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March 20, 2019

New Jersey Board of Public Utilities
Office of Clean Energy
Via email (energy.storage@bpu.nj.gov)

Comment on Energy Storage Analysis

University of Delaware's (UD's) Electric Vehicle R&D Group, under Principal Investigator Willett Kempton, researches and develops technology and policy related to electric vehicle deployment, in particular, vehicle-to-grid systems (V2G). UD has been the leader in V2G development since 1997, when Dr. Kempton laid out the first conceptual design and economic analysis for a V2G system. Since then, the Group has developed an aggregation platform and associated hardware, which is now licensed world-wide to Nuvve, Inc., and is in commercial use in both the US and Europe.

The suite of technologies developed for V2G allows an aggregator to not only control the rate of EV charging ("aggregated controlled charging," also called "V1G" or "managed charging"), but also to export energy from car batteries to the grid. Both functions can provide grid services, but full V2G may have many times the market value of aggregated controlled charging.[1] With a third-party company acting as an aggregator, large numbers of vehicles could be managed to provide all the services that stationary storage is capable of, in both wholesale markets and through retail programs, at lower cost.

In fact, V2G projects have been earning revenue through frequency regulation in wholesale markets since 2013. Projects are ongoing in Delaware, the Netherlands and Denmark, the largest being a fleet of 50 vehicles in Denmark which has been providing frequency regulation since 2017. Pilot programs in the US are focusing on school buses since they have large capacity, downtime aligned with peak grid loads, and the added benefit of saving schoolchildren from breathing diesel fumes.[2]

V2G provides low-cost energy storage

At the end of 2017, the cost for a complete stationary battery system averaged $850 per kW for utility-scale, and much higher for residential.[3] Costs are dropping yearly, but it's likely that these systems won't be economically viable for some time without incentives.

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[1] Coignard, Jonathan, Samveg Saxena, Jeffery Greenblatt, and Dai Wang. 2018. "Clean Vehicles as an Enabler for a Clean Electricity Grid." *Environmental Research Letters* 13 (5): 054031.

[2] For example, Con Edison has a five-bus V2G pilot https://www.coned.com/en/about-con-edison/media/news/20180619/electricity-from-school-bus-batteries-will-support-con-edison-grid-reliability. PSE&G has an EV rate case in process that request funding for V2G school buses.

[3] For 30-minute capability. Green Tech Media. *Energy Storage Monitor Q4 2017.*

The EV R&D group estimates that adding bidirectional (V2G) capabilities to an EV charger will add in the range of $200 - $500 to production cost. An additional $200 of equipment would enable the system to respond to grid operator signals. For a 6.6 kW Nissan LEAF, that would be $700/EV or $106/kW for bidirectional storage. So, in total, $850/kW for a stationary battery versus $106/kW for V2G storage.

Because using EVs for storage is 1/7 the cost of building and operating purpose-built stationary batteries, and because more storage will eventually be needed when at higher levels of penetration of variable generation, EV storage, including V2G, will save ratepayers a significant fraction of the investment needed for storage.

NJ EVs with V2G could meet a significant fraction of New Jersey's storage goals
New Jersey has set a goal of 330,000 zero-emissions vehicles (ZEVs). Could this goal theoretically also meet the State's storage goals of 600 and 2,000 MW? At a typical 6.6 kW/EV, 330,000 EVs would be 2,178 MW of storage, more than enough to meet even the 2030 storage goal. Although not all EVs will have V2G capabilities, and not all will be connected to the grid at all times, this simple calculation illustrates that meeting New Jersey's EV target alone could provide a significant portion of New Jersey's storage capabilities.

V2G promotes EV adoption by lowering the total cost of car ownership
In PJM markets, a 10 kW bidirectional EV can earn $500/year. This may be split with a service provider managing the sale of capacity or ancillary services, but nevertheless could lower the cost of EV ownership by, say, $250 year, about the entire yearly cost of electricity as an EV fuel. Thus, the policies recommended here could help meet NJ's EV goals as well as it's storage goals.

Policies required to integrate V2G into the distribution grid
These changes could be addressed in the BPU regulatory code.

- Adoption of the industry safety standard for grid-integrated EVs
  The Society for Automotive Engineers has developed, approved, and promulgated this standard (called "SAE J3072") specifically to allow the safe interconnection of V2G-enabled vehicles via AC charging stations. The UL standards for solar inverters (UL1741) referred to in state regulations may be applicable for DC charging stations but are inadequate for V2G from AC charging. As such, interconnection rules should state that compliance with the SAE standard is sufficient to meet utility interconnection requirements.

- Retail credit for export
  Utilities should provide retail V2G customers with a credit against their monthly bill without penalty for the energy they export. When time-of-use rates apply to the connection point, this would incentivize customers to charge and discharge when it benefits the grid. (Unlike net-metered solar, which generates on its own schedule, a V2G system only exports to the grid either in response to price signals or when sent a dispatch signal.) This system is already in use in Delaware. It is allowed and regulated by Delaware law.[4]

- Raise the Level 1 interconnection limit to 25 kW or more
  The New Jersey administrative code allows "fast-track" interconnection for small resources that use equipment meeting approved standards. The current limit of 10 kW should be raised to at

[4] 26 Del. C. § 1014(g), § 1001

least 25 kW, as recommended by the Interstate Renewable Energy Council (IREC).[5] The IREC recommendation of a limit of 50 kW should also be considered as it would further cost-effective distributed storage.

- Expand interconnection standards to all distributed resources
  Current interconnection procedures in the New Jersey code apply to "Class 1 renewable energy" resources only. Interconnection of storage and retail credit for storage should be expanded to include storage technologies, including EVs with V2G, which are not under the Class 1 regulatory classification.

- Explicitly acknowledge in the BPU administrative code that EVs will not be prohibited from providing grid services.

The definition of storage should not inadvertently exclude V2G systems

A V2G system requires two components:

1. A "grid-integrated charging system" and its associated equipment that have the ability to allow two-way power flow between a grid-integrated electric vehicle and the electric grid. This includes the communications hardware and software that allow for the external control of the vehicle's battery charging and discharging by an electric distribution company, electric power supplier, PJM Interconnection or a distributed resource aggregator.
2. A "grid-integrated electric vehicle'' defined as a battery-run motor vehicle that has the ability for two-way power flow between the vehicle and the electric grid. The inverter may be located in the vehicle or in the charging system.

Note that since the battery is on board the vehicle and different vehicles may, over time, charge at a single station, the resource being interconnected is the charging station, not the EV. This ambiguity is resolved by V2G safety standard SAE J3072 (mentioned above) which only allows approved, certified EVs to export power at that location.

Discharge duration

The power requirement of 600 MW in New Jersey's Clean Energy Act could be interpreted to be consistent with actual uses for which these batteries might be used. Taking two likely, high value uses, if storage is to be used to bid PJM capacity, it would require 10 hours of discharge. If for spinning reserves or regulation, one hour would be enough for these markets. Thus, there is a reasonable argument for interpreting the MW level as being for either 10 or 1 hour.

FERC 841

FERC Order 841, when implemented, will make it possible for market participants with storage resources, including those behind the meter, to purchase at wholesale rates the portion of their charging energy that is later to be resold in wholesale markets. This means that the inevitable electric losses during cycling will be paid for at wholesale rates. However, this model can't be applied to distributed storage resources unless utilities agree to "net out" this wholesale charging energy from the

[5] Priority Considerations for Interconnection Standards: A Quick Reference Guide for Utility Regulators, IREC, August 2017. For the recommended standards themselves, see: Model Interconnection Procedures, IREC, 2013. https://irecusa.org/publications/model-interconnection-procedures

retail customer's bill.[6] We recommend that utilities evaluate the feasibility of accounting for this netting out of wholesale charging energy. This is a complex issue, and calls for review and discussion.

Our group would be happy to answer questions, provide model legislation, or contribute data and analysis on any of these topics, upon request.

Disclosure
Related to commercialization, we disclose that the University of Delaware as an institution and Willett Kempton as an individual have patents licensed to, and minority ownership rights in, Nuvve, a company that is carrying out V2G commercially. Nevertheless, the University of Delaware and, specifically, the authors of this briefing are committed to providing objective, vendor-neutral information about this storage resource. Enabling this new technology in New Jersey rules would not favor any particular company, rather it would open the market to all companies providing these services.

Sincerely,
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[6] "Each RTO/ISO must specify that the sale of electric energy from the RTO/ISO markets to an electric storage resource that the resource then resells back to those markets must be at the wholesale locational marginal price…To the extent that the host distribution utility is unable…or unwilling to **net out** any energy purchases associated with a resource using the participation model for electric storage resources' wholesale charging activities from the host customer's retail bill, the RTO/ISO would be prevented from charging that resource using the participation model for electric storage resources electric wholesale rates for the charging energy for which it is already paying retail rates….We find that efficiency losses are charging energy and therefore not a component of station power load. Accordingly, the charging energy lost to conversion inefficiencies should also be settled at the wholesale LMP as long as those efficiency losses are an unavoidable component of the conversion, storage, and discharge process that is used to resell energy back to the RTO/ISO markets." FERC Order 841 (2018).