Evaluating the potential benefits of pairing battery energy storage with electric vehicle charging

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Contacts: Alex Cimino-Hurt, alex.ciminohurt@cascadeenergy.com; Paul Gruber, pgruber@freshcoastclimate.com

Project Summary

Pairing battery energy storage systems (BESS) with high-speed electric vehicle (EV) charging can offer cost, permitting and emissions benefits, but these vary by region, charging profile, and utility rate structure. This study analyzed fleet and public EV charging scenarios in Michigan, Massachusetts, and California using National Renewable Energy Laboratory's ReOpt software to optimize cost and emissions savings over an 8-year lifecycle.

- **BESS Cost-effectiveness findings:** Fleet charging with after-hours profiles showed the highest cost-effectiveness for BESS. Michigan generally had longer payback periods and was less cost-effective, while California fleets on standard rates were cost-effective even without tax credits. Inclusion of the Investment Tax Credit (ITC) improved economics in several scenarios across states.
- **BESS Emissions impact:** Greater emissions savings were achievable in regions with higher renewable energy penetration, though often at a cost trade-off depending on utility rates. Emissions savings were modest or negative under some standard scenarios.
- **Other BESS benefits:** Inclusion of a BESS in a high-speed charger facilitates significantly lower utility infrastructure with these new systems requiring one-fifth the electrical footprint of conventional chargers. This in-turn facilitates shorter permitting and deployment timelines as well as broader site eligibility.
- **Electrification Emissions impact:** Electrifying both fleet and public travel through increased charger availability demonstrates over 60% emissions savings over conventional gasoline vehicles.

Project Background

Fresh Coast and Cascade Energy paired up with the start-up electric vehicle (EV) charging company ElectricFish to evaluate the cost and emissions benefits of high-speed electric vehicle charging paired with energy storage for Michigan communities. ElectricFish offers a level 3 charging station that has two 350 kW charging cables as well as 400 kWh of energy storage. Two investigations were conducted related to the installation of this type of high-speed charging station in Michigan communities. The first task examined the economic benefits of a charger with a battery energy storage system (BESS) under different scenarios compared to a conventional high-speed charger, and the second examined the avoided emissions benefits associated with electrification of fleet and public transportation that would be facilitated by installing these chargers.

Task 1: Examine EV-Charging with BESS

Two charging scenarios were examined – fleet and public – in three regions – Michigan, Massachusetts, and California – to show regional differences. In each region a time-of-use (TOU) and standard electric utility rate schedule was tested except in Michigan where two sets of utilities (Consumers Energy and DTE Energy) were evaluated. Then the analysis was conducted a second time to determine the maximum cost-effective carbon emissions savings through strategic battery energy deployment.

Methodology

This analysis was performed with the National Renewable Energy Laboratory's ReOpt software system, a publicly available energy system optimization tool. ReOpt was used to simulate the performance of a BESS when serving the two distinct load profiles representing fleet and public charging sessions. These two charging scenarios were then modeled with TOU and standard medium commercial utility rate schedules for four different utilities (Table 1).

Table 1 - Study Treatment Groups

Site Type	Grid Region	Rate Schedule Type
Fleet	Michigan	Consumers Energy Co: General Service Secondary TOU (GSTU) - Tier 5 (30,001 – 50,000 kWh/mo) Consumers Energy Co: General Service - Secondary (Rate GS) - Tier 5 (30,001 – 50,000kWh/mo)
Public		Consumers Energy Co: General Service Secondary TOU (GSTU) - Tier 5 (30,001 – 50,000 kWh/mo) Consumers Energy Co: General Service - Secondary (Rate GS) - Tier 5 (30,001 – 50,000kWh/mo)
Fleet	Michigan	DTE: TOU General Service D3.11 DTE: Large General Serice D4
Public		DTE: TOU General Service D3.11 DTE: Large General Serice D4

Fleet	Massachusetts	NSTAR: Western MA Small General Service TOU NSTAR Western MA Primary General Service G-2
Public		NSTAR: Western MA Small General Service TOU NSTAR Western MA Primary General Service G-2
Fleet	California	Pacific Gas and Electric TOU - A-10 Pacific Gas and Electric Standard General Service - A-10
Public		Pacific Gas and Electric TOU - A-10 Pacific Gas and Electric Standard General Service - A-10

ReOpt Inputs and Optimization Criteria

ReOpt can set a wide range of optimization criteria. This analysis ran the study treatment groups first to optimize cost and then again to determine maximum carbon emissions reductions achievable under each of the sixteen scenarios. ReOpt leverages hourly regional carbon emissions profiles to determine the hourly impacts of energy use. These analyses optimized on the net present value of ownership of these stations for an assumed 8-year life cycle excluding charging revenue. The results of these analyses were aggregated together in an accompanying Excel spreadsheet along with documentation of assumptions used as well as links to the run results of each scenario tested.

EV Charging Profiles

Two charging load profiles were developed from NREL's Electric Vehicle Station Load Profiles. Multiple event profiles were combined and smoothed to simulate a typical public charging scenario marked by primarily daytime charging and a fleet scenario marked by primarily after-hours charging. The result of the data transformation work was two 8,760 hr/yr demand profiles that were uploaded to ReOpt's analysis platform to simulate the two different charging demand profiles that could be served by a BESS. ReOpt typically sizes an optimized system based on the criteria set by the user, but we wanted to ensure that that analysis modeled the potential performance of ElectricFish's 350Squared system. To do this we had to fix the total energy storage that could be modeled at 400 kWh and let ReOpt choose an optimal output capacity for the unit. Interestingly, in every scenario ReOpt chose 50 kW BESS output capacity as compared to the 150 kW output capacity that the 350Squared BESS units are capable of.

Task 2: Examine Fleet Electrification Emissions Avoidance
The results of task 1 were used to estimate total charging energy for fleet and public use cases of one of these chargers. A representative electric fleet vehicle and public vehicle were chosen to model typical vehicle efficiency, range, and subsequent miles driven based on annual charging energy. An equivalent gasoline vehicle was chosen to represent the internal combustion engine (ICE) alternative (Table 2).

Table 2 - Electrification Vehicle Scenarios

Use Case	Vehicle Type	Model	Combined MPGe
Fleet	Electric Vehicle	2025 Ford E-transit	57
	ICE Vehicle	2025 Ford Transit	17
Public	Electric Vehicle	2025 Ford Mach-e	104
	ICE Vehicle	2025 Ford Escape	30

Emissions associated with the charging energy were compared with the emissions associated with fuel combusted by the ICE vehicle equivalents to drive the same number of miles per year.

Results

Regional energy costs and demand profile play a significant role in the cost effectiveness of pairing BESS with high-speed EV charging. Fleet charging profiles with more after-hour charging demonstrate the highest cost-effectiveness. Michigan demonstrated the longest payback period for TOU schedules for both Fleet and Public charging profiles and are unlikely to be cost effective rates schedules for BESS. Fleets charging on a Standard rate schedule in California demonstrate the highest cost-effectiveness of all the scenarios studied. While the ITC can significantly improve cost effectiveness, all scenarios except the Michigan TOU rates showed positive net present value (NPV) over the eight-year analysis period even without it. When the system optimized solely on cost reduction, emissions savings were negligible in most cases and slightly increased in some. When the system optimized on maximal emissions savings, emissions savings as much as 11% could be achieved but at a penalty to the NPV of the respective projects. In order to achieve more emissions savings, ReOpt had to charge the BESS during periods of higher electrical cost, reducing the overall electrical cost savings benefit. (This is just the emissions reduction associated with battery energy integration on the grid. Task 2 results speak to the vehicle electrification emissions benefits below.)

Table 3 – Task 1 Fleet Charging Results

State	Rate	NPV ($)	Non-BESS Operating Cost ($/yr)	BESS Operating Cost ($/yr)	% Cost Savings	Simple Payback (yrs)	Simple Payback after ITC (yrs)	Standard Emissions Savings	Maximized Emissions Savings
MI	TOU	-$7,200	$49,300	$47,800	3.0%	20.2	11.2	-1.5%	7.2%
	Standard	$74,720	$120,000	$105,800	11.8%	1.7	1.2	-1.2%	7.2%
MA	TOU	$64,930	$140,000	$128,000	8.6%	1.9	1.4	0.0%	1.2%
	Standard	$56,200	$155,000	$144,000	7.1%	2.2	1.5	0.0%	1.1%
CA	TOU	$80,500	$196,000	$181,300	7.5%	1.6	1.1	-1.5%	11.0%
	Standard	$78,480	$197,000	$83,000	57.9%	0.2	0.1	0.0%	11.1%

Table 4 – Task 1 Public Charging Results

State	Rate	NPV ($)	Non-BESS Operating Cost ($/yr)	BESS Operating Cost ($/yr)	% Cost Savings	Simple Payback (yrs)	Simple Payback after ITC (yrs)	Standard Emissions Savings	Maximized Emissions Savings
MI	TOU	-$7,000	$48,700	$47,200	3.1%	19.5	11.2	-1.9%	7.2%
	Standard	$74,560	$89,700	$75,800	15.5%	1.7	1.2	-0.2%	4.2%
MA	TOU	$64,620	$112,000	$99,200	11.4%	1.9	1.3	-0.1%	1.1%
	Standard	$55,800	$128,000	$116,700	8.8%	2.2	1.5	-0.1%	1.1%
CA	TOU	$80,300	$163,000	$148,000	9.2%	1.6	1.1	-2.1%	11.1%
	Standard	$78,500	$162,000	$147,700	8.8%	1.6	1.2	-0.3%	11.1%

Electrifying fleet and public transport by making high-speed charging more readily available can offer significant emissions benefits. Both electric fleet and public vehicle use in lieu of gasoline alternatives resulted in emissions reductions of over 60% (Table 5 - Task 2 Results).

Table 5 - Task 2 Results

	Fleet	Public
Miles Driven (mi/yr)	749,549	1,134,009
EV Emissions (mt/yr)	141	124
ICE Emissions (mt/yr)	387	332
Annual Emissions Savings (mt/yr)	246	208
Percent Reduction	**63.6%**	**62.6%**

Discussion

Though pairing BESS with high-speed EV charging comes at a price premium of as much as $24,000 per charger, in most regions it can offer significant cost savings benefits over the life cycle of the project. Michigan's low TOU rates and low difference between on-peak and off-peak rates explains the smaller benefits associated with EV-BESS pairing. By contrast, in California, TOUs offer a much stronger cost signal for BESS deployment on the grid. Higher emissions savings appear to be more easily achieved in regions with higher amounts of renewable energy but always appear to come at a cost trade-off based on the current utility rate structures.

One significant but unquantified benefit of this new type of charger system is the potential reduction in permitting and installation time. Conventional high-speed chargers require significant load studies and potentially large infrastructure costs on account of the large potential loads. This new type of charger requires roughly one-fifth the power per station, reducing the utility requirements and potentially greatly expanding the number of sites that could site high speed chargers.

This analysis had several limitations including the lack of utility-specific emissions profiles, and optimizer constraints on BESS system specification. Utility-specific emissions would give a clearer picture of emissions impacts of EV charging and BESS integration. Finally, the ReOpt analysis tool essentially shorts the capacity of the actual 350Squared units by only specifying 50 kW output on units capable of 150 kW output. Presumably a more intensive charging profile would require higher recharge rates than the ones used for this analysis.