Enabling V2G: Technology Overview and Policy Implications

Prepared for

New Jersey Retreat on

Advancing Vehicle-to-grid technologies

Trenton, NJ

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The V2G idea and motivation

- Use batteries and chargers in EVs for grid storage, balance fluctuating wind and solar, possibly participate in electric markets…
  - Create a second use when the car is parked (average 23 h/day)
  - Brings a payment to the EV owner, thus lowering TCO
  - Makes very low-cost storage available to the grid, enabling renewable energy to provide >> 50% of electricity

Key Aspects of the V2G concept

- EVs already have both the battery and conversion equipment (charger and motor drive)
- Most light vehicles are parked 95% of the time, typically near a plug
- To provide grid services, existing components may need minor adjustments, e.g.
  - change charger to bidirectional charge & discharge
  - add controls and signaling to respond to grid
- Aggregation means meet trip needs of any individual, and also meet aggregate need for balancing or reserves by TSO
- Light vehicles become part of the solution for CO_2, rather than the biggest problem

How V2G works — User’s view

1 PLUG IN YOUR CAR
to any charger

Courtesy NUVVE

2 CHARGE BATTERY
safely and efficiently in V2G Mode

Courtesy NUVVE

3 MAKE MONEY

by providing power capacity
and sending energy back
and forth to regulate the Grid

OR SAVE COSTS

by using stored energy from
EV batteries to reduce building
energy peak consumption

Courtesy NUVVE

4 YOU'RE READY TO DRIVE

with the charge you set for the day
with advance trip planning using a
mobile fleet management app

Courtesy NUVVE

We will need storage for high-penetration renewables, to meet CO2 goals, but…

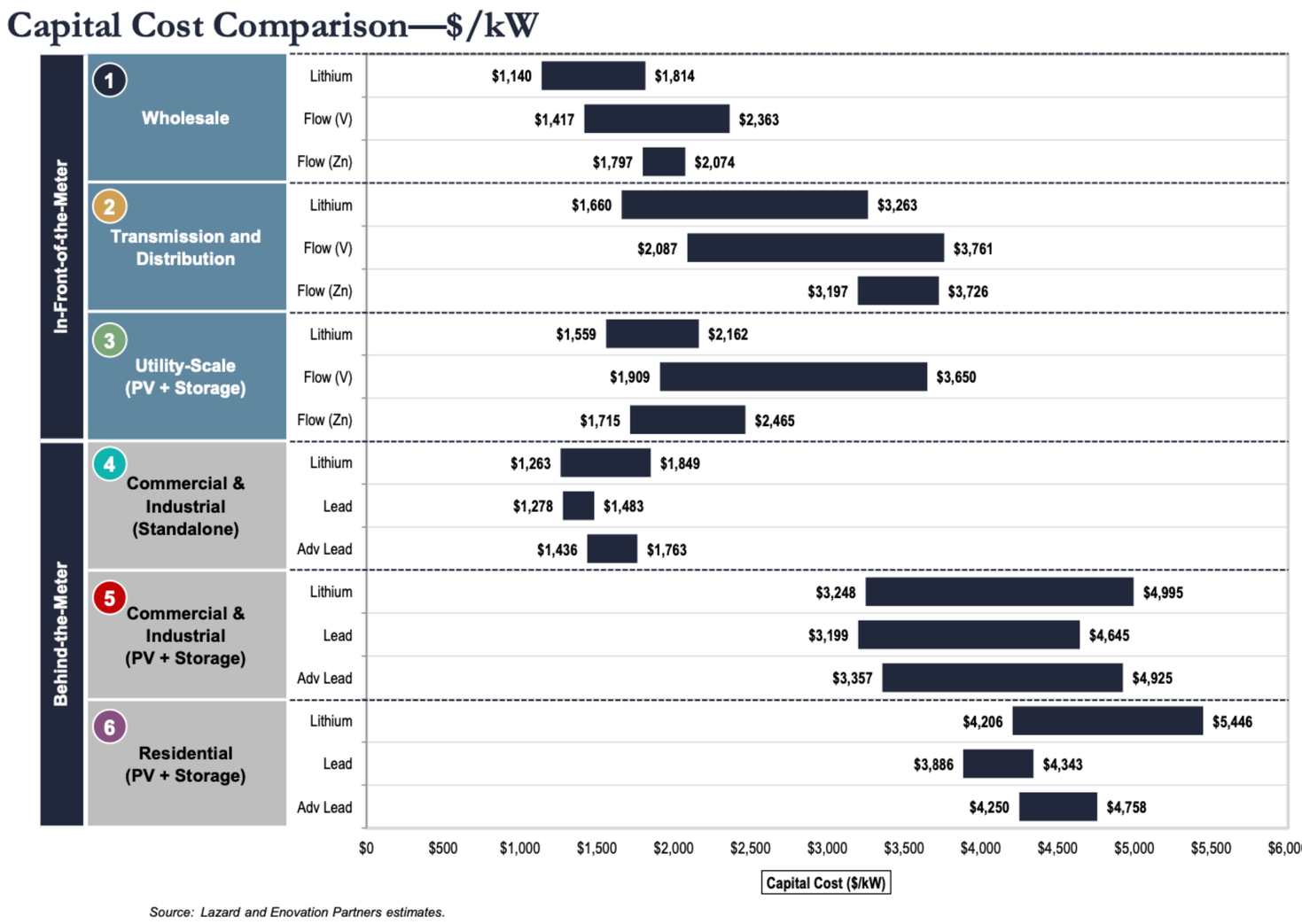
Storage is expensive

So, how to bring up enough storage at least cost?

Purpose-built Storage is expensive

Lazard: Capital cost $1K - $5K / kW

Lazard LCOS v4.0, 2018



Source: Lazard and Enovation Partners estimates.

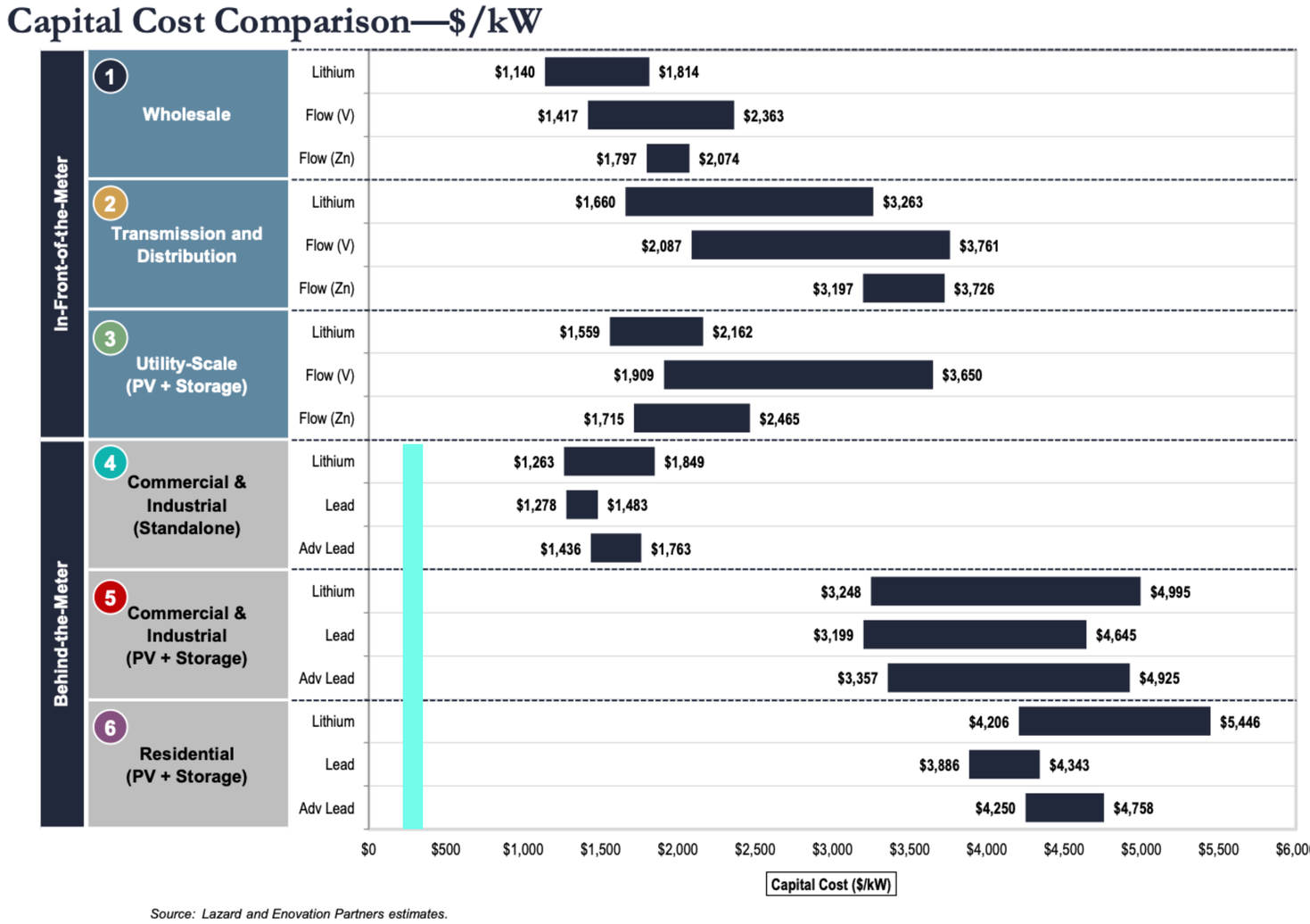
Capital Cost of EV storage

- Assuming AC charging, power conversion on-board EV …
- Demo: Replace on-board charger with 15 kW bidirectional ~$3000 qty 300
- OEM build: Design change of 10 kW on-board charger for bidirectional flow, per-vehicle ~$300
- Add communications and logic to on-board charger and charging station (EVSE). Demo qty: ~$400 incremental cost. OEM: ~$150 per EVSE
  - Demo projects: Capital cost $3400 for 15 kW charger or $227/kW
  - OEM production: Capital cost $450/10 kW = $45/kW
- Service and customer support adds $150/year or $10/kW/year

EV storage is not expensive

EV storage

Demo $227/kW



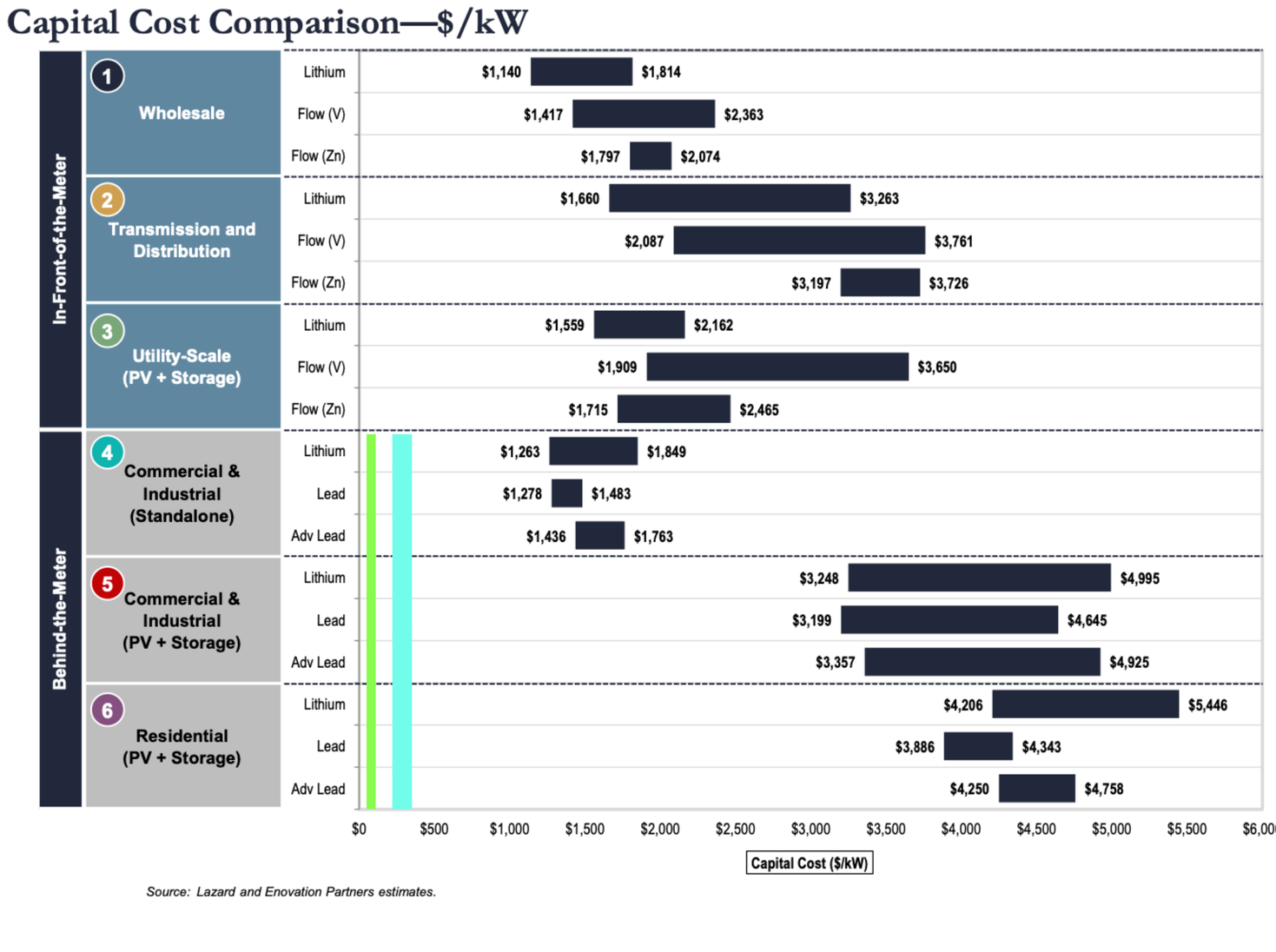
Source: Lazard and Enovation Partners estimates.

EV storage is not expensive

EV storage

Demo $227/kW

OEM production $45/kW



Source: Lazard and Enovation Partners estimates.

Example revenue

- US PJM regulation (System operator service, like balancing): $US 1,200 per EV per year, if consistently plugged in 23h/day at 19 kW.
- Denmark, Primary reserves market, earning €1,600/EV/year, only selling during off-work hours at 10 kW.
- US, typical standard peak/off peak rate arbitrage, $50-$200/year.
- Thus, need to understand market to understand business model—varies from $50 to $1800/EV/year.

The economics are Improving

- On-board (AC) charger, lower cost
  - AC charging 1/3 to 1/2 cost of DC charging
- Bidirectional (V2G) is 13x revenue of controlled charging, but more complex.
- Higher power per car means higher revenue (higher power means kW in/out, may not need higher kWh battery)
- Consistency of driver plug-in when parked, higher revenue

Commercial Operation Today

DENMARK V2G installations

AFA JCDECAUX fleet in Copenhagen

UK’s first V2G installation in Nissan Technical Center in Cranfield + Newcastle University

US projects underway in California and PJM

V2G School Busses in California

Stationary storage in PJM

BMW MiniEs with VSL inside

AC, three-phase charging + V2G

Tested to charging standards at National Renewable Energy Lab, Golden, CO

Participating OEMs

- BMW (demonstrations)
- Honda (Development of commercial EV with V2G built-in)
- Nissan Europe (commercial Leafs & eNV200s warrantied for V2G via DC)
- The Lion Electric (commercial sales of V2G busses)
- Renault (mass produced V2G capable vehicle)
  - Some have done detailed studies of effect on warrantee & battery life & decided that is not a problem

Policy Approach

Regulatory steps needed for a state

- Regulatory changes to allow EVs to provide grid services, including backfeeding (V2G)
  - Interconnection: Safely connect a mobile battery and inverter to the electric grid (governed by law & standards).
  - Credit for export: Fair payment for discharging.
  - Allow offering EDC and RTO services

Support for demonstration program(s)

- Why? Initial program costs more than self-supporting, so some incentive or subsidized demonstration needed
  - Needed to test small scale and decide if, and how to, deploy large scale
  - Could be done by utility, fleet user, or a state agency
- Some form of support by state helpful (either approved utility rate base, or state subsidy for incremental cost).

END

More information:

https://crew.udel.edu/v2g/

twitter @Willett Kempton

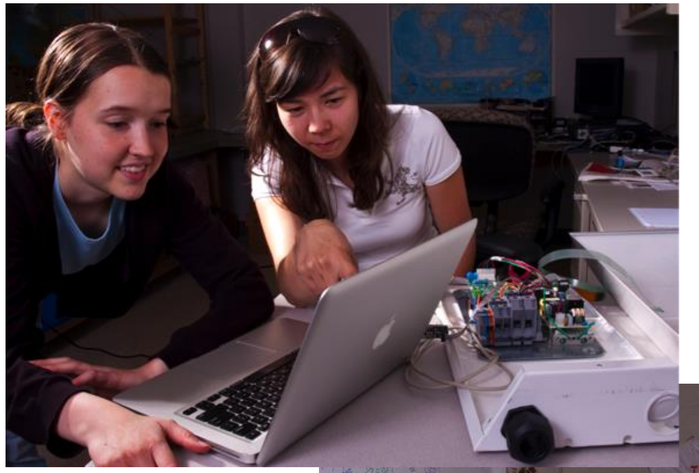
First demonstration, Oct 2007

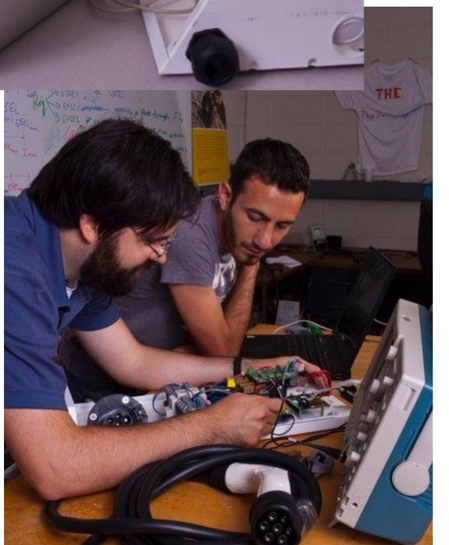
Running EV from TSO Control Signal

UD, Delmarva Power, PJM, Pepco Holdings

Many Contributed

To these technologies, policies demos, and research results…





UD + Nuvve
US teams

Components of a V2G system

Three Components of GIV

- **Aggregation Server** (in central location)
  - Real time operation of a set of vehicles
  - Provide services to an electric grid entity
- **EV with Vehicle Smart Link** (VSL, in car)
  - Control charging, report to server
- **Electric Vehicle Supply Equipment** (EVSE)
  - Grid location, internet portal, power connection, meter, interconnect permit

services

VSL

1. Nuvve aggregation server calculates power available from all vehicles
2. Offers power bids in TSO market
3. Dispatch vehicles as power adjustments are needed

Aggregation Server

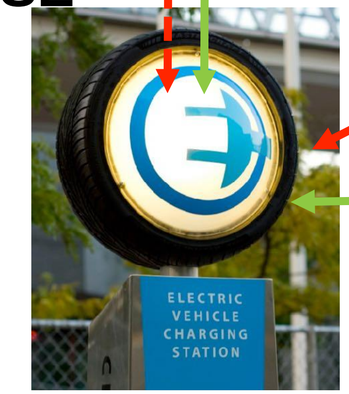
2-way communication.

One or 2-way power flow

IP communication with Nuvve server

Offers power bids, and reconciles statements to, grid operator

EVSE



Energy services delivered at connection point to the grid