS and Demand Management for Data Centers
3. MTA NYC Transit Hybrid Bus Battery Stationary Deployments
4. Other "Closed-Loop" Pilots
5. Developing World Deployments

New York State policymakers can play a key role in advancing the study and deployment of second life packs in stationary applications. In the near term, battery testing, validation, remanufacturing, warehousing and logistics all present viable opportunities for job creation and economic growth in the state's burgeoning energy storage sector. Follow-on service work and monitoring of second-life battery health also could generate employment and help specialized energy storage service companies sprout in key markets statewide.

Ultimately, the promise of second life batteries will hinge largely upon the cost curve for new Li ion packs. Beyond the indisputable logic of the cost curve is, of course, the undeniable imperative of sustainability and climate change mitigation. And the second life battery is uniquely positioned to address several key sustainability challenges and climate change drivers at once, simultaneously offering a lower-cost pathway for energy conservation, storage, and the integration of renewables, while blazing a shortcut to the mass market EV by reducing the upfront cost of the battery pack. Whether the second life pack is methodically re-purposed to advance these goals, or is simply borne along to an as yet undefined grey market, is an outcome that can be shaped by the decisions of today's policymakers and industry leaders, who will either treat the retired EV battery as another inevitable cast-off of the era of the mass market automobile, or as a fortuitous by-product of the age of the EV.

## **Policy Recommendations to Strengthen Secondary Market Opportunities in New York State**

1. NYPA should identify applications for depreciated traction battery packs and report on potential demand for these packs, at both NYPA facilities and at NYPA customer locations around NYS.
2. NYSERDA should issue a request for proposals to implement a 24-month traction pack re-purposing pilot, with clear goals and a timetable for deploying retired packs in stationary energy applications.
3. The NY Green Bank should explore creating an extended warranty product to reduce risk for secondary market players and backstop the value of after-market batteries.
4. State agencies with vehicle fleets should draft, promulgate, and implement EV and PHEV battery reclamation protocols to ensure that the value of battery packs in retired fleet vehicles is optimized.
5. NYSDEC should draft advisory guidelines for municipal fleets statewide regarding EV and PHEV battery reclamation protocols to ensure that the value of battery packs in retired fleet vehicles is optimized.
6. Con Edison and NYSERDA should consider Demand Management premiums for participating customers deploying second life energy storage assets.

## Introduction

The number of electric vehicles (EVs)<sup>1</sup> in New York State has been steadily increasing (Jaffe & Adamson, 2014). The state's ChargeNY initiative anticipates 40,000 EVs on state roadways by 2018 (NYSERDA, 2015). How New York State and its neighbors choose to grapple with retired battery packs in end-of-life vehicles is looming - both as a significant public policy challenge as well as a meaningful private sector opportunity within the state and beyond. Nationally, the Mineta National Transit Research Consortium estimates that by 2035 the U.S. will be awash in up to 6.7 million "post-vehicle" batteries, 85% of which they project will be suitable for re-use in non-vehicular applications (Standridge & Corneal, 2014). Further, a 2014 Navigant study projects that second life battery repurposing will grow from a \$16 million business at present to a \$3 billion industry by 2035 (Jaffe & Adamson, Second-Life Batteries: From PEVs to Stationary Applications, 2014).

An EV battery is considered to have reached its end of life for vehicular use when it can no longer provide 80% of the energy (needed for vehicle range) or 80% of the peak power (needed for acceleration) of a new battery (Standridge & Corneal, 2014) (Heymans, Walker, Young, & Fowler, 2014). It is assumed that EV batteries will reach 80% capacity after about 8 years, on average—consistent with the warranty periods for the Volt and LEAF, and with the U.S. Advanced Battery Consortium (USABC) end-of-life criteria for EVs. A recent report by Neubauer, Smith, Wood & Pesaran (2015), however, indicates that there is little-to-no economic benefit to replace an EV battery prior to the end of the vehicle's service life (estimated at 15 years), when the battery is expected to have about 70% of its capacity remaining. A battery that can no longer meet vehicle performance criteria, however, may still be remanufactured for reuse in vehicles, or capable of satisfying the energy and power requirements of a less demanding, lower-power application (Neubauer & Pesaran, 2010). Stationary battery applications often do not have the severe weight and volume constraints of the EV application and this can translate into lower energy and power requirements.

## Study Approach

This feasibility *and market research study* seeks to identify and analyze after-market applications for depreciated EV traction battery packs from passenger vehicles as well as light and medium-duty EVs used in fleet

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<sup>1</sup> For the purposes of this paper, the acronym EV refers both to battery-electric vehicles (usually referred to as BEV) and plug-in electric vehicles (usually referred to as PEV), unless otherwise indicated.

applications. Establishing the usefulness of these packs in secondary markets is critical to establishing a residual value for what is the single most expensive component in an EV. This study considers several prospective business models for the lifecycle optimization of the lithium ion (or “Li ion”)<sup>2</sup> automotive battery, all of which will ultimately hinge on a better understanding of the battery’s residual value. The implications of a viable battery lifecycle optimization model are manifold and re-use holds the promise of strengthening the power grid, reducing reliance on fossil fuels for power generation, and hedging risk while potentially lowering upfront costs to the EV operator, possibly through scenarios such as battery leasing.

The Study addresses two focus areas as suggested by NYSERDA when it commissioned this project. These include Focus Area 1, EV and Electric Grid Interaction, and Focus Area 2, Regulation Financing and Financial Incentives, through the exploration of several scenarios for after-market deployments of depreciated packs in stationary applications in New York State. The objective is to determine how depreciated traction packs —especially those used in medium-duty electric trucks and light-duty vehicles used in fleet applications—can be best and most cost-effectively monetized in the secondary market.

Currently, the EV marketplace assesses a significant “green premium” for the purchase of a technology that is burdened by an uncertain residual value throughout its useful life. Determining viable secondary market uses and thereby helping to fix a residual value on the battery pack could enable automakers and their partners in the energy storage sector to find ways to reduce up-front battery costs to consumers, such as through a financing product for batteries that can significantly reduce upfront costs for an EV through a 36 – 48-month equipment lease. Such a financial product could strengthen the business case for plug-in EVs in both the fleet market and, significantly, the economy class passenger market for EVs, which has yet to take shape.

The secondary battery market is beginning to emerge. Companies such as BYD, which manufacture batteries for multiple electronic uses beyond EVs, are already investigating secondary market uses in China and other markets around the globe (Li, 2014). Similarly, Nissan is redeploying retired Leaf battery packs for behind-the-meter applications around the U.S. through a partnership with Sumitomo and Green Charge Networks (Shepard, 2015). Performing an analysis that is specific to the NY Region—using real-world

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<sup>2</sup> This study focuses on Lithium Ion and Advanced Lithium Ion batteries as they are the chemistry most commonly found in batteries for EVs and hybrid vehicles.

electricity costs, prospective partnerships and pipelines as well as potential revenue sources—and featuring battery depreciation data already gathered from EVs deployed in metropolitan markets will provide concrete intelligence to gauge the economic feasibility of after-market uses for this very costly EV component.

The Study specifically addresses business concerns about battery degradation, early battery obsolescence, and dynamism in the battery market through determination of the appetite for risk among prospective secondary market players. In the near term, concerns about length of warranty may prove decisive in establishing the viability of a meaningful secondary market and future discussions with battery manufacturers on warranty length extension for after-market applications uses could create the conditions for a robust replacement market. Longer term, the steadily falling price of new Li-ion batteries will in all likelihood prove the strongest challenge to creation of a vibrant secondary market.

## **Study Tasks**

Over the past two years, the study team performed the following work to achieve its results:

1. Developed an advisory committee and held regular meetings;
2. Developed a list of target fleets deploying EVs in the New York region;
3. Developed a list of potential second use battery aggregators, facilitators and end users;
4. Conducted interviews with the targeted primary EV battery users and potential secondary use aggregators, facilitators and end users;
5. Completed Literature Review (see Annex I);
6. Developed a secondary use EV battery storage financial model for utility applications.

## Options for Reuse of Used EV Batteries

The secondary market opportunities for EV batteries appear in both behind-the-meter (customer sited) and front-of-the-meter (utility) applications in seven primary clusters: **Demand Response, Peak Shift, Frequency Regulation, Transmission and Distribution Deferral, Ramp Rate Support, Renewables Integration, and Time-of-Use Arbitrage.**

A fragmented and still fledgling domestic market for battery storage applications necessitates a nimble, multi-variate approach to re-manufacturing and re-purposing of retired automotive battery packs in stationary, secondary market applications. While the New York Independent System Operator (NYISO) is technology-neutral on energy storage technologies, price-competitive Li ion batteries present an increasingly compelling challenge to compressed air, flywheel, pumped hydro, and other traditional forms of energy storage (Davidson, 2015). Several start-ups in the demand management space are already piloting or considering the use of retired Li ion automotive packs for energy storage (Bhade, 2015).

The U.S. energy storage market in all its forms is expanding significantly. In 2014, it grew 40%, installing 61.9 MW of new energy storage, and GTM Research forecasts 220 MW of new energy storage installations by the end of 2015. By 2019, the U.S. will be an 861 MW annual market, valued at \$1.5 billion. While energy storage deployments are growing at an extremely brisk clip, 90% of these new installations have been front-of-the-meter, while only 10% have been behind-the-meter (at residential, commercial, educational, military, and non-profit host locations). But this imbalance may be short-lived —GTM projects that behind-the-meter storage will represent 45 percent of the overall market by 2019 (GTM Research, 2015).

In view of the fast growing and dynamic nature of the emerging energy storage market, the potential re-use of automotive battery packs raises two fundamental questions for policymakers and prospective secondary market players to consider:

- 1) **Which end-uses can be most readily commercialized?**

Bill Acker, Executive Director, NY BEST Consortium—a public-private partnership that provides support, research, and development activities for the NYS energy storage sector—cites the variability of retired packs as a principal driver in determining optimal deployment scenarios. Thus, all packs will not be optimal for all uses. “One consideration is the residual life in used

packs. In more energy dependent applications, the life will be shorter than in the storage or frequency regulation applications.” For more energy intensive applications, the “batteries (will) degrade faster than expected and faster over time. How much life is actually left in the packs? 80% energy isn’t always 80% life—the degradation path gets steeper over time. You want applications that are gentle on the batteries” (Acker, 2015).

Harjinder Bhade, CTO, Green Charge Networks—a demand management technology and “intelligent” energy storage company—argues that in the future both utility and behind-the-meter applications will be important markets for second-life packs. The firm, which has partnered with Nissan to repurpose retired Leaf batteries for demand management applications, projects that it will be able to absorb much of the volume of second-life packs that has begun to enter the market. “The projected volume of Nissan Leaf packs will meet short-term and medium-term needs of Green Charge” (Bhade, 2015).

Importantly, the scale of the opportunity for bulk storage or in-front-of-the-meter applications is largely contingent upon larger policy issues around frequency regulation requirements, mass adoption of renewables, and retirement of aging coal-fired and nuclear power plants. In New York, for instance, as one part of a contingency plan for the potential closure of the Indian Point nuclear power plant, Con Edison filed a proposal to provide 100 MW of load shedding measures including demand response, energy efficiency and energy storage. These unresolved longer-term policy issues render the prospects for large-scale short-term utility use challenging. Over time, both the policy drivers and the players in the market may change and adapt to altered circumstances.

**2) Which industry players are best equipped, capitalized, willing and able to assume risk, and most likely to emerge as leaders in the secondary market for traction packs?**

The array of potential secondary market players includes OEMs, battery manufacturers, utilities, auto salvage/automotive recycling companies, auto auction firms, after-market auto parts distributors, grid storage companies, electronics recyclers, and niche tech start-ups such as Green Charge Networks, Stem, and Innovari. Each offers its own core competencies, market knowledge, and relationships but none is uniquely positioned and qualified to alone leverage the secondary opportunity and manage its inherent challenges. This topic will be addressed in greater detail in subsequent sections of this report.

## Behind-the-Meter Secondary Market Opportunities

### Demand Response

Demand Response or load management programs offer businesses with facilities incentives to shed load during anticipated periods of peak use. Battery storage is one method an entity can use to reduce its reliance on the grid and benefit from new incentives. The NYISO has four Demand Response programs: the Emergency Demand Response Program (EDRP), the ICAP Special Case Resources (SCR) program, the Day Ahead Demand Response Program (DADRP) and the Demand Side Ancillary Services Program (DSASP) (Davidson, 2015).

In New York, Con Edison has teamed with NYSERDA to offer the [Demand Management Program](#), a joint effort to provide demand reduction incentives to customers for a variety of applications, including battery storage. The new incentive for battery storage applications after July 1, 2015, is \$2,100 per KW of energy saved during demand periods (the summer period is between the hours of 2pm-6pm, Monday through Friday, from June 1 through September 30, excluding legal holidays).

Innovari, a tech start-up in the demand management space, initially considered the deployment of retired automotive packs for its systems, as long as they were able to consistently perform in a stationary application. While Innovari is generally battery-agnostic, their preferred chemistry is lithium cobalt and energy density is crucial, due to space constraints in some urban centers. “What we need is a battery that can provide 1 full charge and 1 full discharge every day for ten years—over 4,000 full cycles,” reports Innovari’s Clark Korbisch (Korbisch, 2015).

The return to the ratepayer can be significant, especially in markets with high demand charges. According to Green Charge Network’s Bhade, “in many parts of California, 30-50% of a bill is in demand charges and this cost can be reduced by technology. This application creates value; San Diego has the highest demand-charges in the state, for instance” (Bhade, 2015).

### Peak Shift

Peak shift relates to shifting energy consumption from periods of peak demand (and thus when power is most expensive) to periods when demand bottoms out (“off-peak”) and power is least expensive. Energy storage in the form of battery systems can provide power directly to an end-user, reducing reliance on grid power during peaks. This allows users to avoid peak demand or Time of Use (TOU) charges by shifting energy use to off-peak hours. It can

also serve as an uninterruptible power supply (UPS) in the event of scheduled or unscheduled outages.

Voluntary TOU are available both in New York City and the Lower Hudson Valley. As illustrated below, in New York City the summer peak rate is 1,425% higher than the off- peak rate, which could lead to significant savings in the electricity bill.

**Table 1. Lower Hudson Valley TOU Rates Availability**

County	Service Provider	Voluntary TOU
Sullivan	NYSEG	✓
Ulster	Central Hudson	✓
Dutchess	NYSEG/Central Hudson	✓
Putnam	Central Hudson	✓
Westchester	ConEdison	✓
Orange	O&R (ConEdison)	✓
Rockland	O&R (ConEdison)	✓

**Table 2. Con Edison TOU Rates for New York City as of July 2014**

	PEAK 8am - Midnight	OFF-PEAK Midnight - 8am	SUPER PEAK 2pm-6pm
June 1 - Sept 30	19.01 cents/kWh	1.34 cents/kWh	19.01 cents/kWh
All other months	7.04 cents/kWh	1.34 cents/kWh	N/A

Source: Con Edison

## Front-of-the-Meter Secondary Market Opportunities

### Frequency Regulation

Frequency regulation is an ancillary service that involves managing and matching interchange flows between control areas in order to maintain balance in the grid during variations in power supply and demand. This balances momentary power supply and demand differences caused by

fluctuations in generation and loads. Generating units that are online and ready to increase or decrease power as needed are used for regulation and their output is increased when there is a momentary shortfall of generation to provide “up regulation.” Conversely, regulation resources’ output is reduced to provide “down regulation” when momentary excess power generation occurs. An important consideration in this case is that large thermal base-load generation units in regulation incur a degree of wear and tear when they provide variable power needed for regulation duty. Some of the main drivers for frequency regulation are mandatory reliability standards set by the Federal Energy Regulatory Commission (FERC) (U.S. Department of Energy, 2013).

New York has pioneered initiatives to couple battery storage with ancillary services such as frequency regulation. The Cuomo Administration continues to support R&D efforts in the state with a \$23 million public-private investment in an upstate battery storage test and commercialization center announced in 2013 (New York State Office of the Governor, 2014).

Although primarily limited to large-scale systems, NYISO already allows energy storage assets to participate in day-ahead and real-time wholesale markets and was the first electricity market in the U.S. to implement rules allowing storage assets to participate in frequency regulation services. Further, NYISO followed PJM to become the second grid operator to implement FERC Order 755, which requires grid operators under its jurisdiction to increase the pay for “fast” responding frequency regulation sources, including battery storage (Davidson, 2015).

According to NYISO’s Gary Davidson, in NY’s grid services space, “...the primary market for batteries is frequency regulation” (Davidson, 2015). The frequency regulation market in New York State is, however, still in its infancy regarding storage investment, but reliability concerns following Hurricane Sandy and increasing power prices will probably drive the market in coming years. It is not only large facilities that are investigating storage; for example, neighborhood 7-Eleven stores in the New York area are investing in storage and seeing sizeable reductions in peak charges (Tweed, 3 States Driving Energy Storage for Utilities and Customers, 2014).

In other states grid operators have deployed EVs for frequency regulation. For example, ERCOTT in Texas launched a pilot program involving a fleet of a dozen EV trucks to provide sub 1-second regulation services to a 36 MW storage battery at a Duke and Extreme Power facility (Tweed, Electric Trucks Provide Frequency Regulation for ERCOT, 2014).

Many after-market packs may be well-equipped for frequency regulation, as Davion Hill and Benjamin Gully of DNV GL note, since “for this use, a battery pack largely resides at between 40-60% state of charge,” a profile that would not significantly shorten the operational life of the secondary market pack (Hill & Gully, 2015).

While pricing for regulation services is set according to system needs and conditions and may move daily, Davidson reports that “regulation services pricing has collapsed,” and there is a “thin market for regulation services in NYS at this time—300 MW in New York State is the total market.” Even the NYISO wind integration study—which identified a potential of 8,000 MW of new wind generation—only indicated an “incremental need for new regulation services” (Davidson, 2015). Noel Crisostomo, a Public Utilities Regulatory Analyst with California’s Public Utilities Commission (CPUC) cited similar concerns. “Definitely an important element to consider,” Crisostomo states, “since the market for grid services is unknown” (Crisostomo, 2015).

Lastly, Davidson cited price volatility in the energy sector as a potential driver of the demand for battery storage assets for ancillary services. “If the price of natural gas goes up, then there will likely be more interest in frequency regulation and storage” (Davidson, 2015).

### **Transmission and Distribution Deferral**

Transmission and Distribution deferral involves delaying, reducing the size of, or entirely avoiding utility investments in transmission or distribution system upgrades necessary to meet projected load growth on specific regions of the grid. A recent study by the Rocky Mountain Institute analyzed a distribution upgrade deferral in New York. The study suggests that Con Edison’s Brooklyn Queens Demand Management Program (BQDMP), which aimed to defer two substation upgrades in Brooklyn and Queens, could save the utility and ratepayers an estimated \$1 billion through the deployment of grid-scale batteries or other technologies to defer the cost of a substation (Fitzgerald, Mandel, Morris, & Touati, 2015).

According to NYISO’s Davidson the BQDMP, which will integrate as much as 11 MW of energy storage, is an example of “investing \$200 million in storage to avoid investing \$1 billion in sub-stations or generation.” Orange and Rockland, another metro area utility affiliated with Con Edison, is also utilizing storage assets to reduce need for new sub-stations (Davidson, 2015).

### **Ramp Rate Support**

The ramp rate is essentially the speed at which a generator can increase (ramp up) or decrease (ramp down) generation. Generating units have

different characteristics; making some more suited to supplying certain needed functions. Electricity storage can alleviate some of the cycling of power plants. Energy storage technologies can perform better than existing systems and potentially achieve efficiencies of 70 to 95 percent while operating at partial capacity with lower efficiency penalties, while still maintaining near-instantaneous response times.

### **Renewables Integration**

Over 30 states have adopted renewable energy portfolio standards (RPS) focused on the reliable integration of zero-emission resources such as solar and wind power. By planning carefully and giving diverse types of power providers equal access to the grid and its marketplace, these states and their ISOs, utilities and public/private associations can advance a sustainable energy future. Battery storage can play an important part of this development.

In a case study of New York, the American Physical Society recognized the enormous potential of the state's capacity for integrating renewable energy:

*"Like the nation, New York has ample renewable resources to meet its renewable portfolio standards. The challenge is not capacity, but implementation: developing technology to harvest the plentiful renewable resources, operating procedures to integrate them on the grid, and regulatory structures to ensure that the grid is reliable and that value and cost are shared appropriately among stakeholders. The remote location of renewable energy resources and their high variability requires a new level of wide-area coordination across traditional physical, ownership, and regulatory boundaries. Developing the necessary technological, operating and regulatory structures to address these integration challenges is the major energy task for New York and the nation in the coming decades"* (American Physical Society Panel on Public Affairs, 2010).

According to Davidson, a NYISO solar study is currently being conducted internally. This will help determine the scale of the state's regulation and integration needs and may offer the impetus to further explore deployment of retired traction packs. New wind sources may also present opportunities for traction pack deployment in stationary applications. "If you get to 8,000 MW of wind, NYS will need additional frequency regulation services to integrate power from renewables, but it will be an incremental increase" (Davidson, 2015).

### **Time of Use Arbitrage**

Time of use arbitrage or electric energy time-shift is the purchase of inexpensive electric energy, available during periods when prices or system marginal costs are low, to charge a storage system for future re-sale of the stored energy when the prices are higher. Arbitrage service is not practiced by entities that generate power, but instead by a third party that purchases and stores electricity and subsequently takes advantage of the price differential. Batteries can be deployed for arbitrage by charging them during off-peak time periods and then selling the stored energy for use during peak demand time periods.

An example of a peak energy consumer that seeks to bank off-peak power and has considered re-purposed traction batteries is IdleAir, a national technology company that provides travel center electrification services for over-the-road trucks. In certain West Coast markets where time-of-use price differentials are significant, IdleAir is especially motivated to identify and deploy affordable energy storage opportunities to make daytime power provision more affordable. "IdleAir has a very strong interest in stationary and semi-stationary applications for used Li ion batteries," Idleair CEO Ethan Garber reports. "We had been discussing a mix of approximately 50 kWh batteries (current capacity) combined in some cases with cold plates for nighttime charging plus daytime solar (to enable) mid-day power shutdown" (Garber, 2015).

### **Repurposing for Behind-the-Meter Use: Pros and Cons**

#### *Behind-the-meter Pros:*

- Immediate small-scale demand;
- A number of nimble players able to market and deploy battery technology;
- Utility incentives for peak shaving, demand management, and time of use;
- Potential partnerships with residential and commercial solar developers.

#### *Behind-the-meter Cons:*

- Tesla Powerwall and variants positioned to enter this market with new packs that further bend the cost curve for new packs;
- Atomized market--customer acquisition is costly and difficult;
- Many current players with demand management solutions are under-capitalized and dependent upon pilot subsidy programs.

### **Re-Purposing for Front-of-the-Meter Use: Pros and Cons**

#### *Front-of-the-meter Pros:*

- Mature industry with clear deployment applications in frequency regulation;
- Economies of scale for aggregation/logistics, testing, re-purposing, and re-deployment;
- Strong and growing demand for Li ion storage in utility sector;
- Potential overseas market.

*Cons:*

- Long time horizon to meet potential demand;
- Scale of demand largely dependent on changes in the policy environment (i.e. closing of Indian Point, etc.);
- Variations in chemistries & battery management systems may complicate large-scale aggregation and unitary solutions;
- New battery pack price curve will diminish appeal of refurbished packs.

## Conclusions

Noel Crisostomo of CALPUC presented the case for the cost-effectiveness of utility-scale deployments that would enable local utilities “to defer distribution upgrades, so substation construction would be deferred with storage.” But, Crisostomo noted, “the market for grid services is unknown. The key part of our (California’s) carbon reduction goal is transportation—constitutes 40% of the carbon load in California” (Crisostomo, 2015).

While opinions vary widely on optimal secondary market applications, there is little doubt that California offers a near-term opportunity to pilot after-market batteries in storage applications—and Green Charge Networks, in collaboration with Nissan, is already deploying retired Leaf packs at a California Nissan facility to offset demand charges.

“California is probably the best market in US for energy storage. The state is seeking 50% RPS in the next several years,” reports Next Energy’s Kelly Jezierski. “And investor-owned utilities are seeking to incorporate battery storage into the grid” (Jezierski, 2015).

The optimal application of after-market packs may ultimately hinge not only on the energy demands of the use and incentives embedded in the local energy market, but also on other key variables, such as the cost and availability of space and the mission-critical imperatives inherent in the type of use. As Bill Acker, Executive Director of the NY BEST Consortium noted, “The question is how a (secondary-market) battery dies. If you’re going to put a battery out in the field until it dies, how does it die? How far do you let

it go? For a battery system in a building in Manhattan, the answer may be different than for the pack left out in a parking lot" (Acker, 2015).

## **Secondary Use EV Battery Storage Financial Model Description**

### **Introduction and Approach**

Many studies have attempted to calculate the residual value of secondary use battery packs. Because battery packs in EVs and hybrids reach 'end of life' with 70-80% of their initial capacity and power remaining, the batteries may be applied to other uses and continue to generate significant value for decades. Capturing this value would have the effect of reducing the cost of such vehicles, potentially increasing their demand, as well as providing the energy generation market with a more cost effective and "green" source for direct use or storage.

Residual value is dependent on a variety of factors, some of which include ultimate end-use application, market price for new battery storage, electricity cost, and demand for battery storage. The value of secondary use batteries can also vary widely by geographic region, level of economic development, and maturity of the energy markets. Envisioning a large-scale deployment of battery repurposing requires a model where demand for battery storage is significant and stable. With this in consideration, the approach taken most frequently views the battery packs as cash flow generating assets whose value derives from the ability to provide a service to an end user. This approach is the most consistent and replicable method of determining a value per kWh of battery storage. Battery storage generates cash flow by providing savings, services, or arbitrage to an end user, most frequently electric utilities, but also increasingly private individuals, businesses, and government entities. By modeling the financial life cycle of a battery storage system, from repurposing and remanufacture, to operation, through end of life, the net present value (NPV) of the system's operations can be calculated and the value of the asset identified.

In this study, we attempt to value secondary use EV batteries using a straightforward model with large-scale application potential and readily available data. The valuation of real assets is traditionally performed using one of three methods. The first method uses a cost-based approach, where the total value of the asset is equal to the cost to deliver the asset to the owner. The costs included in a cost-approach valuation can include materials

cost, manufacturing cost, transportation cost, and/or harvesting cost. The second method is the comparable sales approach, where the asset's value is determined by identifying comparable assets purchased recently and averaging and adjusting to arrive at an appropriate value. The third, and often most reliable approach is the income approach, where the free cash flows generated by the asset over its lifetime are discounted to the present and summed to generate an accurate estimation of value. In the literature, the income approach is used most frequently to make estimations of value of secondary use EV batteries. The income generated by the batteries can be from many different sources, be it utility-scale storage, or more downstream consumer uses. Based on the examples of researchers from the Transportation Sustainability Research Center at the University of Berkeley, and the Pacific Northwest National Laboratory, we chose utility-scale storage/grid services as the paradigm for our valuation exercise. "Second Use of Transportation Batteries" by Vilayanur V. Viswanathan and Michael Kintner-Meyer (2011), and "Strategy for Overcoming Cost Hurdles of Plug-In-Hybrid Battery in California" by Brett D. Williams and Timothy E. Lipman (2010) outline a NPV approach to valuing secondary use EV batteries. In this hypothetical repurposing model, the secondary use batteries provide ancillary grid services to a utility in California. These grid services range from frequency regulation to time-of-use arbitrage and have varying levels of value to the utility. Through the operation of the energy storage system, the utility creates value beyond the costs to remanufacture, operate, and maintain the system, leading to a net positive value for each kWh of battery storage. By applying an appropriate discount rate, the researchers calculate the value per kW of the secondary use batteries, which accounts for all life-cycle costs and benefits of providing energy or grid services.

This team used a similar methodology to assess the residual value of used EV batteries. The consultant team prepared a financial model to calculate the NPV of an emergent use in New York State, the provision of grid services for a utility user, by an average supplier. In the utility-use model the grid services provided by the storage application include demand response, frequency regulation, peak shift, transmission and distribution deferral, renewables integration, time of use arbitrage, and ramp rate support. In this model, retired vehicle batteries are remanufactured into stationary storage systems that provide stacked grid services as a percentage of available power and energy. In the traditional utility-centric energy storage approach, the power producing utility purchases energy storage systems from technology companies to address required grid services. Energy storage often provides a lower-cost alternative to constructing new generating capacity, while also providing demand and frequency regulation services.

Operators such as AES Energy Storage have deployed energy storage systems worldwide in this, albeit through target pilot partnerships with utilities.

New York State utilities and grid operators have begun to adopt energy storage in many forms as a way to better maintain grid stability and reduce capital expenditure related to meeting peak demand in a landscape of power station decommissioning and increased concentration of energy demand.

Battery energy storage is one of the many energy storage options available to utilities, but due to the advances in battery manufacture and associated reduction in costs, battery storage is expected to grow significantly worldwide in the coming years. Additionally, the emergence of hybrid and all EVs will create enormous supply of batteries at the end of their useful automotive life over the next decade, creating a feedstock for energy storage applications going forward.

Attempting to calculate the residual value of these batteries is challenging in a brand new market, as many assumptions and simplifications must be made. The methodology used in this valuation is described in greater detail below.

## **Model Description and Assumptions**

### **General Approach and Precedents**

The model used in this study utilizes an approach based on the Electric Power Research Institute's (EPRI) Energy Storage Valuation Tool (ESVT) adapted to accommodate valuation of secondary use battery packs from EVs (2013).

EPRI is a U.S. based non-profit that conducts research on implementation of electric generation and delivery. EPRI developed a comprehensive ESVT to calculate the value of a variety of battery chemistries and configurations.

The ESVT uses a pro forma financial analysis with a discounted cash flow approach to calculate the NPV of a battery storage installation. Starting from a single battery pack with given operational characteristics including energy capacity, power, and degree of discharge, the model supposes the construction of a large storage system designed for utility use, in our case 4 MW. Then, using a pro forma cash flow analysis, the system is modeled through a twenty-year life cycle of operation providing grid services to a utility. During this operational life, revenues from grid services and costs from charging, maintenance, operation, and replacement are tracked resulting in an operating profit or loss each year. By discounting these cash flows, summing, and subtracting the initial capital expenditure, we end up with the NPV of the system. After dividing by the total installed capacity in kWh, you arrive at a value per kilowatt-hour of the installed system.

Underlying the operational model are many variables that describe the battery's chemistry and performance, remanufacture of the EV batteries, the operation of the storage system, electricity pricing, grid service pricing, and subsidy programs. These inputs are described below.

### Chemistry

The chemistries most relevant to this study are the Li ion and Advanced Li ion batteries; those most commonly found in batteries for EVs and hybrids. For each of these chemistries, EPRI has pre-populated operational data. To adapt the ESVT for valuation of secondary market batteries in New York State, the operational and cost data must be altered to reflect local power and energy market conditions, and capacity of the batteries and the cost to remanufacture traction packs into larger assemblies. Battery packs are assumed to have 80% of original capacity after four years of vehicular use. This value, coupled with the appropriate operational depth of discharge (DoD) gives the available kWh and KW for storage applications.

### Costs and Pricing

Although EV batteries come in a variety of sizes, for this study, we use the 16.5 kWh Chevrolet Volt battery pack as a reference because of the data available for both manufacturing cost and repurposing cost in a study performed by the Mineta National Transportation Research Consortium, "Remanufacturing, Repurposing, and Recycling of Post-Vehicle-Application Lithium-Ion Batteries" (Standridge & Corneal, 2014). In the study, they estimate the remanufacturing cost of a 16.5 kWh Volt Li ion battery to be \$4,500 in 2015, including labor, replacement materials, overhead, R&D costs, transportation, materials handling and receiving, and initial plant recovery costs. This equates to approximately \$275/kWh for remanufacture. This estimate is somewhat high compared to other studies, but was deemed appropriate given the lack of existing infrastructure in the northeast for battery remanufacture and repurposing.

Based on the batteries' chemistry and then assembly of the battery packs into a storage system, different grid services will be provided. Utility companies price these grid services on a per kWh (energy provided) or per KW (power provided) basis. The pro forma model allocates the available kWh and KW to these different services and applies the relevant price to calculate the overall revenue generated by the system in a given year. In New York State, the market for grid services is immature, and therefore the only grid services modeled for this system are demand charge reduction and peak shift. Battery storage can eliminate the marginal cost of adding generating capacity to the grid to meet demand during peak use, and as a result, utilities are willing to pay per KW of power capacity added to the grid.

Alternatively, utilities are interested in smoothing demand for energy over time, and assign value to being able to store energy during times of low-cost generation to then supply during times of high-cost generation. This peak shifting can create significant cost savings for both utility and end user. To account for the different potential grid service pricing regimes, the model includes conservative, base case, and optimistic scenarios. Pricing for the two selected grid services can be seen below.

**Table 3. Grid Service Pricing**

	Demand Charge	Peak Shift
<b>Optimistic</b>	\$150 /kW	\$0.20 /kWh
<b>Base Case</b>	\$100 /kW	\$0.15 /kWh
<b>Conservative</b>	\$50 /kWh	\$0.10 /kWh

EPRI's model uses a 20-year product life to analyze battery value. All products are assumed to undergo 365 charge-discharge cycles per year. The model assumes that each year the battery experiences degradation of long-term energy storage and power capacity. Once the battery system reaches 70% of original storage capacity, it is assumed to have reached the end of its useful life, and the product then undergoes replacement and major maintenance to extend operational life at a cost of 80% of the original capital expenditure of the system.

In addition to grid service revenue, the local utility in southern New York State, Con Edison, provides a capital cost subsidy to businesses or individuals who install grid-connected battery energy storage. As discussed in Section 2 of this report, this Demand Management Program provides a subsidy of \$2,100 per KW for systems greater in size than 50 KW. For systems larger than 500 KW, a 10% bonus subsidy is provided and for systems larger than 1 MW, a 15% bonus is provided. Incentives from this program, though, are capped at 50% of the installed cost of the system. Although this program only is available for systems put in to service before June 1, 2016, we include this subsidy in the model to represent the current value of secondary use batteries. Additionally, we expect Con Edison to extend the program, as the avoided cost of adding generating capacity is lower than the cost to fund the Demand Management Program.

## **Operation and Valuation**

At this level of analysis, taxes and interest are not modeled in detail in the pro forma tool. Operational profit, defined as the power and energy revenue less operational expenses, is used to calculate the NPV. Revenue includes proceeds from grid services and operating expenditures includes charging cost, periodic maintenance, fixed and variable O&M costs, property tax, and insurance. Property tax is calculated as 1% of the product purchase price at installation, although in New York State, the applicable tax rate would be applied to a portion of the assessed value of the battery installation (in New York City utilities are taxed under Tax Class 3 or 11.125% [2014-15 rate] times the assessed value).

Currently, both charging costs and grid service prices are based on EPRI's original inputs, representing an average hypothetical utility operator. To adapt the model to a New York State analysis, data from both battery storage operators and utilities will be needed. Because utility-scale battery storage has not been adopted in the Northeast beyond a few pilot projects and test cases, data specific to the region is difficult to secure and can be assumed to be unrepresentative of an eventual mature energy storage market. The primary research conducted for the study through interviews has highlighted several organizations, agencies, and private companies who are currently working on implementing energy storage in the Northeast (specifically New York State), and as the market matures, would be able to provide more accurate data related to the operation of energy storage.

The current model calculates the value of a specific utility-facing implementation of batteries for storage. Calculating the value of a user-facing installation rather than a utility-facing installation would require a different set of data and will be subject to greater variability based on the selected user. For example, a system designed to help Duane Reade reduce demand charges and shave peak demand would have a different set of revenue streams and cost than the utility-scale installation modeled here. The value of a battery pack will change dramatically based on intended application.

The results show the NPV per kWh for six different model scenarios. The values represent the highest amount a utility would be willing to pay per kilowatt-hour for secondary use batteries given the cost of operating, remanufacturing, and factoring in a 10% discount rate. Essentially, this represents the breakeven value for utility users for this type of storage application. In each case a 4W system provides demand charge and peak shift grid services over a 20-year life cycle. The variables that were altered to provide a sensitivity analysis were battery chemistry and pricing regime.

Pricing is highly dependent on the level of regulation that exists in a given market. *Strong regulation* in favor of renewables and energy storage in California leads to high effective prices for grid storage, so California's market would resemble the Optimistic case. *Low regulation* leads to lower demand for grid services, represented more by the Conservative pricing case. Advanced Li ion batteries provide greater degree of discharge, and therefore more capacity for providing grid services. New York State is closely following California's lead in introducing progressive regulation that favors renewables integration, distributed generation, and smart grid technology. As New York's utilities and energy users react to these new regulations, such as RPS, pricing for grid services will rise and increase the feasibility of grid-connected energy storage.

### **Results and Conclusion**

These results lead to the conclusion that under a strict regulatory regime with advanced battery technology, there is a viable market for secondary use EV batteries. Based on the results, secondary use of EV batteries is not financially feasible under a conservative pricing scheme for either the Li-ion or Advanced Li-ion chemistries. In addition, the best situation for capturing residual value of the secondary use batteries exists under an optimistic pricing regime. Of course, the impact on initial cost of EVs diminishes as the value per kWh decreases. An additional factor to consider in the viability of the secondary use battery market is the market price of new batteries. As manufacturing capacity increases worldwide, and costs to manufacture batteries decreases, the price per kWh of new batteries decreases as well. This puts pressure on the feasibility of using secondary use batteries in novel applications as described in this study. Although this outcome may be advantageous for reducing the direct cost of EVs, it also exacerbates the problem of battery waste as the financially viable secondary uses for batteries diminish.

It is important to note that the Conservative pricing case produces negative values for both the Li ion and Advanced Li ion chemistries. Negative residual values indicate that given the inputs, using the secondary use batteries in a utility-facing storage application has negative value and would not be undertaken. Rather than viewing the negative values as indicative as the level of additional investment needed to reach breakeven, because of the structure of the model they should indicate a general magnitude of infeasibility. Simply put, repurposing EV batteries does not make sense under the described conditions (conservative pricing).

**Table 4. Residual (Breakeven) Value of Secondary Use Batteries**

	Li-Ion	Advanced Li-Ion
Optimistic	\$217.13 /kWh	\$314.75 /kWh
Base Case	\$54.04 /kWh	\$75.62 /kWh
Conservative	(\$109.05/kWh)	(\$165.31)/kWh)

## Next Steps

This study laid the groundwork for evaluating the secondary use EV battery market in New York State by suggesting a valuation approach. The results show that given the assumption of a utility user, and associated capital and operational costs, these batteries can produce value over their life cycle, which may help reduce the upfront cost of EVs as well as provide a more cost efficient and environmentally desirable source of energy generation. Despite the outcome of this study, though, much more has to happen for this market to become fully understood.

## Mature Market and Improved Data

The immaturity of the market for energy storage poses a serious problem both for the future adoption of secondary use batteries in storage application, and attempts to value these batteries from a financial perspective. Battery storage is growing rapidly in scope and reach in the energy industry, although at this point, reliable local (New York State) operational, cost, and pricing data are hard to obtain. In this model, general inputs are based primarily on the California market, where regulation has led to energy storage being adopted more quickly than the rest of the country. Still, energy generation is a highly regional industry, and dependent on factors such as fuel mix, vintage of generating sites, state regulation, and quality of the grid. This means that using general assumptions for model inputs can provide a good estimate of how a system might function generally, but cannot provide insight on how it may perform locally. As utilities and grid operators adopt grid energy storage more broadly in the Northeast, data related to costs, demand, pricing, and functionality would help to improve the results of this model.

## Alternative Implementation for Secondary Use Batteries

This financial model only looked at utility-scale uses in calculating the residual value of EV batteries. As discussed in other sections of this report, there are in fact many other potential implementations where these batteries

could be put to valuable use. The aforementioned behind-the-meter application is one case, where smaller-scale installations of battery systems could reduce and moderate residential and commercial energy demand, resulting in positive benefits for both the energy customer and utility. Green Charge Networks, a firm interviewed in this study, recently announced a partnership with Nissan to purchase and repurpose EV batteries in behind-the-meter applications after the batteries' useful automotive life (Hanbury-Brown, 2015). Calculating the value of these batteries requires more targeted business model information, and is difficult to perform successfully on a general, larger-scale basis. Green Charge Network's business model requires careful analysis of the client's energy use, the battery system anticipated increases or decreases in energy use, and charge/deploy the energy storage to optimize. This necessarily makes revenue and cost forecasting very user-specific, and not straightforward for a generalized analysis.

Another alternative implementation for secondary use batteries exists overseas. Most developing nations struggle with unreliable electrical grids and energy systems, with many people having access to electricity for only a few hours a day, if at all. Energy storage offers an opportunity to increase reliability of access to electricity, especially through integration with sources of renewable energy such as wind and solar. Although the value capture potential in deploying batteries abroad is fairly low given the inability of most energy-stressed individuals to pay high prices, the potential impact on quality of life and wellbeing is enormous. As newly manufactured batteries drop in cost, reducing the residual value of secondary use batteries, one potential productive use for older batteries would be to increase access to clean and reliable energy overseas. Though not directly supporting used battery energy generation potential in the New York State market, overseas opportunities for used batteries may help support a more robust market for EVs in general, and/or an opportunity for a local aggregator of the battery packs.

## Battery Remanufacturing for Secondary Markets: Challenges and Requirements

*"It's very fortuitous that modules are very similar between the stationary and transportation sectors but that only gets you so far."*

--Bill Acker, Executive Director, NY BEST Consortium (2015)

Any potential player in the after-market EV battery space will require at least four core competencies: materials handling, logistics, specialized warehousing, and testing/validation capabilities. Further, an effective aggregator will also require the capacity to forge and maintain strong partnerships to ensure a robust pipeline of retired packs. And while there are several experienced re-manufacturers poised to participate in the secondary market, few have achieved any notable success in secondary market placement beyond pilot programs and publicly-funded studies.

To help build a vital secondary market for retired traction batteries, a number of threshold issues must be addressed. The study team identified 6 core challenges that may require new investment, protocols, or further study to address. The principal concern cited by all prospective secondary market users interviewed by the study team was the long-term reliability and warranty of the after-market packs. Secondary concerns regarded movement, handling, storage, and siting of retired packs. A final challenge cited by informants is a cultural one—a domestic consumer preference that may limit the appeal of re-purposed battery packs. A final, and perhaps decisive, concern is the price of re-purposed vs. new batteries.

### Testing & Validation

Battery testing and degradation path analysis to help identify viable after-market packs and determine optimal secondary applications are essential to any re-use business model. But the cost of laboratory testing of each cell in a battery pack may offset much of the savings achieved by re-purposing.

Bill Acker, Executive Director of NY Best Consortium, states, "I don't think every battery will go through a test lab and get certified for re-use. You can assess where the pack is in projected performance from its past use. You can make predictions on how they will perform. As packs come out of vehicles, you know a lot about that history from the vehicle. You can make pretty good predictions about how those packs are going to perform based on past usage and the targeted application" (Acker, 2015).

## **Toyota Battery Re-Purposing Pilot**

In 2014, Toyota initiated a national program through its dealer network to recover used nickel hydride batteries from its hybrid models. The dealers encouraged customers to turn in batteries in cases in which:

- a vehicle's onboard system indicated a problem with the battery
- the vehicle was involved in a collision
- a warranty issue with the battery had arisen

When the program launched, the automaker had no formal process or diagnostics for battery recovery. Through testing of a significant number of battery packs with performance issues, Toyota was able to establish a core value for the return of a battery and offered car owners an incentive to participate in a battery replacement program. Over the course of the 18-month collection program, Toyota dealers collected 320 battery packs, with 60% of these found to be suitable for stationary use. The packs consist of 34 modules with 6 cells in each module. Toyota technicians tested every battery pack component and then assembled a 95 KW system for Yellowstone National Park, composed of 208 reclaimed batteries. According to Toyota's Jim Evanoff, the storage system can function within a range of 85 kWh – 140 kWh of storage capacity, serving a micro grid and working in tandem with a 40 KW solar array (J. Evanoff, personal communication, April 2, 2015).

**Figure 1. Toyota Battery Re-Purposing Pilot**

The engineering firm DNV GL in Rochester, NY, offers a model that is predictive based on past use and duty cycle. The company's 'Battery XT' software examines "trends and tendencies" in lifetime use of Li ion packs and plots a degradation path based on data regarding temperature, cycling, power level, and state of charge. The platform helps model duty cycles for packs and then seeks to match battery characteristics with discrete after-market applications, like frequency regulation. Battery XT is currently being used to evaluate BAE Systems battery packs retired from NYC Transit hybrid buses (Hill & Gully, 2015).

Hill and Gully's work is central to the business case for secondary market use, as Acker notes, "An aggregator of packs will need to provide some information on where the packs came from and their status to assure end user." According to Acker, "that is the key issue —the price is entirely dependent on how long the packs are going to last" and that people's comfort level with batteries, including where they were used and what the warranties were, is key. "There is a psychological barrier to comfort level with second life batteries" (Acker, 2015). While Battery XT "reduces the testing matrix" and hedges risk in the secondary market, however, it "requires interpolation," cautions Gully (2015).

Robust testing and validation protocols are key considerations to even the most likely and motivated early adopters of re-purposed packs. Innovari, a demand management technology start-up, considered the deployment of re-

purposed EV battery packs in its initial business model, but now sources its batteries from Samsung. “Our systems require 1 full charge/1 full discharge every day for ten years—over 4,000 full cycles,” Clark Korbisch, Innovari’s Vice President for Sales, states. “And we will not accept packs until they have been inspected by the supplier, Samsung. Their BMS system provides us with maintenance warnings and we undertake a quarterly maintenance and annual inspection of system and change the filter on inverters. Our service personnel visit the deployment location regularly” (Korbisch, 2015).

Others do not, however, view testing and validation protocols as significant barriers to the marketplace for after-market packs. “All OEM packs have sophisticated battery management systems embedded already—the (re-use) process should simply integrate into OEM traction pack battery management modules,” offered Joe Ambrosio. “Thermal management, packaging, are already in place. A couple of cycles on each module could establish the health of a battery pack” (Ambrosio, 2015).

### **Profile: DNV GL’s Battery XT Platform**

DNV GL provides testing and advisory services across the energy value chain, including renewables and energy efficiency. The firm’s expertise spans onshore and offshore wind power, solar, conventional generation, transmission and distribution, smart grids, and sustainable energy use, as well as energy markets and regulations. DNV GL energy experts support clients across the globe.

Battery XT is a customized DNV GL platform that determines lifetime characteristics and then matches them and battery chemistry with appropriate second life applications. XT uses validated datasets to derive expected life and capacity loss trends for battery storage systems. Temperature, time and cycling components determine the shape and slope of the life curve as rendered by XT. Understanding this curve enables battery system integrators to optimize capital costs, expected lifetime, and functionality requirements for their systems. DNV GL engineers in Rochester are currently undertaking what Davion Hill and Benjamin Gully term “conceptual work on the secondary market” and deploying software that examines “trends and tendencies” in lifetime use of Li ion packs.

Currently, the DNV GL team is applying Battery XT to the analysis of BAE Systems’ hybrid drive battery packs retired from MTA NYC Transit hybrid buses. Battery XT is helping DNV GL engineers to model duty cycles and ultimately match battery characteristics with discrete applications, like frequency regulation. (Hill & Gully, 2015)

**Figure 2. Profile: DNV GL’s Battery XT Platform**

## Safety & Materials Handling Concerns

Safe storage and handling of the retired EV battery packs is a serious concern of secondary market players who note that currently there are no mandated storage and handling protocols.

According to DNV GL's Davion Hill, after-market packs are optimally stored at a partial State-of-Charge. "40-60% is generally best," offered Hill, raising concerns among some potential secondary market players regarding workplace safety (Hill & Gully, 2015).

"Every pack we get is defective," reports Hank Sybesma, Global's President and Founder. "With us, if we hook up a pack it could blow up. We have set up protocols to ensure safety." But while "people automatically assume that Li ion packs are dangerous, never ever have we seen a battery have a problem on its own. It's always been a control issue. Battery failure is not caused by battery modules, but by its control functions" (Sybesma, 2015).

"Our mechanics have received training to service the batteries," stated Jonathan Ells, Fleet Manager, NYC Department of Citywide Administrative Services. "Some of our staff already works on these packs. What concerns me is the storage of these packs. For gasoline storage, for instance, we need spill containment protocols. I don't know how FDNY would feel about this" (Ells, 2015).

"Safety is principal concern," according to Joe Ambrosio, President, Unique Technical Services (UTS), an engineering firm active in the transportation and energy sectors. "I know what goes into designing these batteries and they're getting better every day. Shock, vibration, and thermal cycling issues are a concern. Cell pressure changes as temperature goes up and down. While chemistry can handle another 10,000 cycles, can thermal management handle those cycles? Leakage, pressure relief valves could present problems. Prismatic cells would need to be assessed for integrity" (Ambrosio, 2015).

Establishing workforce training and safety certification protocols is one opportunity for policymakers and regulators to help advance the prospects for a viable secondary market. "We need standardization in the industry," contends Ellington Ellis, Director of Development for Global Battery Solutions of Holland, Michigan. Trade unions such as the IBEW also have an interest in the standardization of protocols that could provide safety and reduce risk. "Installers and trainers should be licensed to install a pack," offers Ellis (2015).

Outsourcing to specialized equipment handling firms is one strategy that is currently being piloted by Green Charge Networks, a demand management technology company. A third-party operator--Four R Energy--handles logistics, warehousing, testing and validation for Green Charge's pilot re-purposing of retired Nissan Leaf packs (Bhade, 2015).

Similarly, Global Battery Solutions contracts with Fedex to provide specialized handling for the shipping of A123 modules to Global's Holland, MI, testing and repair facility. According to Global's Ellington Ellis, the cost is extremely competitive - \$1.70 per Li ion module (Ellis, 2015).

### **The Warranty Challenge**

Many secondary market players insist that a warranty is fundamental. For Bhade of Green Charge Networks, the 10-year warranty provided by Nissan & Four R Energy (Nissan & Sumitomo collaboration) was essential to the battery re-use business model (Bhade, 2015).

"Degradation happens more quickly after 10 years—it is non-linear," stated Korbisch of Innovari. "Samsung, our current battery supplier, has to provide a warranty and degradation curve platform" (Korbisch, 2015). While Innovari is battery agnostic, it requires its supplier to provide a warranty on each unit's battery management system. The warranty is a function of the terms of its program funding —10-year performance and warranty are required to ensure that Innovari's technology provides a 4-hour supply over the 10-year life of the program (Ponkratz, 2015).

### **Space and Size Constraints**

Dense East Coast metropolitan areas like New York City may prove especially challenging for secondary market battery deployments due in part to the cost and availability of space in crowded cities where both behind-the-meter and front-of-the-meter applications would be especially valuable. The size of re-deployed packs will in part be driven by the testing and re-manufacturing protocols they undergo. "One question is to what extent you can reuse whole modules," Acker stated. "Rather than replacing individual cells—it could save a lot of money." But re-manufacturing economics may collide with real estate imperatives in markets where every square foot commands a premium price" (Acker, 2015).

Green Charge Networks' efforts in this regard are noteworthy as its re-purposed Leaf packs are used "as they are", meaning they are typically oversized (since underperforming cells take up space in modules but add no capacity). According to Green Charge CTO Harjinder Bhade, the packs are

"not refurbished or remanufactured, which will add cost to GCN's technology" (Bhade, 2015).

For most of Green Charge Network's clients, however, footprint is not an issue. For the West Coast industrial, educational, and warehouse operations currently deploying Green Charge Networks technology, the cost and allocation of space to house batteries poses little or no challenge.

For Innovari, another demand management technology start-up, the choice of energy storage is in part driven by space constraints, so chemistry and technology that provides density is crucial (Ortega, 2015).

Other siting concerns may ultimately override cost and availability issues. "There will be siting issues wherever these packs are deployed," contends Joe Ambrosio of UTS (2015).

### **Climate-Controlled Warehousing**

As Hill and Gully note, "Different chemistries have different tolerances for temperature and the average temperature that a battery will see will dictate lifespan of battery" (Hill & Gully, 2015). As such, temperature-controlled warehouses will be a crucial link in the value chain.

"The colder the better," states Hank Sybesma of Global Battery Systems. "Colder conditions would result in 1-2% discharge per year. With warmer conditions, you'd see 3 – 4% deterioration" (Sybesma, 2015).

This may be a threshold issue for some potential players in the secondary market. "We have salvage yards nationwide—we can collect these packs nationwide. We have a collection process but we don't generally deal with climate control," reported Mike Vota, Region Vice-President for LKQ Corporation, the largest distributor of salvage collision parts in North America (Vota, 2015).

### **Market Preferences & Cultural Concerns**

Some secondary market players expressed concern about the American cultural preference for new versus old, worrying that some consumers will pay a premium for a new item rather than purchase repurposed battery packs. "There is a real reluctance to re-use products in the US; cultural factors are in play," offered Byron Stigge, CEO of LEVEL Infrastructure, a planning and design firm active in the developing world. "Overseas deployments might be better applications—those markets are comfortable with and more accepting of re-use of first world technology" (Stigge, 2015).

## **Price of New Batteries vs. Repurposed Batteries**

Pricing is a critical factor for EV battery second life. As the cost of new batteries continues to decrease, repurposed batteries become less attractive. Bill Acker of NY BEST Consortium states, "Price-points will be driven down by both Tesla giga-factory and Chinese manufacturers, which could impact domestic market for second life batteries" (Acker, 2015).

Kelly Jezierski of NEXT Energy questions, "What is the remanufacturing cost for re-purposed traction packs? If the cost of new packs goes down to \$180/kWh by 2020.... (as Navigant anticipates) then secondary use of packs is no longer viable" and "all bets are off..." (Jezierski, 2015).

A 2014 report by the Mineta National Transit Research Consortium posits that re-purposing for stationary applications will be viable as long as the re-manufacturing cost never exceeds \$83-114/kWh (Standridge & Corneal, 2014).

Primary market competitors to retired packs are, of course, not simply newly manufactured Li ion packs; there are also older battery technologies that are extremely price-competitive. Joe Ambrosio of UTS states, "I have some skepticism about how the battery will perform in a second life, but if the price is right, you really have something to build on. I think that's the big barrier here. The price for lead acid is just so low" (Ambrosio, 2015).

## **Why New York Metro Region Makes Sense for Battery Storage**

### **Supply of EV Batteries in the New York Metro Region is Expanding Rapidly**

#### **The Number of EVs on the Road is Increasing**

In 2014 nearly 120,000 EVs (PHEVs and BEVs) were sold in the U.S., a 23% increase over the prior year and a remarkable 128% over 2012 sales.

Between 2011-2014, a total of 286,824 EVs were sold in the U.S. As of October 2015, EV sales estimates were over 82,000 cars for the year (Inside EVs, 2015) (Inside EVs, 2015). The trend in EV ownership favors metropolitan areas, but specifically the less-dense suburban and exurban parts of cities (Energetics Corporation, 2013).

In New York State, EV numbers have grown from approximately 1,000 to more than 10,000 from 2011-2014 (WXY Architecture + Urban Design, Barretto Bay Strategies, Energetics, 2015). As of October 2015, the number of electric cars registered in New York was over 14,000, representing nearly a 50% increase from the previous year (Markowitz, 2015).

As of April 2014, there were 1,083 passenger EVs in New York City, which is just 0.055 % of the total 2 million registered vehicles. It is worth noting that the numbers of EVs more than doubles when neighboring Lower Hudson Valley is considered, and more than quadruples when Nassau and Suffolk counties are included (See NYSERDA EV registration map at <http://www.nyserda.ny.gov/Cleantech-and-Innovation/Electric-Vehicles/Tools/Electric-Vehicle-Registration-Map>).

#### **Fleets: Private and Governmental**

Several large companies with a global or national presence have made significant investments in deploying EV fleets. Those with over 500 BEV/HEVs include GE, AT&T, PG&E, Coca-Cola, Pepsi/Frito Lay, FedEx Express and Verizon (Suizo, 2013).

The share of EVs in the New York State government fleet is relatively small but will increase significantly over the next few years. Beginning in 2016, the Clean Fleets New York program involving the Department of Environmental Conservation (DEC), New York Power Authority (NYPA), and NYSERDA, and other agencies commits that at least 50% of new, administrative-use vehicles will be zero-emission vehicles (ZEVs), which include battery electric, plug-in electric hybrid, and hydrogen fuel cell vehicles. These agencies will undertake an initiative to explore innovative

ZEV acquisition models (such as leasing) to take advantage of federal tax incentives and lifecycle savings to reduce costs (NYSERDA, n.d.). New York State is committing to lead by example with select agency vehicles through Clean Fleets NY.

The New York City Fleet currently operates over 800 EVs, of which 178 are passenger EVs, with plans to reach 1,000 by 2017. To support the fleet, there are 203 EV chargers, making it the largest network in New York State. In 2016, the City also plans to introduce fast-charging chargers and at least one solar carport (The City of New York, 2015). There are over 153 city fleet chargers, and 260 public chargers (PlaNYC, 2014). NYC's Mayor de Blasio announced December 1, 2015, however, that the city will have the largest municipal fleet of EVs in the country within 10 years, and employ a network of charging stations to support it. According to the new plan, the city will replace 2,000 city-owned sedans with EVs, resulting in half of the non-emergency city vehicles being zero emission within the decade (Grynbaum, 2015).

## **New York State and City Policies that Will Encourage EV Adoption**

### **New York in the Multi-State Zero Emission Vehicle Program**

In October 2013, New York Gov. Cuomo joined the governors of California, Connecticut, Maryland, Massachusetts, Oregon, Rhode Island and Vermont in signing of memorandum of understanding (MOU) that committed to undertaking coordinated actions to ensure the successful implementation of their state ZEV programs. Collectively, the states have committed to 3.3 million ZEVs on the roadways by 2025, with New York State establishing the goal of having 851,855 ZEVs operating by that deadline. To achieve this goal, NYS would need to reach 52,793 ZEVs in 2017 (more than triple current numbers) and 229, 762 in 2020 (Rushlow, Coplon-Newfield, LeBel, & Norton, 2015).

Additionally, New York State has been working with the Northeast and Mid-Atlantic states, along with the District of Columbia, through the Transportation and Climate Initiative (TCI) to create regional initiatives and improve state programs.

To encourage ZEV uptake, New York State has implemented several statewide incentive program:

- New York State's Clean Pass is a multiagency pilot program among the State Departments of Transportation, Motor Vehicles, and Environmental Conservation that allows EVs and other low-emission

- and energy-efficient vehicles to use the High Occupancy Vehicles (HOV) facilities of the Long Island Expressway regardless of occupancy.
- The Port Authority of New York and New Jersey offers a Green Pass Discount Plan that rewards drivers using EVs and other low-emission vehicles with a substantial discount on tunnel and bridge tolls. Drivers with qualifying vehicles receive a green E-ZPass tag and are charged a reduced toll during off-peak hours. The New York State Thruway provides a 10 percent toll discount for ZEVs.

The [\*\*ChargeNY\*\*](#) program aims to put more than 30,000 EVs on the road and install over 2,500 additional public and workplace charging stations statewide by 2018. The initiative endeavors to increase New York State's EV readiness further by reforming regulations at the state and local level to facilitate EV charging, educating consumers and policymakers about the benefits of EVs and using the State fleet to test advanced EV technologies and demonstrating their benefits to the public.

### **New York City is Developing Infrastructure to Further Increase EV Usage**

In addition to the abovementioned measures to increase the city EV fleet, NYS is encouraging private adoption of EVs. New York City implemented a comprehensive sustainability plan called PlaNYC, which laid out an aggressive strategy to reduce the City's greenhouse gas emissions in 2030 by 30% from 2005 levels. A PlaNYC report, [Exploring Electric Vehicle Adoption in New York City](#), was released in January 2010 (McKinsey & Co.). It aimed to discover what the City and other stakeholders could do to facilitate early adoption of EV technology, and makes several recommendations relevant to EV policymaking and deployment.

Empire Clean Cities has partnered with New York City to educate and engage the public around EVs in an initiative called Mission Electric. This initiative provides information resources about EVs, but also invites input from the public to cultivate ideas, preferences and interests related to EV and EVSE deployment, planning and funding. As a part of this Mission Electric program, the City of New York Office of the Mayor released a DOE-funded project report called [The New York City EV Readiness Plan: Unlocking Urban Demand](#) to formulate a plan for EV charging and infrastructure deployment in New York City (Kahn & Ficicchia, 2012).

In 2013, New York City Council passed into law a requirement that 20% of future parking spots be prewired for charging stations. [Local Law Number 130 for 2013](#) is projected to create over 10,000 charger-ready parking spots, with 5,000 in the next seven years alone. As a result, since the end of 2014,

the electrical systems of all new parking lots and garages, and any that undergo increases in electric service, must be able to support EV charging stations.

### New Yorkers and EVs

According to the study conducted by McKinsey for PlaNYC (2010), 21% of New Yorkers are potential early EV adopters, and three distinctive characteristics are true for them.

**\*Willingness to change behavior to accommodate EVs:** This may include switching from an on-street parking space to one in a local parking garage to access necessary infrastructure (dedicated parking). Coincidentally, there is a sizeable share of car-owning households in NYC that have access to an assigned parking spot, where the vehicle always parks in a specific spot in a private garage, or a commercial garage or parking lot. While approximately 50% of car owners in Manhattan have assigned parking; the figure rises to nearly 80% in Staten Island.

**\*Interest in the technology and "going green":** New Yorkers' attitude, rather than their driving or parking behaviors are strong indicators of their willingness to adopt EVs. They expressed a desire to espouse an environmentally-friendly lifestyle, possess vehicles with the latest technologies, and/or challenge themselves to reduce their fuel usage. Moreover, not only do early adopters want to be the first on their block to own the latest vehicle technology, but also want to be recognized as such – and they would like everyone else on their block to be aware of this fact as well.

**\*Inclination to consider total cost of ownership and potentially higher upfront cost:** early adopters also appear more willing to pay a higher upfront price to save on maintenance and fuel costs over the long run.

## Opportunities for Reusing NYC Fleet EV Batteries

### NYC Fleet Pipeline and Scale of Opportunity

The City EV fleet began in 2002 with neighborhood electric vehicles (NEVs), and has now expanded to 800 EV plug-ins. The fleet includes Gem cars/NEVS, Ford Focus EVs and increasingly, Nissan Leafs (due to their affordability). In total the, City fleet includes 6,900 alternative fuel vehicles, of which 100 are CNG and 5,500 – 5,900 are hybrids.

The NYC Department of Citywide Administrative Services manages a "substantial" EV and plug-in hybrid fleet, including Volts, Leafs, and Navistar eStars (Ells, 2015). Agency policy dictates that conventional vehicles be replaced with hybrids and hybrids with EVs. The City plans to replace 2,000

city-owned sedans with EVs within the next 10 years, giving NYC the largest municipal fleet of EVs in the country.

### **NYC Fleet Salvage Policy and Typical Depreciation Patterns**

Once taken out of service, City vehicles are processed through NYC DCAS for salvage or auction. According to Ells, EVs are typically deemed a total loss in a collision and proceeds in the range of \$3,000 for a salvaged EV are typical (Ells, 2015). Fleet vehicles are auctioned through [www.propertyroom.com](http://www.propertyroom.com).

Fleet policy is 7-8 years, 70 - 80,000 miles before retirement can be considered, but the mileage on vehicles depends on agency use. For example, uniformed agencies tend to put more mileage on vehicles; some vehicles are used for commuting purposes, resulting in additional mileage. Parks Department vehicles typically have less mileage – and therefore less depreciation of batteries; 2,500 miles per year is minimum that could be expected from a NYC fleet vehicle (Ells, 2015).

According to Ells, "2018 could be a watershed year for EV retirement," as the first NYC fleet EVs will be retired then. Ells is not aware of any major issues with Li ion batteries in the City's EV fleet and the EVs and PHEVs have standard warranties on their batteries (Ells, 2015).

### **Alternative Retirement Scenarios**

"The City has to receive value for the assets it purchased," stated Ells. But that value could also be derived from inter-agency transfers— from a fleet to a stationary use, for instance, to furnish back-up power or demand management

services to a municipal facility, such as a school, hospital, or DEP plant (personal communication, February 26, 2015).

### **The Private Fleet Opportunity: DHL**

Global courier DHL operates a fleet of 30 Ford Transit Connect plug-in electric compact cargo vans in Manhattan. According to DHL's Thomas Wirth, the company disposes of aging vehicles by auction. The vehicle is sold entirely with the exception of its GPS tracker and generally, at this point in the vehicle's life, the battery is likely more valuable than the rest of the truck.

DHL is looking to expand EV use in places like Brooklyn. The company is considering new EV manufacturers and is likely to deploy newer, larger EVs "within 18 months." Wirth reports that the route for the new models will total 70 miles per day (Wirth, 2015).

**Figure 3. The Private Fleet Opportunity: DHL**

## **Utility Fleets and Battery Re-Purposing**

Con Edison's John Shipman reports that the iconic NY utility has deployed 15 plug-in electric vehicles, ranging from sedans to medium-duty trucks. Models include Chevy Volts, Prius plug-ins, Navistar eStars, Ford Fusion PHEVs, and Nissan Leafs (on order), with an average age of 3 years. The utility's passenger vehicles are generally retired after 5 – 7 years; the comparable figure for vans is 7 – 9 years. Con Edison auctions off its retired vehicles and would not typically disaggregate the battery pack from the vehicle upon retirement. "Our view is that we would retire the vehicle with the battery," Shipman told the study team. "We're not looking to refurbish batteries. We would look at a third party for that." The pipeline of retired EVs and PHEVs from the utility will only grow in future years as the utility makes good on its new commitment to allocate 5% of its capital expenditures on procurement of EVs and plug-ins.

When asked about potential re-purposing scenarios for battery packs, Shipman suggested deployments for peak demand reduction to take advantage of the utility's load reduction incentive of \$2,100 per KW, offered between June 1<sup>st</sup> – September 30<sup>th</sup>. "We've talked to Nissan and BMW" regarding demand reduction services at local dealerships with EV chargers. A dealership that adds 2 24KW fast chargers to its 50 KW load, for instance, would see a significantly increased bill due to the increased load. "With battery packs they could cut the increase in half or eliminate it."

And which players are most likely to emerge to dominate the secondary market space? "OEM's have vested interest in maximizing value of packs for secondary use so they should manage programs," Shipman asserted. "It is easiest for OEM's to keep it all in house, manage battery retirement on their own without a third party" (Shipman, 2015).

**Figure 4. Utility Fleets and Battery Re-Purposing**

## **Emerging Regulatory Reform and Policy Challenges and Opportunities**

### **REV and New York's Energy Grid**

New York State's Governor Cuomo initiated a "Reforming the Energy Vision" (REV) strategy that is completely redefining the regulator-utility relationship and providing opportunities for innovative approaches to clean energy in the state. Under the strategy, investor-owned distribution utilities will be transformed into investor-owned "Distributed Service Platform Providers" (DSPPs). With the new system, DSPPs will operate distribution lines, but will not have ownership of grid-connected assets including power plants, battery storage, solar panels or other means of power generation or management. DSPPs will identify the most efficient power generation sources and will be compensated according to how effectively they meet the state's reliability, environmental and customer choice goals (McKinney, 2015). New York has set a goal of 50% generation or electricity from renewable energy sources by 2030, and the REV strategy will increase penetration of renewable energy

sources and will result in increased deployment of “distributed” energy resources, including battery storage (see NYS DPS webpage).

According to Davidson of NYISO, however, REV may not result in significantly increased bulk energy storage: “CALISO has mandates to integrate storage—the policy push for renewables in CA results in more demand for storage and regulation. The increased penetration of renewables in CA contributes to demand for storage and regulation. We (NYS) don’t have same need for bulk storage as CA.” Further, “From a REV perspective, we feel that it (REV) calls for more resources deployed at the distribution level rather than bulk storage level.” He maintains that how the REV initiative will affect demand for storage and frequency remains an open question (Davidson, 2015).

Bill Acker of NY Best Consortium believes that REV may help enhance the EV battery secondary use market: “With REV, there are some potentially very nice applications in demand-reduction. Behind-the-meter and peak load reduction at sub-stations and other sites are promising and are being looked at by REV” (Acker, 2015).

### **Other Emerging Energy Challenges in New York State**

#### **EPA Clean Power Plan**

Other changes in the regulatory landscape, including the EPA Clean Power Plan, have the potential to affect the EV battery second use market.

Announced on August 3, 2015, by President Obama, the Clean Power Plan will go a long way towards reducing carbon pollution from power plants (U.S. Environmental Protection Agency, 2015).

According to NYISO’s Davidson, “In NYS, existing tools are working for us. But there is a longer-term view that storage is something that we will need to integrate on a larger-scale in the future. For instance, EPA clean power plant policy may result in retirement of older plants, especially dual-fuel plants downstate,” (Davidson, 2015).

#### **Hurricane Sandy**

Hurricane Sandy, which hit the east coast in October 2012, raised awareness about resiliency and adaptation to severe weather events both among citizens and government authorities. Existing consumer behaviors as well as post-storm resiliency-building policies could contribute to the uptake of EVs and battery storage.

As a result of the storm, on June 11, 2013, the Bloomberg administration released “A Stronger, More Resilient New York” (PlaNYC, 2013), a comprehensive plan that contains actionable recommendations both for

rebuilding the communities impacted by Sandy and increasing the resilience of infrastructure and systems, including making New York City's energy networks more resilient. While reducing energy demand and increasing energy options for the city are among the proposals, it is worth noting the "Initiative 22: Incorporate resiliency into the design of City electric vehicle initiatives and pilot storage technologies:

**"With future enhancements, they (EVs) also could have resiliency benefits.** For example, during a power outage, an EV potentially could be used as an energy source to power a small home for a day.

*The City, acting thorough the OLTPS (Office of Long-Term Planning and Sustainability), will build on its work to accelerate EV adoption in the city, incorporating resilient features into electric vehicle infrastructure (...). The City will work to ensure that the EV infrastructure being built today us sufficiently robust to accommodate two-way power in the future.*

**In addition, the City will pilot new battery storage applications and streamline regulation to enable private sector adoption.** For example, NYCEDC (New York City Economic Development Corporation) is piloting a large battery storage system at the Brooklyn Army Terminal that will pave the way for adoption of distributed storage applications that could improve grid reliability, provide emergency power to critical systems, and manage peak loads."

### **Indian Point Shutdown**

Indian Point, a nuclear plant owned by Entergy in Buchanan, NY serves about 25% of the power needs of New York City and Westchester County. Its location in the suburbs of New York City, with 17 million people within 50 miles of the plant, has raised significant safety concerns, particularly after the 9/11 attacks in 2001 when one of the hijacked planes flew over the nuclear power plant on the way to the World Trade Center. The tsunami and Fukushima meltdown in Japan in 2011 increased fears. Operating licenses for the plant have expired and the Nuclear Regulatory Commission is currently holding hearings to determine whether to grant a 30-year renewal license. Renewal is opposed by New York State and environmental groups, but a decision is unlikely in the near future. Davidson of NYISO notes that, "If Indian Point would need to be replaced—you can't just take it out of service without replacement—it's 2,000 MW," (Davidson, 2015).

## Potential Partners

*"A lot of companies will tell you that they can re-purpose these packs. But there's not a lot that can."*

-- Hank Sybesma, President, Global Battery Solutions (2015)

There exists a huge array of players in the automotive industry and energy services sector that each offer crucial skill sets, market knowledge, relationships, and core capacities necessary to activate a vibrant secondary market for automotive battery packs. These include OEMs, salvage/automotive recycling companies, auto auction companies, electronics recyclers, after-market auto parts distributors, the battery manufacturers themselves, grid storage companies, utilities, and niche tech start-ups like Green Charge, Stem, Demand Energy, and Innovari.

### Prospective Aggregators, Re-manufacturers and Distributors

As noted in a prior section of this report, minimal business requirements for secondary market players are advanced logistics and materials handling capabilities; strategically located climate-controlled warehouses; a trained workforce; and the capacity to establish pipelines for retired packs as well as distribution and deployment channels.

But study participants offered a wide range of recommendations for the roster of likely candidates sufficiently well-positioned to activate a viable secondary market.

#### Renewables Developers

Byron Stigge of LEVEL Infrastructure posits, "(Retired) batteries would be best sold to renewables developers and those developers would then assume responsibility for battery analysis and re-purposing work" (Stigge, 2015).

#### System Integrators

According to Bill Acker of NY BEST, "Reuse strategies have to involve the systems integrators - the players that use batteries. A couple of dozen companies are engaged in reuse of packs - about 8 are focused on behind-the-meter apps" (Acker, 2015).

#### Auto Salvage Distributors

Auto salvage distributors are also potential partners in the EV battery secondary use market. "What are people's comfort level with batteries that don't have a 'trackable pedigree?' Auto salvager might not be able to

provide the same level of comfort to end user given battery safety concerns," (Acker, 2015).

LKQ Corp, the largest distributor of salvage collision parts in the North America, sees "mostly normal hybrids totaled, not plug-ins yet," according to Regional Vice President Mike Vota. While the company does "some remanufacturing", it mostly handles easily re-purposed commodities. Tires, for instance, become feedstock for waste-to-energy plants while bumper covers are re-purposed for rubber playground surfaces. A third party recycler currently handles conventional batteries for LKQ (Vota, 2015).

### Battery Re-manufacturers

Global Battery Systems, a 6-year-old battery testing and remanufacturing subsidiary of Sybesma's Electronics, has developed a proprietary "cut-and-paste" method for re-assembling and restoring defective packs. Currently, Global has stockpiled 30,000 lbs. of automotive packs—often prototype



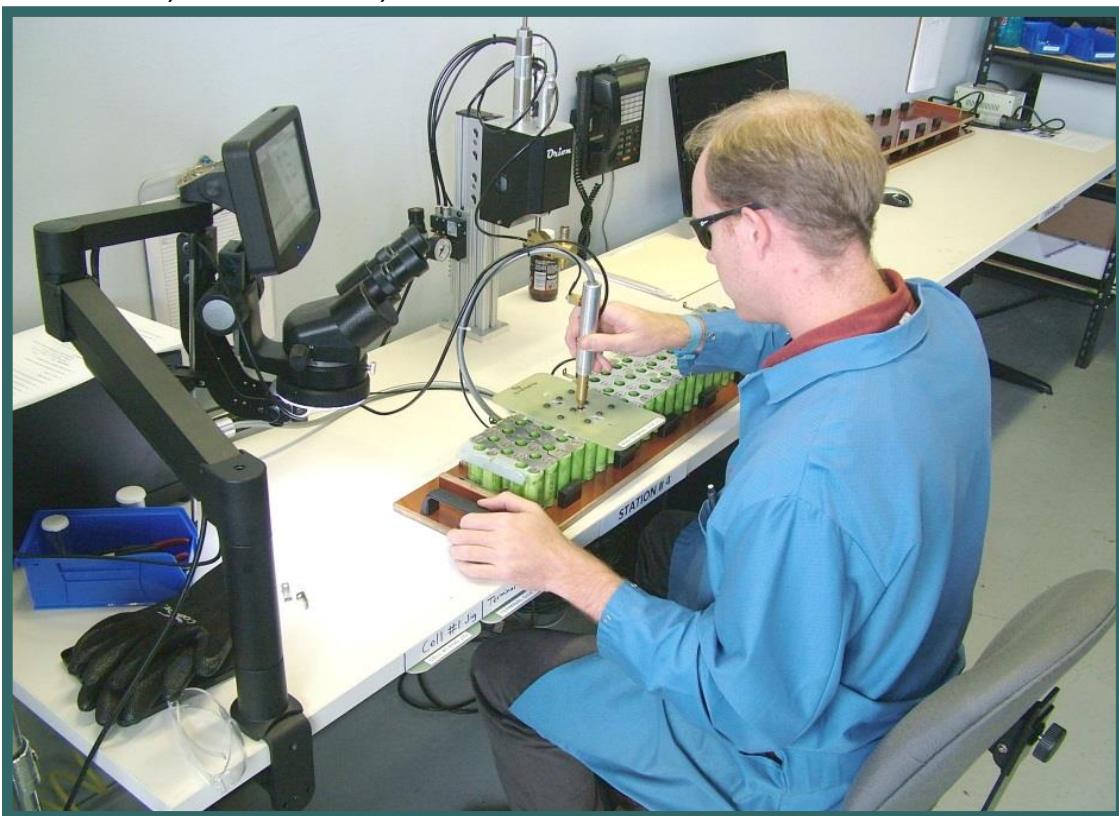
**Figure 5. Global Battery Solutions Remanufacturing Li-ion Battery Cells**  
*Photo courtesy of Global Battery Solutions.*

batteries from first generation EV models—in its Holland, Michigan warehouse. By diagnosing, removing, and then replacing defective cells in otherwise healthy modules, Global has accumulated 3-4,000 battery modules in

inventory for re-purposing. "I need a market for these packs," states Sybesma (2015).



**Figure 6. Global Battery System Has a Process That Quickly Diagnoses Battery Packs, Repairs Them, and Thoroughly Tests Them to Meet Top-Quality Standards**  
*Photo courtesy of Global Battery Solutions.*



**Figure 7. GBS Remanufacturing Includes Disassembly and Recovery, Replacing Worn Out or Obsolete Cells and Electronics and Upgrading the Module to the More Current Revision**

*Photo courtesy of Global Battery Solutions.*

## Case Studies

### Case Study 1: BAE Systems HDS

Based in Endicott, NY, BAE Systems HDS provides and services the hybrid drive systems in 4,500 hybrid buses around the globe, including 1,600 in New York City, 12 in Binghamton, and 50 in other parts of NY such as Buffalo/Syracuse/Albany, and about 6 in Westchester County. BAE has also deployed over 1,000 hybrid commuter buses in Europe. The company has achieved an unusual degree of vertical and life cycle integration, assembling nano iron phosphate cells into battery modules, servicing the modules and hybrid drive systems, and removing and warehousing retired modules at the end of their useful life.

While its energy storage systems are monitored throughout their life cycle, BAE typically refurbishes its hybrid drive systems at the equipment's halfway point. The average age of BAE's hybrid equipment currently deployed around the U.S. is 5 – 6 years, so a significant share of its technology is beyond the mid-point of a projected 12-year lifespan. BAE's life cycle analysis is pegged to a projected annual mileage at 50-60,000 miles per year. In BAE's first generation hybrids, these projections did not take into account dwell time—when buses layover, for instance, at the end of a route or while waiting for passengers to board. Now, the effects of onboard electronics and accessories (power steering, pumps, air conditioning, etc.) are also accounted for in BAE's life cycle projections.

When a hybrid drive system reaches its mid-point, battery "tubs" (packs) typically return to BAE for refurbishment. The refurbishment process includes upgrades to the battery management system and battery tub and testing of all battery modules. New modules are often mixed with remanufactured modules in this process. Some degraded modules are retired or disposed of. Others are simply warehoused for future non-traction (after-market) uses. According to Hroncich, the whole process can take 1-3 weeks for stripping down and refurbishing a pack.

"The market is now mature enough and fleets are now old enough that we have a steady volume and constant flow of product," Hroncich reported, accounting for the growing array of de-energized packs accumulating in BAE's Endicott warehouse. Currently, the facility is receiving between 6 and 24 11.5 kWh batteries each week, approximately ½ of which are shipped back out to return to service. "So between 3 – 12 packs go on The Pile a week," Hroncich explained.

Retired packs are categorized and grouped according to remaining battery capacity. Packs with fewer than 4 amp hours of capacity are disposed of; those with between 4 – 14 amp hours are warehoused; and anything above 14 amp hours is returned to service in buses. “The debate internally is whether 12 amp hours can be returned to service,” Hroncich said.

Despite the market opportunity presented by its rising mountain of retired packs, the firm has no secondary market ambitions of its own or a plan for a future chain of custody. “We’re fine with just collecting these modules,” Hroncich said.

Its warranty structure also would not lend itself to encouraging secondary market applications. Upon deployment, BAE issues base (2 years) or specialized extended warranties. Annual service contracts with various transportation authorities effectively extend the warranty. But BAE is uncertain about stretching a battery pack’s warranty for non-traction uses. “We’re happy just selling packs to a middleman,” explained John Hroncich, Senior Market Analyst at BAE HDS. “We just don’t have the arms and legs to get involved in the grid storage market” (Hroncich, 2015).

### **Case Study 2: Green Charge Networks**

In June 2015, Nissan Motor Company and Green Charge Networks, an energy storage and demand management company, announced a partnership to repurpose and redeploy second-life Nissan Leaf battery packs in domestic and overseas markets (Green Charge Networks, 2015). The first Green Charge energy storage unit powered by second-life packs will be deployed at a California Nissan research facility in the last quarter of 2015 and will provide peak demand shaving services (McCafferty, 2015). 4R Energy, a joint venture of Nissan and Sumitomo, will manage the pilots and assume custody of second life Li ion battery packs from Nissan dealers (Kane, 2015).



**Figure 8. Sumitomo's Frequency Regulation Modules Use 16 Depreciated Nissan Leaf Batteries and Serve Nearby Hikari-no-Mori Solar Array**  
Photo Courtesy of Sumitomo Corporation.

Founded in 2009, Green Charge is a California-based firm with offices in New York City and a growing roster of commercial and institutional customers. Green Charge's proprietary software and energy storage technology helps large energy users flatten their demand by offsetting spikes in power usage with timely discharges from "GreenStation" battery installations. According to Green Charge, the GreenStation can reduce a customer's demand charges "by up to 50%" without requiring any change in energy usage patterns (Green Charge Networks, n.d.).

Green Charge hedges risk and reduces cost to the customer by applying a "shared savings" approach to its business model, enabling customers to share in the upside of averted demand charges and utility incentives. The company installs and maintains its technology and software at no charge to its customers under a Power Efficiency Agreement, an innovative financing model pioneered by Green Charge. "95% of our customers are taking advantage of the shared savings model. Because it's an emerging technology, customers are not ready to own and maintain the assets themselves," Green Charge's Rachel McCafferty explained (2015).

"Everyone's really interested in second life stuff. A lot of universities and colleges have expressed interest in it," observed McCafferty. "We're still learning ourselves. More and more people are asking about it. Where demand charges aren't as high, second life batteries create savings and make our model more attractive" (McCafferty, 2015).

"In San Diego, we can make any building work because they have an incentive of \$45/kWh," McCafferty continued. "Re-purposed batteries enable us to enter markets where we couldn't ordinarily go because of lower incentives and lower demand charges. Lower cost batteries reduce system costs." Working with Nissan has heightened Green Charge's understanding of the broader implications of its re-purposing work. "Ultimately, this re-use and re-purposing (of second life packs) cuts down on costs for automakers," observed Green Charge CTO Harinder Bhade. "We have done testing for over 1 year for the profiles we are seeking. So far, we are very satisfied, very happy with them" (Bhade, 2015).

### **Case Study 3: BMWi**

Introduced to U.S. markets in March, 2014, BMW's new i series includes the i8, a plug-in hybrid sports model, and the i3, a four-door EV with an all-electric range of 81 miles and an optional 2-cylinder engine that increases range to approximately 150 miles. Since the introduction of the i series, BMW reports that sales of the i3 have totaled 15,694 units, making BMW the third largest EV OEM in the U.S. —behind Tesla and Nissan.

The i3's 22 kWh Li ion battery pack (18.8 kWh of usable energy) is assembled in Leipzig, Germany, from cells manufactured in Korea by Samsung but designed by BMW engineers. In fact, all the major battery pack elements are designed by BMW—"these are not off-the-shelf components," remarked BMW's Cliff Fietzek, BMW North America's Manager for Connected eMobility (Fietzek, 2015). Integration of energy management, temperature control, and safety systems into battery modules is completed by BMW at its Leipzig plant, which is powered entirely by renewable energy sources.

The design and configuration of the i3 battery pack is intended to facilitate re-purposing and, according to Fietzek, the packs are purpose-built for relatively seamless transitioning to a number of second-life stationary applications. "The idea is to re-use i3 packs as they are. We are not intending to disassemble the packs (at the end of their useful lives for transportation)," Fietzek remarked. "If you do that, you need to add energy management systems, heating/cooling systems, diagnosis, etc. We offer the

opportunity to use the batteries as they are. You don't have to install cooling systems. No one needs to go into the housing."

Fietzek emphasized the value to the secondary market of integrating all management systems into each module. "The packs can be used in any climate conditions without any special housing, any special climate control measures. It's all integrated into the pack. And you can combine as many of the battery modules as you like."

The life cycle optimization approach to the i3 battery pack design was clearly driven in part by the automaker's experience with an earlier EV model, the ActiveE, a demonstration EV based on BMW's 1 series. "In the ActiveE, if you wanted to re-purpose the pack (for stationary uses), you had to create a new battery management system and add a cooling system. In the i3, you can re-use the pack *as is*," observed Fietzek. "A lot of the energy consumption in the building of the car goes into the battery pack so it would be a waste to dispose of them (before the end of their useful life)," Fietzek noted.

Confidence in battery performance throughout a pack's life cycle also seems to play a role in the company's long-term strategy. "We are quite confident about 70% capacity after 8 years. But based on field testing, (battery health) will probably be much higher than that," stated Fietzak. That confidence also translates to an interest in warranty extension for secondary market applications. When asked if BMW would consider extending its traction battery warranty for stationary uses, Christine Fleisher, Department Manager for BMWi, replied, "It may depend on how many units you buy. But yes, we can find a solution for that. It would need to be evaluated on a case-by-case basis. It depends on the usage—as long as you use the battery within the specified usages. You need to use the battery as prescribed" (Fleisher, 2015).

BMW's authorized i3 dealers will be key to any serious secondary market strategy since they typically handle batteries in trade-ins or vehicles coming off lease. And each has the technical capacity to evaluate battery health throughout a pack's life-cycle. "We can check the state of health at the dealership at end of lease. If you come in with concerns about range issues in your car, we can do car diagnosis at the dealership," Fietzek explained. "So our techs can do the same with a battery that is returning at the end of lease."

Fietzek and Fleisher envision a robust secondary market for i3 packs in the U.S. "We have more opportunities for re-purposing battery packs in the United States than in Europe," Fleisher observed. The automaker itself has already deployed its retired packs for demand management, peak shaving,

and energy storage applications at 8 BMW facilities around the globe, including 4 in the U.S. While these pilots are shedding new light on the performance capabilities of re-purposed batteries, they are still not the utility-scale deployments that BMW envisions for its retired packs. "We are more interested in larger-scale applications than one-offs," Fietzek remarked.

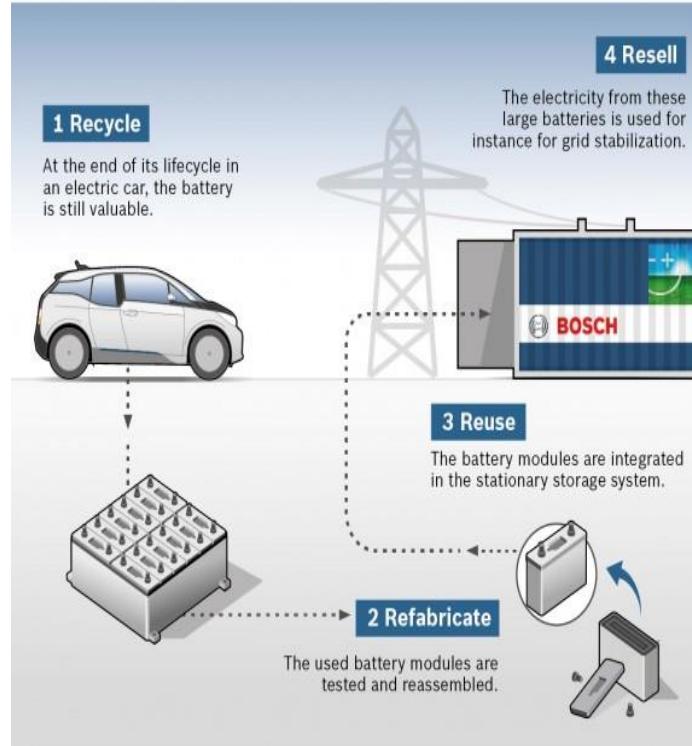
While BMW is bullish about the secondary market prospects for its battery packs, its current focus is on building a primary market for its EVs. "If (a battery) is good for an electric car, it is good or more than good for storage applications. The first product is the car, however," stated Fietzek.

But it is clear that a more sweeping strategic vision is also at work. "(With the i3) BMW's intent was to offer mobility services and that goes beyond the car," remarked Fleisher. "There was intentionality from the engineers. It's a holistic approach to recycling." Indeed, the BMW corporate culture appears to reinforce the life cycle optimization strategy. "We do it because we want to do it! It's also the core of the BMWi philosophy," remarked Fietzek. "The i3 maximizes the use of recycled and recyclable material for all of its components. The battery is an essential part of that approach."

According to Fietzek, 95% of the i3 can be recycled and the batteries from 700 retired ActiveE's are already actively deployed or awaiting deployment in several large storage projects. BMW is acutely aware of its growing reputation for sustainability and the formidable power green branding commands in its key markets. "BMW," Fleisher affirmed, "has a long history of being the most sustainable auto company in the world." And that reputation can of course also help sell cars and build market share. Optimizing the life of its batteries aligns neatly with the company's brand and just might also evolve into a sound business model for the company (Fietzek, 2015).

## Second Life for electric-vehicle batteries

Following use in electric cars, lithium-ions batteries are reused for stationary applications and thereby begin a "second-life".



**Figure 9. Second Life Batteries Alliance: BMW, Bosch & Vattenfall**  
Figure Courtesy of BMW.

## Potential Projects

### The Demand Management Opportunity

As noted earlier, the burgeoning field of demand management offers secondary market players an immediate small-scale demand for energy storage in an application suited to the typical energy density profile of retired traction packs. The demand opportunity offers a secondary market player potential partnerships with nimble start-ups able to market and deploy refurbished battery technology as well as generous utility incentives for the service in a number of key markets—including the Con Edison service area in lower New York State.

Innovari, a demand management technology start-up, envisions at least two potential demand management battery re-purposing pilots. In one demonstration project, Innovari would replace new batteries deployed at a client site in the Con Edison service area with refurbished secondary market packs. The refurbished packs would be required to meet the firm's contractual obligation to provide a 4-hour discharge each day, enabling the customer to participate in the Con Edison/NYSERDA Demand Management Program.

A second potential pilot would add a second installation - typically, energy storage assets in an intermodal container - of refurbished battery packs to one of Innovari's current installations at a demand management client location. For Innovari, supplementing an installation with an additional unit is more cost-effective than developing a new location for a pilot.

In both cases, the ample pipeline of low-cost secondary market packs could be a boon to the Innovari business model (Ortega, 2015).

### Dual-Purposing Second Life Packs: UPS & Demand Management for Data Centers

The diesel backup generator has been the guarantor of Internet business continuity since the advent of large multi-user data centers in the late 1990's. While back-up generators typically provide the emergency power needed to keep servers online during utility power outages, even the most sophisticated equipment requires several seconds to become operational. In the event of an outage - or whenever grid power is out of standard operating range—Uninterruptible Power Supply (UPS) systems help a data center bridge disruptions to grid power provision, thereby ensuring business continuity for the data center's customers.

The battery backup unit (BBU) is the critical component of the UPS and while it typically does not provide prolonged power, the BBU does provide a crucial bridge-to-backup functionality. While UPS systems are generally battery-based, battery components are still sealed lead acid in nearly 50% of data center BBUs (Nakhleh, 2012). The environmental impacts, size, and other limitations of sealed lead-acid (SLA) batteries have been widely studied and remarked upon (GreenIT Sustainable Information Technology, 2005) (Dogra, 2012).

As such, Microsoft engineers and others have begun to explore the implications of broader Li ion battery deployments at its data centers (Govindam, Wang, Sivasubramaniam, & Urgaonkar, 2012). Lithium iron phosphate BBUs for UPS systems are already being produced by Palladium Energy and others to lower battery maintenance costs and provide more power in a smaller footprint, preserving valuable real estate for the data center.

UPS by itself is not, however, “a dynamic asset,” noted McCafferty, and therefore more difficult to monetize through Green Charge’s shared savings model unless a demand management service is layered into the business case (McCafferty, 2015).

“Peak demand shaving and demand response is what our software is built for,” continued McCafferty, who sees a potential dual-use opportunity for Green Charge technology at data centers. “We’d like the asset to be able to do peak demand shaving *and* UPS. Customization would be required for the software.”

In a hypothetical pilot deployment, Green Charge’s shared savings approach harnessed to the reduced cost of re-purposed packs would create a viable business case for a dual-use Li ion UPS system at a data center in the Con Edison service area. The UPS system would serve the mission critical bridge-to-backup function and also provide the peak demand shaving services that Green Charge’s technology typically offers, and thereby furnish the customer with a financial incentive to pilot after-market packs in its BBU.

## **MTA NYC Transit Hybrid Bus Battery Stationary Deployments**

The retirement of BAE HDS hybrid battery packs from Metropolitan Transportation Authority (MTA) NYC Transit buses creates several opportunities for stationary deployments and a “closed loop” pilot, shifting packs from the MTA’s surface transit operations to other divisions of the agency.

In one scenario, “batteries could be re-deployed from MTA buses to capture energy from subway braking,” offered Nathan Ortega, a Vice President for Engineering at Innovari. “(By) coupling a generating source with an inverter, regenerative braking could save the MTA enormous amounts of money in energy and cost savings” (Ortega, 2015). MTA’s fleet



**Figure 10. MTA Hybrid Bus, One of 1,600 in Service in NYC**  
Photo Courtesy of MTA.

of New Technologies subway cars (also known as “New Millennium Trains”) already have deployed regenerative braking, enabling them to channel energy back into the third rail that is typically lost as heat as the train’s brakes are applied. These R-142, R-142A, R-143, and R-160 subway car-models, which run on the 2, 4, 5, 6, L, and N routes, could offer opportunities for the MTA to bank energy for load shifting at subways stations for a summer emergency response program or peak demand reduction initiative (Metropolitan Transportation Authority, n.d.).

Other potential pilot scenarios include stationary deployments for load shedding and demand management for subway shops, barns, substations, and bus depots during the summer season. NYPA and the MTA already collaborate on a Peak Reduction Program that requires the MTA to reduce power consumption at all NYC substations, a rail service yard, and 28 NYC Transit bus depots during peak demand days. The program, which went into effect in the summer of 2015, was first activated on July 29<sup>th</sup> in response to anticipated peaks in demand due to high temperatures and humidity in the MTA service area. Under its agreement with NYPA, the MTA agreed to reduce its overall consumption by almost 13.6 MW from noon to 6 PM on designated peak demand days between June 1<sup>st</sup> and September 30<sup>th</sup> in return for a payment of \$25 per KW curtailed through the program (New York Power Authority, 2015).

## **Other “Closed-Loop” Pilots**

Municipal government may offer a proving ground for repurposed second-life batteries within a closed loop system of public sector ownership. "Within the mayoral agencies, we do have the capacity to transfer assets," offered Jonathan Ells, the NYC DCAS fleet manager. "For instance, from Parks to DEP (Department of Environmental Protection). There is already a protocol in place" (Ells, 2015). In one inter-agency re-purposing scenario, batteries from fleet EVs deployed by the NYC Department of Parks and Recreation could be transferred for load management or back-up power at DEP plants.

Similarly, a small number of private sector operators that have already incorporated EVs into their fleets and that have large electrical loads also present an opportunity for a continuous chain of custody from fleet uses to stationary deployments to battery retirement. Fleets such as Frito Lay and Duane Reade are outstanding candidates for proving the closed loop model. "(These) closed-loop systems should be considered—500 Smith Vehicles and batteries would be re-used by fleet operator," UTS' Joe Ambrosio observed. "If the battery remains with the operator, can it be deployed for other uses within the business? The outstanding question: Would that facilitate warranty extension" (Ambrosio, 2015)?

Lastly, a burgeoning ecosystem of EV drivers with photovoltaic (PV) installations on homes or businesses presents another clear path to closed loop deployments to meet energy storage and demand management needs. "Because 37% of EVSE (Electric Vehicle Supply Equipment) owners also have solar," Next Energy's Jezierski remarked, "a closed loop system" of retired traction battery packs re-purposed for energy storage is a viable scenario (Jezierski, 2015). One potential candidate for a commercial pilot is Manhattan Beer Distributors, which operates a fleet of hybrid electric diesel trucks and also boasts one of the largest commercial PV installations in New York City at its Hunts Point distribution facility.

## **Developing World Deployments**

Finally, the export market may offer New York State energy storage businesses the promise of overseas customers with a high degree of comfort with re-manufactured products and a growing demand for affordable energy storage options. "Overseas micro grids – there's a lot of appetite for this. Lots of interest, as well, in solar installations with energy storage in the developing world," noted NY Best's Acker. "There's also a pretty big market for cell tower battery backup, especially in hot climates where lead acid batteries degrade rapidly" (Acker, 2015).

Deployment of renewables in developing countries and places where grid is unreliable are “huge opportunities for retired battery packs,” observed Level’s Byron Stigge (Stigge, 2015). “In global markets, the goal would be to pair energy storage with solar and renewables. The route to market would be through renewables manufacturers like Siemens or Vestas. Also, Rockefeller Foundation has a distributed solar power program in India and NGOs are deploying 2 – 10 KW systems in the developing world,” according to Stigge. Cost-effective energy storage assets would facilitate these grid-islanding efforts and offer a potential solution to the lack of infrastructure throughout the developing world.

## Conclusions and Policy Recommendations

A growing stockpile of retired EV batteries presents a tantalizing opportunity to bring to market lower-cost energy storage assets, optimize the lifetime value of the traction battery pack, and ultimately reduce the cost to the consumer of the EV. But it also looms as a vexing public policy issue that, if left unaddressed, could emerge as a troubling solid waste challenge and, moreover, squander a remarkable opportunity to augment and diversify the supply of energy storage assets, so crucial to meeting energy conservation and climate change mitigation objectives.

New York State policymakers can play a key role in advancing the study and deployment of second life packs in stationary applications. Some have already begun to consider the scale of the opportunity. "Secondary market battery storage makes sense to me," remarked NYISO's Davidson. "If the batteries can perform as we need them, then we wouldn't have any concerns" (Davidson, 2015).

In the near term, battery testing, validation, remanufacturing, warehousing and logistics all present viable opportunities for job creation and economic growth in the state's burgeoning energy storage sector. Follow-on service work and monitoring of second-life battery health also could generate employment and help specialized energy storage service companies sprout in key markets statewide. "A longer-term relationship is envisioned for UTC with (battery) deployment sites—the company would monitor thermal and cellular health and the state of health of battery would be relayed to vendor and support provided when necessary," predicted UTS' Joe Ambrosio (Ambrosio, 2015).

In addition to UTS in Smithtown, potential New York State players poised to play leading roles in the second life marketplace include Rochester's DNV-GL, Endicott's BAE Systems HDS, and Albany's NY-BEST Consortium. "On-shoring" these jobs and opportunities close to a growing pipeline of retired traction packs—from municipal, surface transit, and private sector fleets, as well as an expanding cohort of EV early adopters—makes sense to those who are already immersed in the remanufacturing of packs. "You can't ship second life batteries to China—it's cost-prohibitive," noted Global's Ellis (2015).

Ultimately, the promise of second life batteries will hinge largely upon the cost curve for new Li ion packs. To the extent that the cost curve continues its downward trend, the domestic market for second life packs may be

limited to niche, price-sensitive, and non-mission critical applications. But the arc of that cost curve will be shaped by a number of variables and contingencies that often operate beyond the reach of U.S. policymakers and current private sector actors. These include the dynamism of the energy storage market, rapidly unfolding advances in research into alternatives to Li ion technology, and the cost and availability of lithium and other key battery components in the global marketplace. Political and economic developments in Bolivia, Argentina, Chile, and China, as well as the health of trade relationships between these countries and the U.S. will inevitably affect the long-term availability and pricing of this crucial alkali metal.

Even weather conditions can and have influenced the worldwide availability of lithium - in 2013, difficulties attributed to poor weather conditions reduced the output of Argentina's largest lithium producer (U.S. Geological Survey, 2015). With the global EV market expected to reach 1 million vehicles this year (Ayre, 2015) and the Tesla "Gigafactory" projected to produce Li ion packs for an estimated 500,000 vehicles by 2020, these variables are further complicated by blossoming global demand which could strain current supply chains and enhance the appeal of lower-cost, domestically-sourced second life packs.

Beyond the indisputable logic of the cost curve is, of course, the undeniable imperative of sustainability and climate change mitigation. And the second life battery is uniquely positioned to address several key sustainability challenges and climate change drivers at once, simultaneously offering a lower-cost pathway for energy conservation, storage, and the integration of renewables, while blazing a shortcut to the mass market EV by reducing the upfront cost of the battery pack. Whether the second life pack is methodically re-purposed to advance these goals, or is simply borne along to an as yet undefined grey market, is an outcome that can be shaped by the decisions of today's policymakers and industry leaders, who will either treat the retired EV battery as another inevitable cast-off of the era of the mass market automobile, or as a fortuitous by-product of the age of the EV.

### **Policy Recommendations to Strengthen Secondary Market Opportunities in New York State**

1. NYPA should identify applications for depreciated traction battery packs and report on potential demand for these packs, at both NYPA facilities and at NYPA customer locations around NYS.

2. NYSERDA should issue a request for proposals to implement a 24-month traction pack re-purposing pilot, with clear goals and a timetable for deploying retired packs in stationary energy applications.
3. The NY Green Bank should explore creating an extended warranty product to reduce risk for secondary market players and backstop the value of after-market batteries.
4. State agencies with vehicle fleets should draft, promulgate, and implement EV and PHEV battery reclamation protocols to ensure that the value of battery packs in retired fleet vehicles is optimized.
5. NYSDEC should draft advisory guidelines for municipal fleets statewide regarding EV and PHEV battery reclamation protocols to ensure that the value of battery packs in retired fleet vehicles is optimized.
6. Con Edison and NYSERDA should consider Demand Management premiums for participating customers deploying second life energy storage assets.

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