Enabling Vehicle-to-Grid (V2G)
Recommendations for New York State

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EVs Can Benefit the Grid by:

- Managed charging (V1G): doesn’t discharge
- Vehicle-to-building: discharges onsite

- **Vehicle-to-Grid (V2G)**
  - Exports to distribution system
  - Compensation at retail or wholesale (e.g., NYISO, PJM)
    - Frequency regulation and other wholesale ancillary services
    - Energy and capacity markets
  - Third-party aggregator is key
    - Customers set preferences and travel schedules
    - Manages for revenue while maintaining battery life
    - Appears as single, reliable resource
University of Delaware’s Role

• Willett Kempton first laid out a V2G system & economics in 1997
• Developed aggregation platform, and hardware, now licensed world-wide
• This licensee, Nuvve Inc., provides my grant, and other, funding

1997 V2G Design

NEXT TRIP

DISTANCE NEEDED FOR NEXT TRIP
100 miles
50 miles
10 miles
2 miles
1 mile

TIME OF NEXT TRIP
SET HOUR

CHARGED ENOUGH FOR
20.6 MI

NOTE: CHARGE MILEAGE IS ESTIMATED, IT WILL BE LESS FOR FULL LOADS OR HILLY TERRAIN

COST SINCE LAST RESET
$15.73
(NEGATIVE INDICATES CREDIT)

CHARGING
DISCHARGING
SELLING ELECTRICITY

ALWAYS MAINTAIN ENOUGH CHARGE FOR
Never Sell
100 miles
50 miles
10 miles
2 miles
1 mile
V2G vs. Managed Charging (V1G)

- V1G on its own can provide substantial grid benefits
- Two automakers (Nissan and Mitsubishi) currently have production model export-capable EVs; BMW, Honda, Hyundai, and PSA are actively pursuing

Per LBNL 2018, V2G can provide “many times” the benefits of V1G in California\(^1\)
CA Peak Load Minus Solar Production (LBNL)
Battery Degradation - 1

- A number of studies modeling V2G have shown degradation, others are beginning to ease this concern:
  - Toyota 2015: used data from actual participation in the PJM frequency regulation market, at ± 4 kW: for small state-of-charge variation (normal in symmetric regulation), showed minimal additional degradation\(^2\)
Battery Degradation - 2

- Uddin 2017: when V2G optimized to reduce degradation, batteries showed less capacity and power fade than unmanaged daily charging (CF up to 9% less, PF up to 12% less) and even delayed charging

- Battery quality improving

- Nissan Europe will be first to provide same battery warranty whether or not owners provide V2G (requires approved aggregator and charging station)
V2G is operating commercially

- **UD/NRG 2013-2016**: world’s first V2G revenue

- **Denmark**: fleet providing frequency regulation since 2017, revenue of €1,400/yr/car, 20 vans now, soon 50

- **UD** currently in PJM queue: first interconnection as Small Generator

- **Pilots**
  - In Europe and CA
  - **School bus** pilots ongoing or proposed in CA, DE, and NJ – 100 to 200 kW per vehicle
Policy Needs - 1

1. Clear regulatory definition: are V2G systems storage, or a special category?
   • Make V2G an eligible resource for storage programs

2. Regulations updated in 2018 for distributed storage block V2G from interconnecting in a couple of ways, most importantly:
   • Requires certification to standard UL 1741: does not apply to AC charging systems’ on-board inverters
     • The Society of Automotive Engineers created standard J3072:
       • Acts as “protective gatekeeper” to only allow EVs with acceptable inverters to export
       • Like UL 1741, compliant with parent standard IEEE 1547
     • Automaker or third-party, instead of NRTL (Nationally Recognized Testing Lab) certification
3. V2G, and all BTM exporters, should be able to aggregate to meet minimums, and to switch between participation in wholesale markets and retail programs.

4. Charging and discharging rates
   - Retail level:
     - include in VDER Phase Two which addresses storage
     - Buyback programs
   - Wholesale markets: FERC Order 841 requires storage resources, including behind-the-meter, to be charged wholesale rates for the charging energy (including losses) later resold in wholesale markets
   - Unless utilities assist in “netting out” of end-use and energy for resale, storage resources must pay retail
Sources


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FERC Order 841

• “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.”
Battery Capacity Fade


Figure 6. Transition of state-of-charge

Figure 7. Capacity retention rate after high temperature durability tests, showing near equivalence in capacity whether or not V2G is added.