Introduction: Lancaster Advanced Energy Community Project: Second Life Battery Analysis

Objective:	As part of the Lancaster Advanced Energy Community Project, ZNE Alliance has been tasked with analyzing the economic viability of using second life electric vehicle batteries for energy storage
Goals:	The goal of this report is to: • Provide clarity on economic factors that drive battery re-use versus battery recycling • Understand how different levers affect viability of second life batteries • Analyze economic viability over time under a variety of scenarios • Evaluate when it is economical to use second life batteries

To explore: For second life batteries to be economically viable, must have lower cost than new

New Batteries

New Battery Cost * SGIP Funds[1] ~40% of total costs

≥

Second Life Batteries

Total Second Life Battery Costs: Used Battery Cost * Additional Batteries to Offset Reduced Efficiency

* Additional Costs of Casing Construction

Working hypotheses

1. Potential for very low or negative costs for orgs who bear cost of disposal
2. Low price energy use could preserve cost advantage in spite of efficiency losses
3. Use case could be sized so that no additional capacity is needed
4. Economies of scale could unlock lower construction costs

Are there any circumstances when it is **cost effective** to use second life batteries?

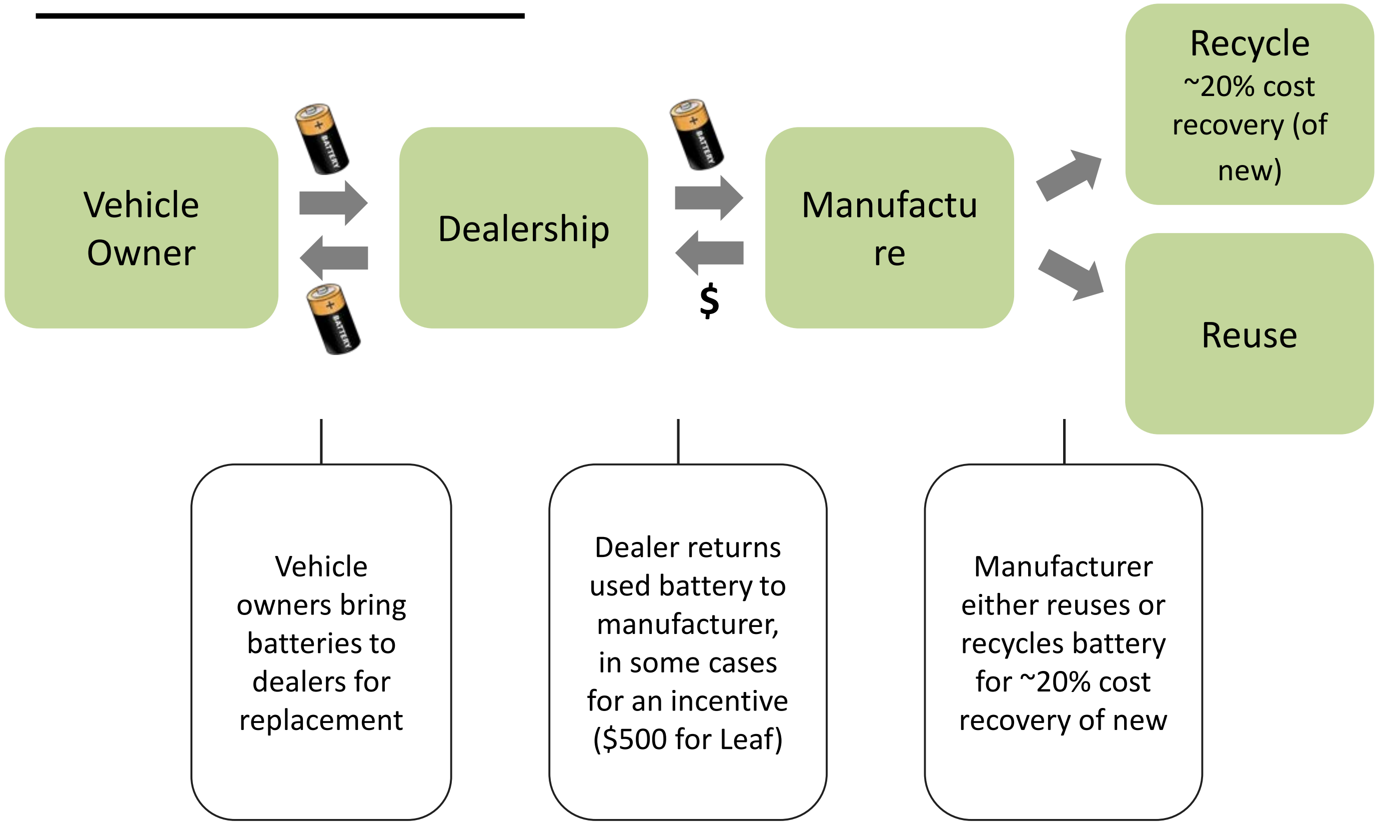
1. Self Generation Incentive Program

Analytical approaches are used to explore hypotheses

	Hypothesis to explore		Analytical Approach
1	Business opportunities for lower battery costs	→	Understand existing life cycle models and explore economic factors that would affect battery costs
2	Low cost energy use could preserve cost advantage	→	Explore how different factors, including electricity price, affect economic viability of second life batteries in comparison with new
3	Right-sizing use-cases	→	Explore feasibility of variety of use cases, given standard vehicle batteries
4	Economies of scale could unlock lower construction costs	→	Understand construction cost increase and model potential scale discounts

1 **To explore:** Potential for very low or negative costs for orgs who bear cost of disposal

Existing Value Chain



Implications

In order for re-use to be viable, manufacturers need to be able to offset 20% opportunity cost of not recycling

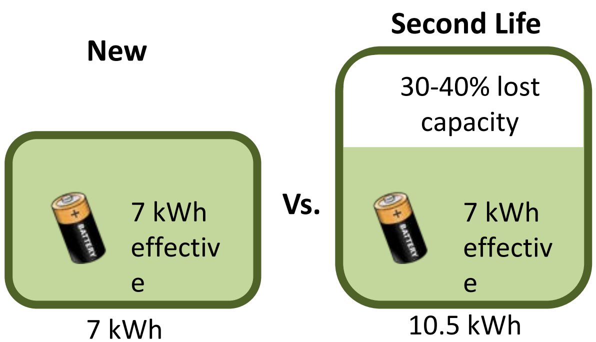
1 **Conclusion:** Potential for very low or negative costs for orgs who bear cost of disposal

Scenario	Economics	Drivers		Implications
Battery recycling becomes un - economical	Battery costs decrease faster than recycling costs, rendering the post-recycle value of a battery less than the recycling process	Battery costs have dropped by 77% from 2010-2016. If this trend continues, it is likely that this will outstrip the costs in recycling	➡	Potential for second life battery costs to be **less than 20%** of original value
Uneconomical battery recycling & disposal costs	In addition to uneconomical recycling, costs exist for battery disposal	Regulations could require that manufactures pay disposal fees for used batteries	➡	Potential for second life batteries to have a **negative costs** as an alternative to a costly disposal

McKinsey & Company, *Electrifying Insights: How automakers can drive electrified vehicle sales and profitability,* January 2017.

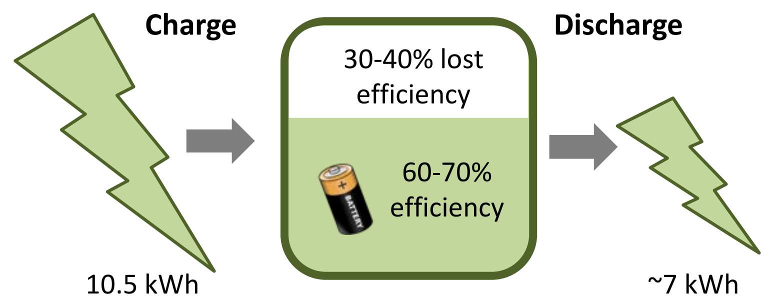
2 **To explore:** Narrowing use cases to low or zero cost of energy times maintains cost advantage

Lower capacity requires additional battery size….



- Capacity of second life batteries is **between 60-80%** that of new batteries
- To same-size a second life system, additional nominal capacity will need to be procured**, adding to upfront costs**

…And lower discharge efficiency requires more energy to charge



- Discharge efficiency is also lower for second-life batteries, meaning **more energy is needed** to produce the same discharge as a new battery
- If the electricity charging the battery has any cost, this will add a **greater ongoing cost** than using new batteries

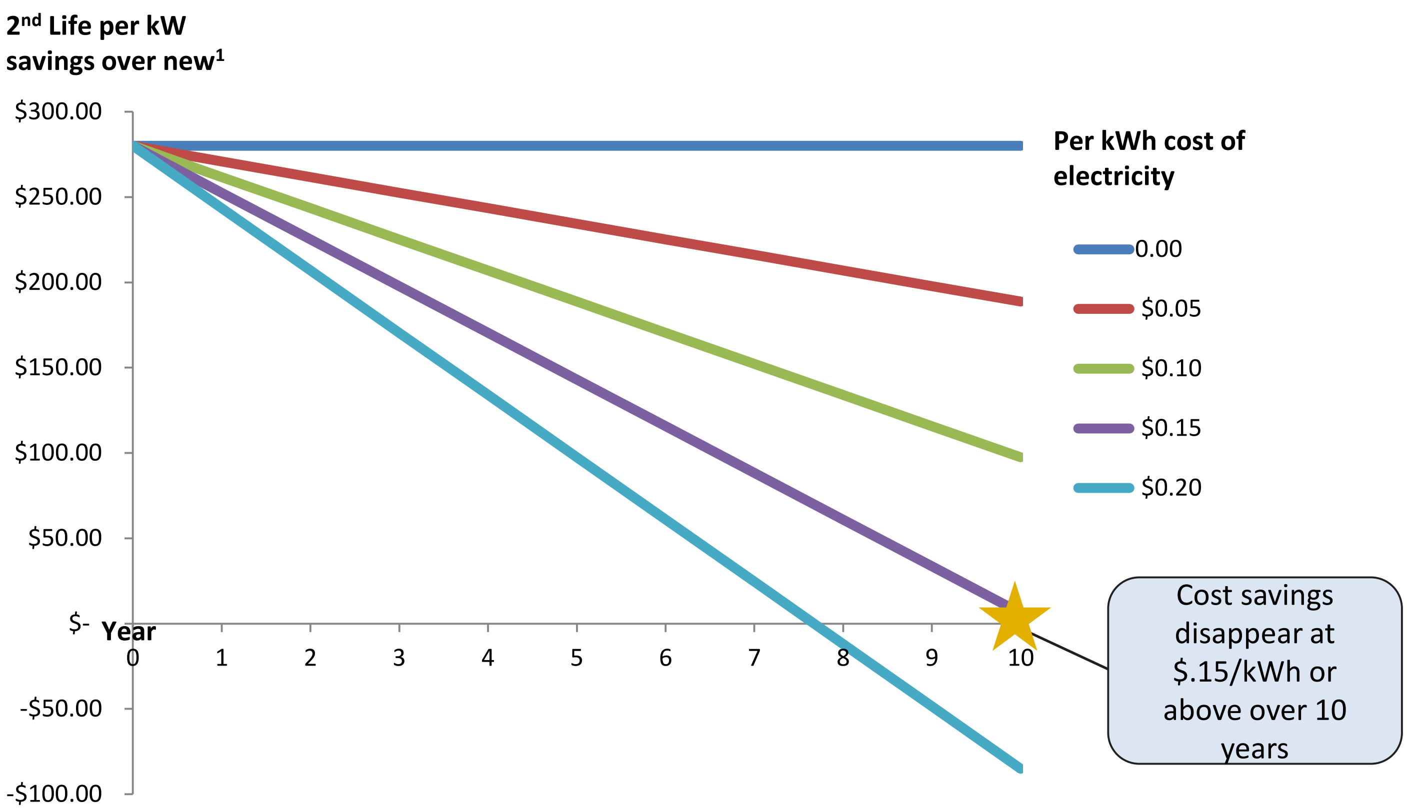
McKinsey & Company, *Electrifying Insights: How automakers can drive electrified vehicle sales and profitability,* January 2017, GreenCharge Networks analysis.

Conclusion: Once electricity price reaches $.15 per kWh, cost advantage disappears

2

2nd Life Savings Assuming Daily Use

Assumptions	
Per kW battery cost[2]	
$400	New
$80	2nd life
Discharge Efficiency[3]	
90%	New
60%	2nd life
Other[4]	
Daily	Discharge frequency
No	Include incentives?



1. Note that LCOE was not used as there is uncertainty as to cycle life of second life batteries as compared to first. 2. Battery costs based on price for consumer; approximated based on Tesla Powerwall price and Nissan Leaf battery replacement price (which Nissan claims they loose money on). 3. Based on approximations from https://cleantechnica.com/2015/05/09/tesla-powerwall-powerblocks-per-kwh-lifetime-prices-vs-aquion-energy-eos-energy-imergy/ and https://cscown.files.wordpress.com/2015/06/power-d-15-01157r1.pdf. 4. Assumptions mirror daily usage, in non SGIP scenario

2 **Conclusion:** Cost advantage even narrower with SGIP incentives for new batteries

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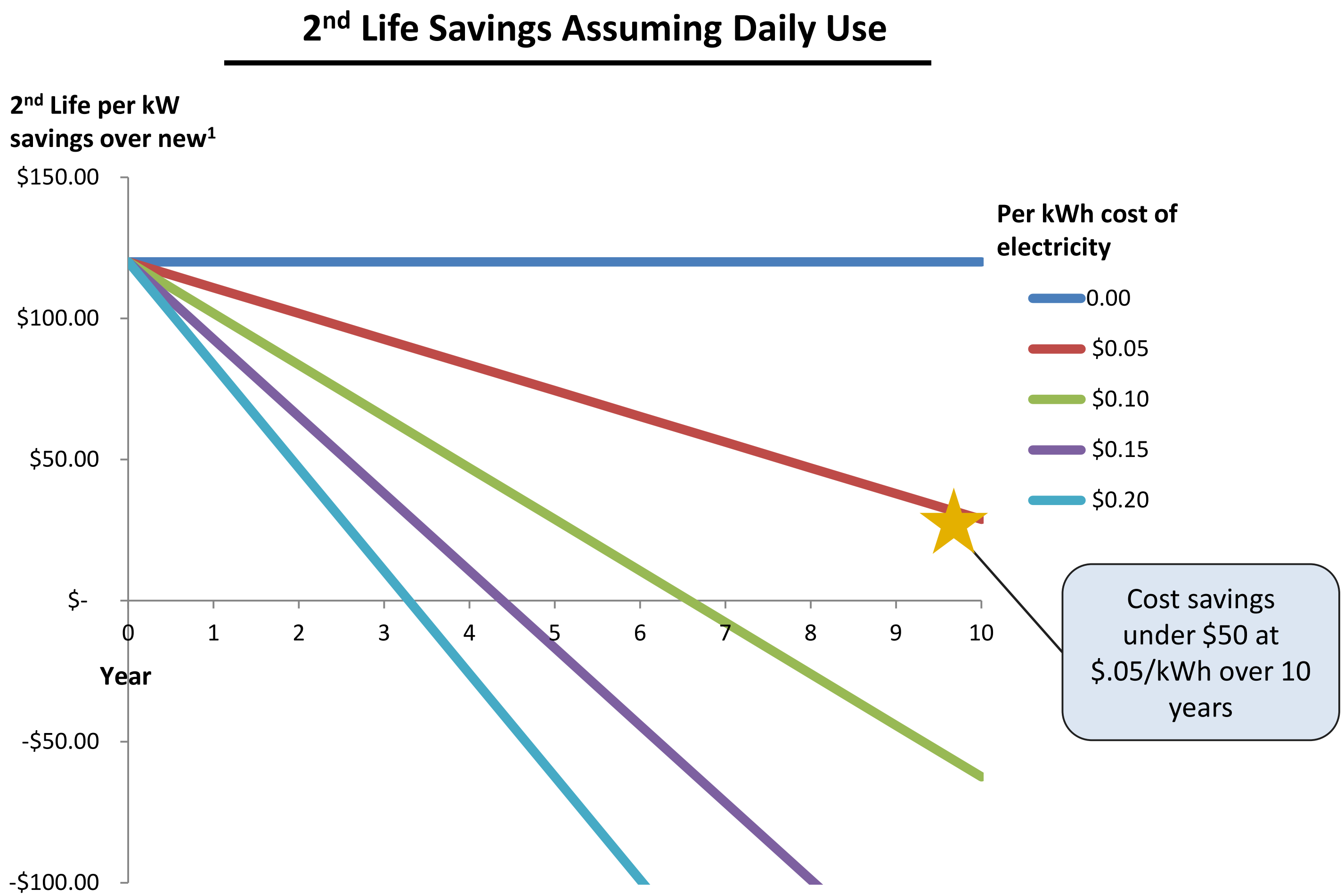

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3 4 **To Explore:** Right-sized use-cases and economies of scale can bring down construction costs

At present, reduced capacity increases costs in two ways…

Additional Batteries needed to Offset Reduced Capacity ↑$

- As used batteries have less capacity than new batteries, additional kWh must be procured

Cause additional Costs in Casing Construction ↑$

- Casing for used batteries has not yet been standardized, thus raising the costs for customization

…Requiring both a short term…

By **strategically sizing use cases**, (i.e., a 24kW used EV battery operating at 70% can approximate a 13.5kW solution), potential to

….And long term solution

Economies of scale have the potential to economize cell removal and drive modularized casing, thus lowering costs

Conclusion: Through right-sizing use cases in the short term, and economies of scale in the long term, construction costs could likely be reduced

In Conclusion: Economic viability is possible under very specific use cases

		Example projects[1]		Vs.	Best Case Scenario for second life batteries	
		New	**Second Life**		**Second Life**	**Enabling factor**
Battery Cost		$25K	0$ (batteries donated)		~$7K	Assuming economic factors make recycling uneconomical, adding add'l capacity to compensate for decreased performance
		+	+		+	
Installation and casing	Enclosure	$5K	$10K		$5K	Assuming economies of scale drive price parity
		+	+		+	
Installation and casing	Inverter	$5K	$5K		$5K	Costs for inverters are expected to be equivalent
		+	+		+	
Installation and casing	Installation	$5K	$10K		$5K	Assuming economies of scale drive price parity
		*	*		*	
Incentive discount (SGIP)		50% of all project costs	0%		0%	Assuming incentives limited to new
		=	=		=	
Total		**$20K**	**$25K**		**~$17K**	Potential for lower upfront cost in certain circumstances, but questions remain

1. Based on conversations with Doug Sampson at GreenCharge Networks. GreenCharge Networks partnered with Nissan in 2016 to install second life Leaf batteries in dealerships.

Note: Assumes configuration costs of zero due to economies of scale

In Conclusion: Viability depends on key constraints and questions remain

Viability under very specific circumstances…

- Assuming price parity in construction costs due to economies of scale *and*
- Assuming 20% of new battery cost or lower) *and*
- Assuming low or zero ongoing electricity costs, and that battery maintains an average of 60% discharge efficiency over 10 years

…but opportunities for further study exist

- Battery deterioration is non-linear — can we estimate the point of rapid decline based on use case?[1] How will this impact warrantees?
- Changes in incentives and new battery costs have an enormous effect on the viability equation – how will these factors change in the next 5 years?

1.If the point of rapid decline occurs within 10 years of second life battery usage, the equation tilts away from viability