Developing a GridView Flexible Electric Vehicle Charging Model

Future Grid Reliability Study

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Purpose of this Presentation

- In response to various questions about electric vehicles (EVs), the ISO has prepared this presentation:
  - To review current proposals to represent Electric Vehicles in the Future Grid Reliability Study (FGRS)
  - To discuss limitations in both data and modeling
  - To examine a conceptual model for flexible EV charging suitable for either
    - One-way "charging only" mode
    - Two-way "Vehicle-to-Grid ("V-2-Grid") mode
  - Request feedback on the preference for fixed EV charging profile vs. an LMP based "system benefits" flexible charging model

Conceptual Model of Integrated EV Charging

- Develop a framework where EV charging would respond to system LMPs
  - Mesh with GridView's "objective function" for "minimizing production cost"
  - Represent charging flexibility to allow GridView to maximize "system benefits"
- Explore concepts around flexible charging
  - Amount of flexibility could be adjusted
    - One-way, "charging only" mode
      - Would have a limited operating range to increase or decrease charging
      - Probably limited to the minimum amount of charging load (no exporting to the grid)
    - Two-way, V-2-Grid mode
      - Charging and discharging can be a significant fraction of the charging load
      - Even vehicles not driven (and charged) on a daily basis can be assumed to participate

Background on Electric Vehicle Batteries

- Large amounts of vehicle battery storage capability have been implied
  - 2020 Economic Study assumed 2.2 million electric vehicles
  - Equivalent to 180,000 MWh of vehicle battery storage
    - Based on Tesla Model 3 at 82 kWh
    - About 22 times the assumed market facing batteries in the 2020 Economic Study
      - 2020 study assumed 8,000 MWh
      - Based on assumed 2,000 MW at 4 MWh/MW
    - Only a small portion of the vehicle flexible storage capability MWh will be used
- EV batteries are envisioned to withstand extensive cycling
  - "Million mile batteries" are being developed
  - See https://www.greencarreports.com/news/1128221_gm-battery-chief-600-mile-evs-viable-million-mile-battery-in-sight
  - EV mobile batteries appear resilient and can be repurposed when their energy density to weight ratio degrades (used in stationary battery facilities)

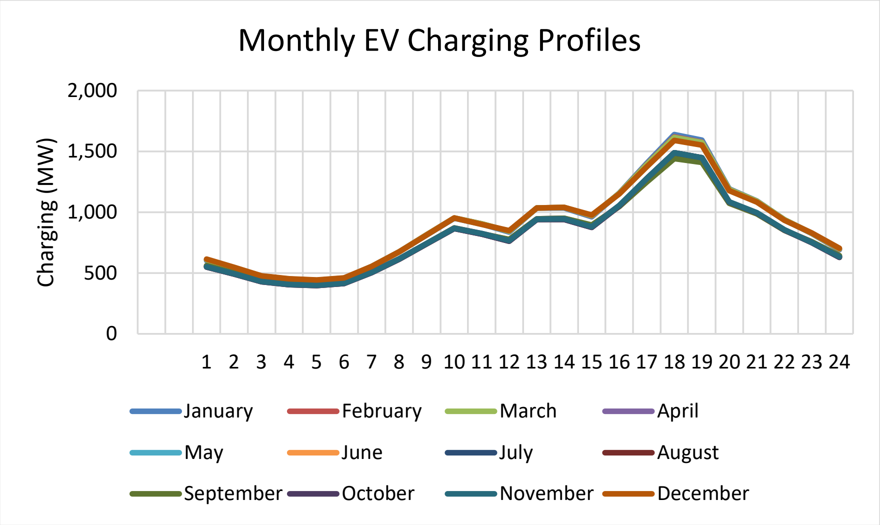
REVIEW OF EV PROPOSALS

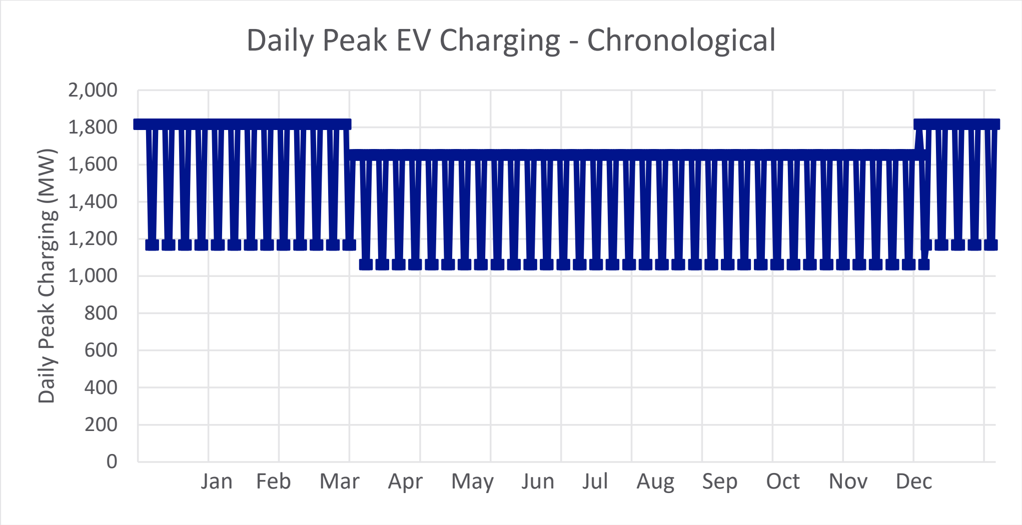
FGRS Matrix Scenarios

Matrix Scenario – EV Assumptions

Scenario	Transportation
Matrix Scenario 1	Peak: 1,817 MW Demand: 7.3TWh Hourly shapes, broken down by subarea proportional to population; Generally charging is lowest in the morning and peaks at hour ending 18:00 2035 EV assumptions represent a top-down projection of electric vehicle adoption. It focuses on light-duty vehicles and is absent of significant incremental policy support, including policies designed to impact EV charge timing. The EV load represents 2.2 million light-duty vehicles electrified by 2035 in ISONE (~19% of vehicle stock, 50% of new sales). May 20, 2020 PAC, slide 13 June 17, 2020 PAC, slides 22-23
Matrix Scenario 2	EV contribution to winter 8PM peak: 3,578 MW EV Demand: 18.5 TWh EV stock based on forecast total vehicle miles and transportation sector emission targets EV demand profiles based on ISO-NE "Final Draft 2020 Transportation Electrification Forecast", adjusted to account for more coordinated charging
Matrix Scenario 3	Transportation 39.9 TWh (embedded in load forecast from EnergyPATHWAYS) (Primary fuel type emissions reduced by approximately two-thirds relative to 2020)

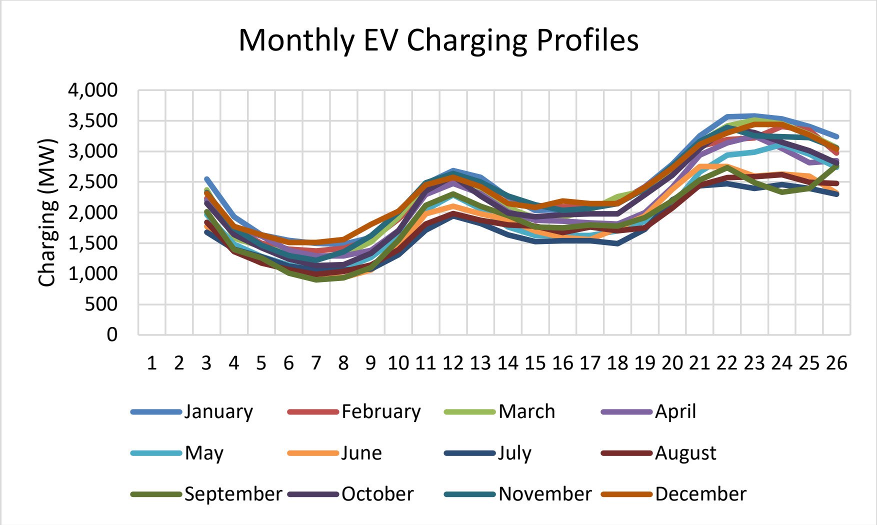
Matrix Scenario 1 – 1,817 MW/7.3 TWh

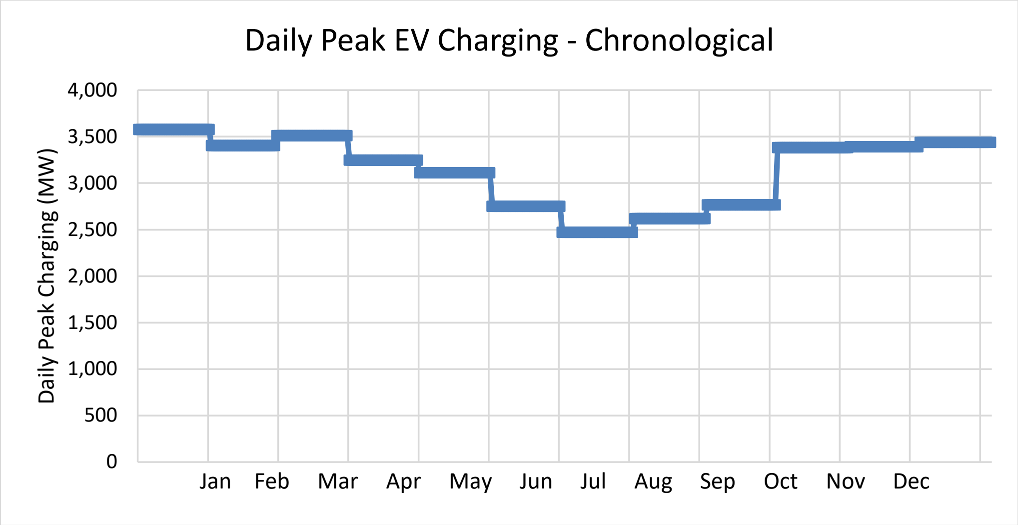




The January 1st weekday charging energy is 12% of the assumed 180,400 MWh fleet capability (based on 82 kWh/vehicle)

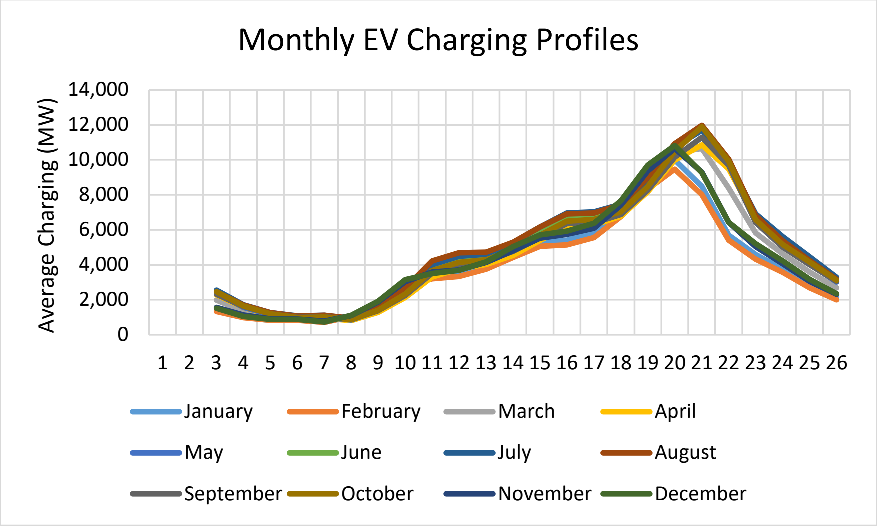
Matrix Scenario 2 – 3,575 MW/18.5 TWh

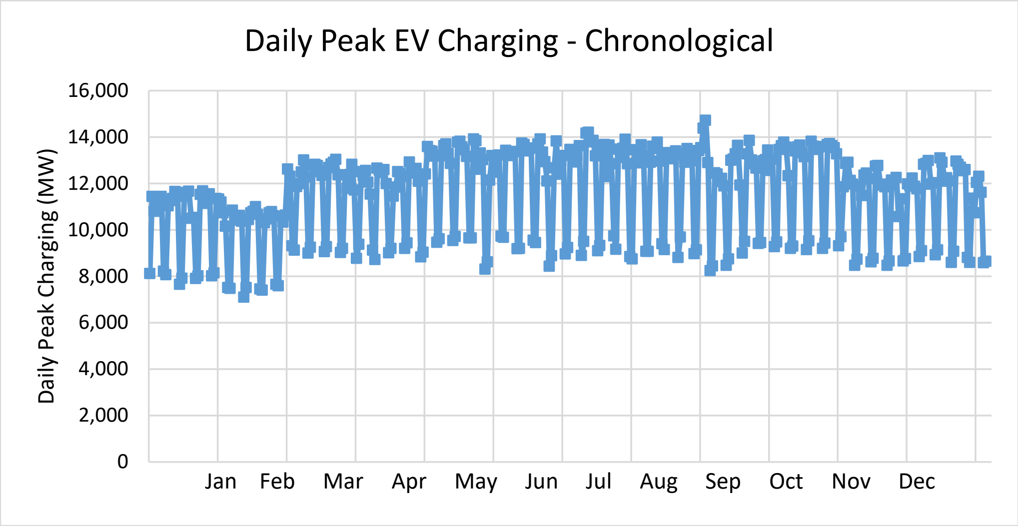




The January 1st weekday charging energy is 19% of the assumed 303,400 MWh fleet capability (based on 82 kWh/vehicle)

Matrix Scenario 3 – 14,714 MW/39.9 TWh





The January 1st weekday charging energy is 15% of the assumed 647,800 MWh fleet capability (based on 82 kWh/vehicle)

LIMITATIONS IN EV DATA AND MODELING

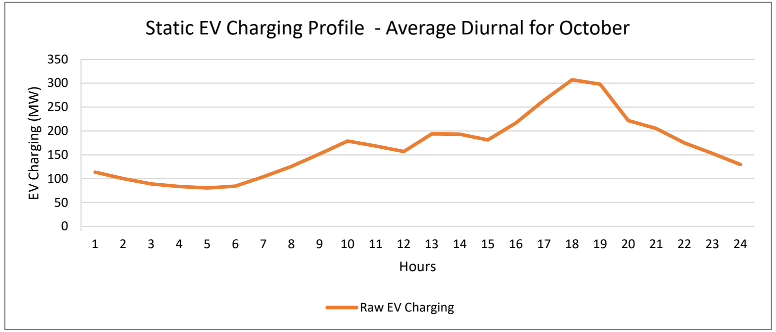
FGRS Modeling Challenge

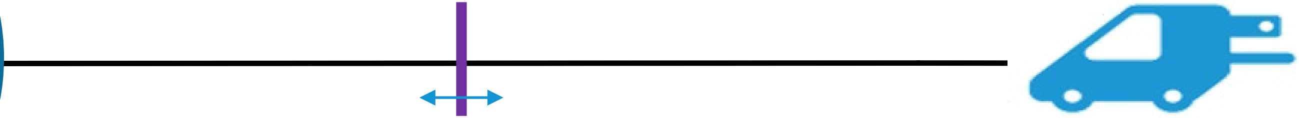
EV Data Issues

- Future EV charging profiles are unknown
  - Expectations in proposed Matrix Scenario profiles seem to reflect:
    - EV energy consumption (e.g., vehicle mileage driven) will dominate daytime hours and early evening
    - Roughly corresponds to daily work week/school week
    - Charging will be mostly in evenings and overnight
  - Amount of flexibility in future EV charging is unknown and depends on:
    - Driving range capabilities of future EVs (e.g., “range anxiety”)
    - Mid-day recharging opportunities (convenience and availability)
    - Time-of-charging incentives

- Incentives for EV charging behavior can influence apparent load

Fixed EV Charging Profile: Flow Across Interface





EV Interface can be monitored

Incentives for EV Charging Behavior

- Time-of-day incentives
  - Unlikely to induce a robust, beneficial charge/discharge profile every day
  - Charging and discharging at inopportune times to be expected
- Potential for two-way interactions between vehicle batteries and "the grid" (V-2-Grid)
  - Charge batteries when LMPs suggest renewable resources are on the margin
  - Discharge batteries when LMPs suggest non-renewable resources are on the margin
  - Provide energy and/or load following ancillary services
    - Assumes V-2-Grid batteries charge and discharge to provide "system benefits"
    - To provide "system benefits" dispatch signals must emanate from ISO control room
      - LMP key parameter for charging/discharging
      - ISO control room regulation signal may also be available for charging and discharging

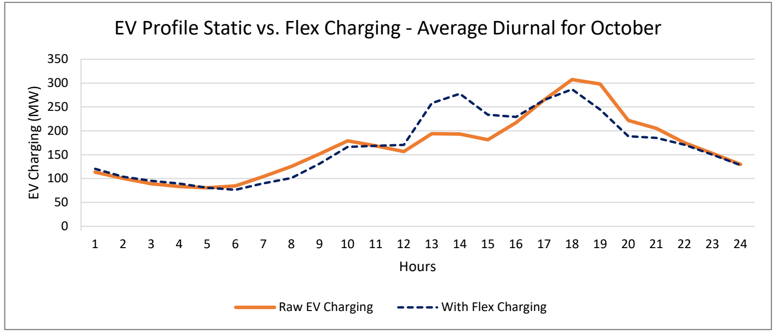
EXPLORING CONCEPTUAL EV FLEX CHARGING

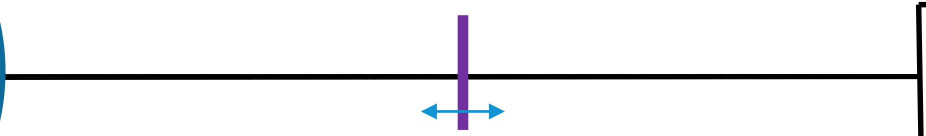
“Systems Benefit” Framework

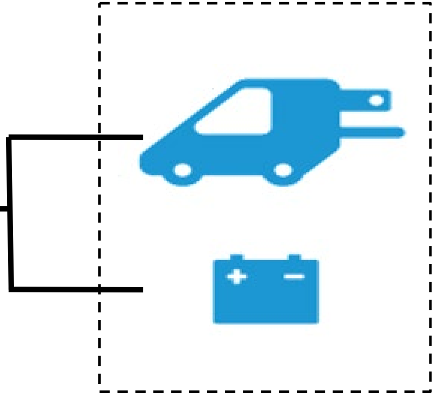
Exploring a Conceptual EV Model

- Assumptions are required for the conceptual EV model
- Vehicle batteries with highest energy density to weight ratio are preferred
  - Degradation of energy density is a concern of all EV owner/operators
  - Need to reflect a value for the degradation of energy density
- Assumed vehicle battery Variable O&M
  - Variable O&M for mobile batteries need to reflect premium for preservation of energy density to weight ratio
  - Assumed to be $9/MWh (each direction)
- “Trading Friction” on EV interface can also be added to reflect owner/operator reluctance to offer bi-directionality

EV Charging Model: Flows Across Flex Interface







"Flex" Interface can be defined

"Trading friction" can be applied to flows in one or both directions

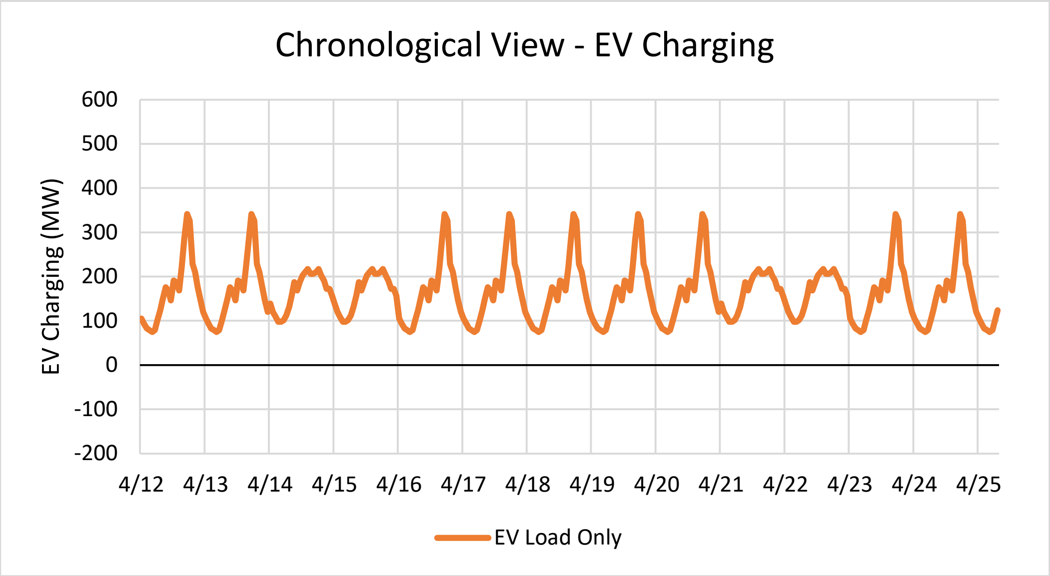
CONCEPTUAL EV MODEL

LMP Responsive EV Model Based on System Benefits

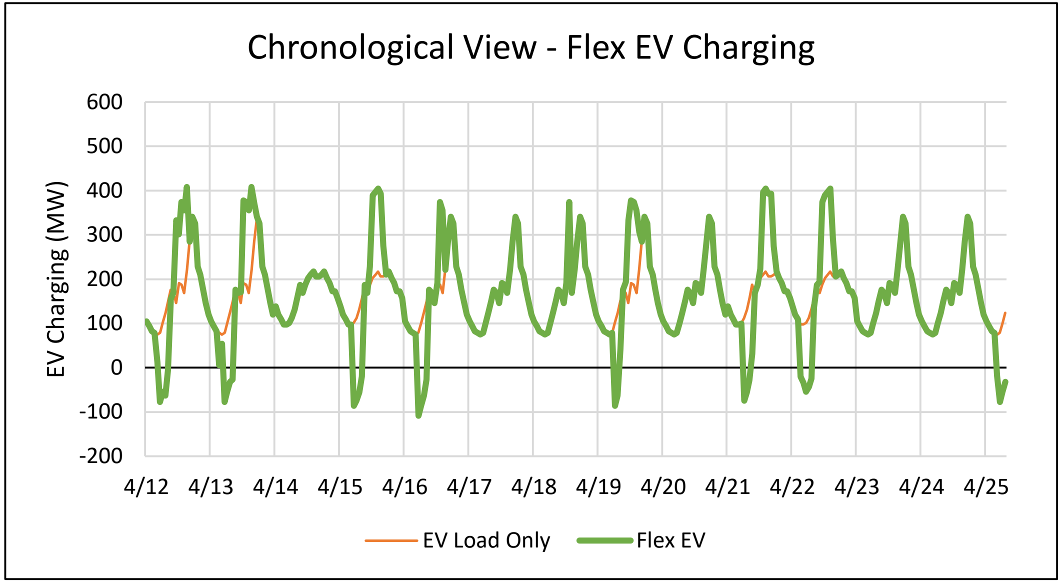
Conceptual EV Flex Charging Model: Example

- A conceptual Flex charging model has been developed
  - Responds to LMPs
    - Opportunity to charge when LMPs are “lower”
    - Opportunities to discharge to the grid when LMPs are “higher”
  - Uses GridView’s energy storage algorithm
    - Minimization of production cost
    - Use of battery capability for “system benefit”
  - Example assumes following parameters
    - EV load modeled at an aggregate RSP sub-area level
    - Battery MW (“inverter”) size is 50% of RSP sub-area peak charging pattern
    - Battery capability is four MWhs/MW of “inverter”
    - Battery variable O&M is $9/MWh (each way) to represent preservation of high energy density to weight (3 times variable O&M for grid-facing battery)
    - Zero additional trading friction across vehicle-to-grid “interface”
    - Round-trip efficiency of 86 percent

Chronological EV Charging (14 Days in April)

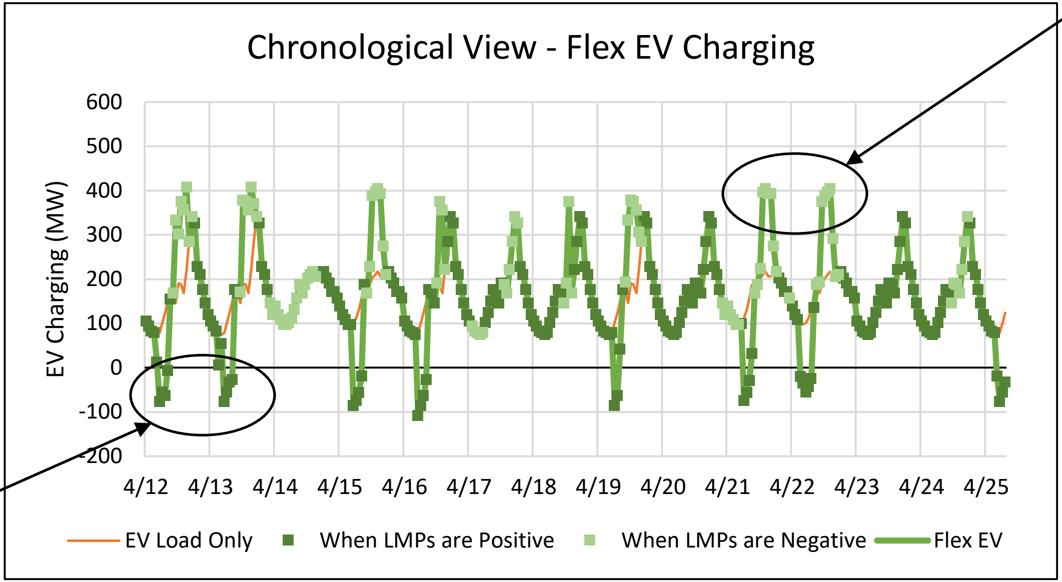


Chronological Flex Charging (14 Days in April)



NOTE: LMP induced flows may be either “into” or “out of” the EV/battery system depending on state-of-charge and LMPs in adjacent hours, not just one specific hour.

Chronological Flex Charging With LMPs

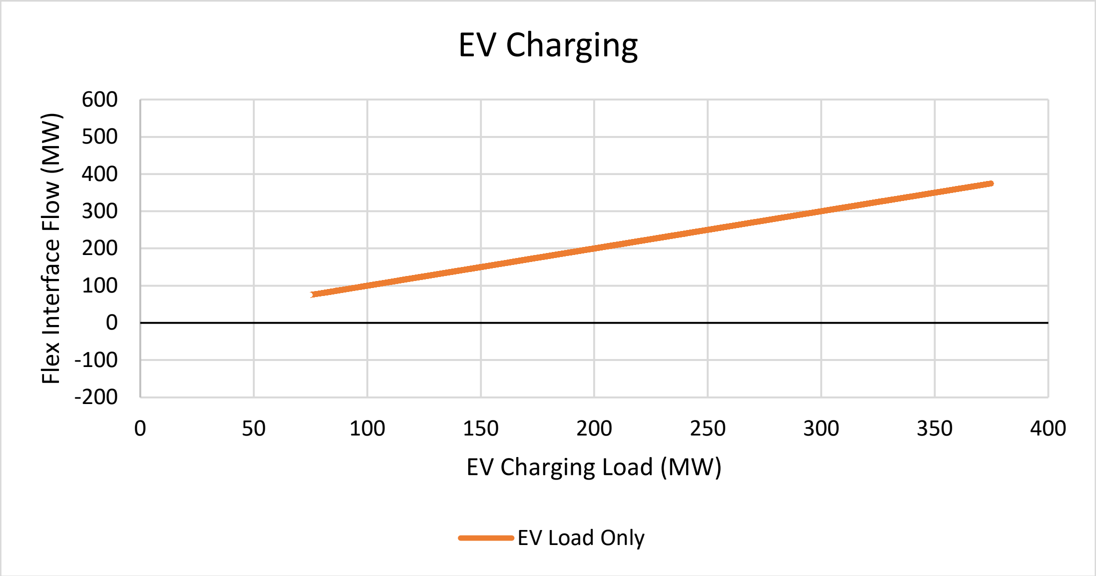


Additional EV charging

Reduced EV charging and/or export to the grid

NOTE: Charging tends to increase when LMPs are negative.
Charging tends to decrease (or export) when flows are positive

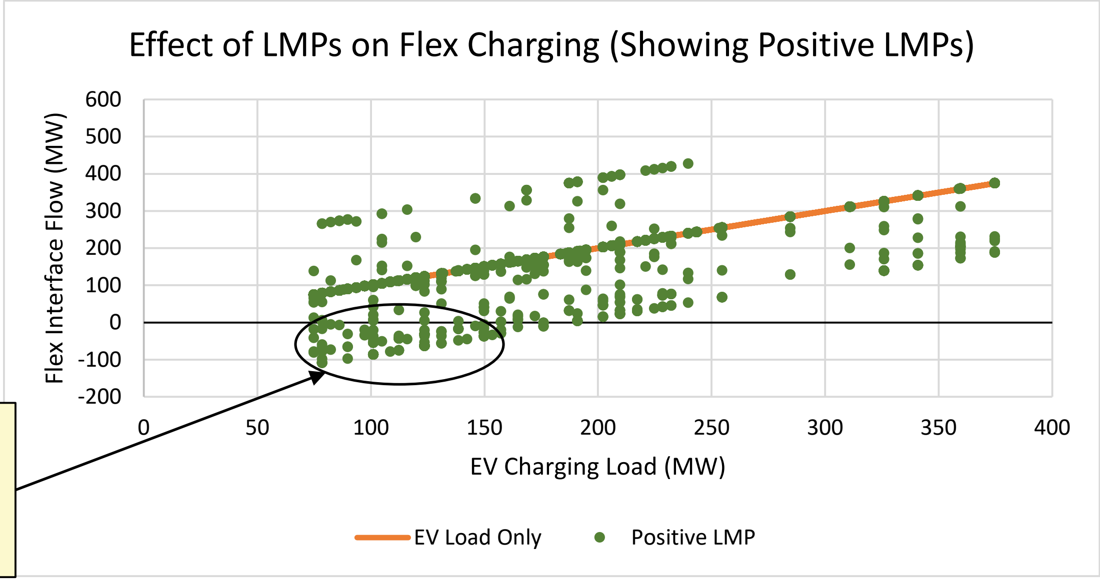
Flex Interface Flow: No Flex – EV Charging Only



All 8760 hours

With no flex charging, interface flow equal EV charging

Flex Interface Flow: When LMPs are Positive

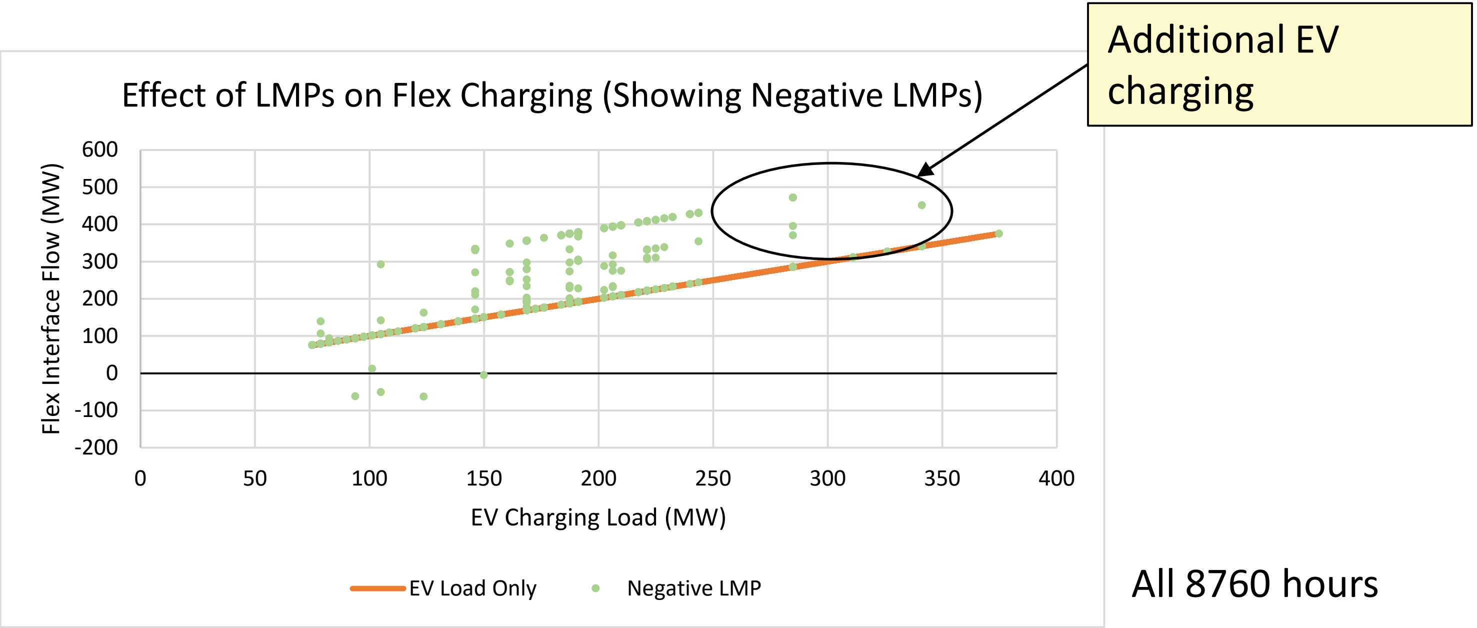


Reduced EV charging and/or export to the grid

All 8760 hours

With Flex charging, positive LMPs tend to decrease charging and possibly export to the grid

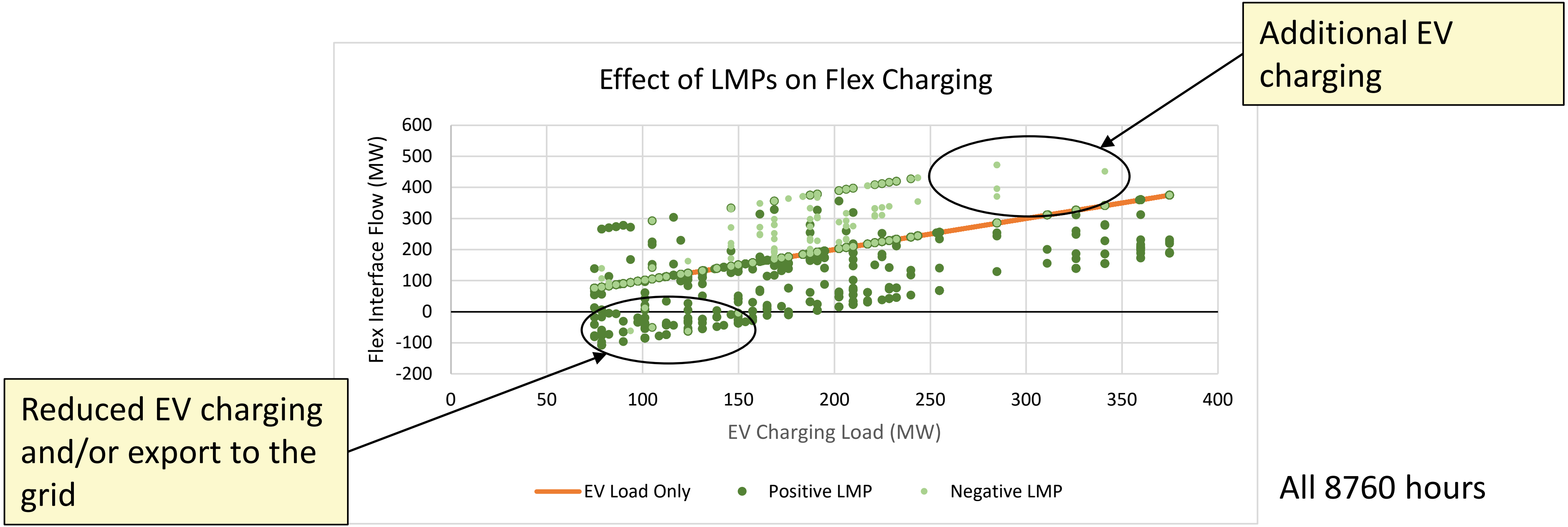
Flex Interface Flow: When LMPs are Negative



All 8760 hours

With flex charging, negative LMPs tend to increase charging

Flex Interface Flow: All LMPs



All 8760 hours

With flex charging, interface flow responds to LMPs

OBSERVATIONS ABOUT FLEX CHARGING MODEL

FGRS EV Modeling Questions

Broad Assumptions Used in Conceptual EV Model

- Key assumptions to review:
  - Flex charging allowed V-2-Grid exports, but exports to the grid are optional
  - Willingness of vehicle owner/operators to make battery capability available to provide “system benefits” was assumed
  - Assumed Flex charging to be 50 percent of EV peak charging MW
  - Assumed 4 MWh/MW of participating EV load for:
    - “additional” charging/absorption
    - “additional” discharging/depletion capability
  - Variable O&M of $9/MWh (each way) seems like a reasonable barrier to excessive degradation of energy density to weight from low-value operation
  - Additional “trading friction” across interface seems unnecessary
  - Distribution system assumed to have an ability to support V-2-grid

FGRS Matrix Scenario – EV Assumptions

Scenario	Number of Vehicles (Million)	Total EV Peak Charging (MW)	Total EV Battery Storage (MWh) *	EV/battery "Inverter" (MW)	EV/Battery Capacity (MWh)
Matrix Scenario (Profile) Assumptions				Flex Model Assumptions	
Matrix Scenario 1	2.2	1,817	180,400	909	3,634
Matrix Scenario 2	3.7	3,578	303,400	1,789	7,156
Matrix Scenario 3	7.9	14,714	647,800	7,357	29,428

* Total EV Battery Storage (MWh) based on 82 kWh/vehicle

Observations About Flex Charging Model

- EV charging has typically been represented as a static profile
  - Static profile can be adjusted to reflect time-of-use incentives
  - However, time-of-use creates a different assumed static profile
- Flexible EV charging may be a better representation than a static profile
  - Responds to system conditions as reflected in LMPs
  - Parameters can be adjusted for “charging only” or two-way “V-2-grid” operation
  - Based on assumptions about
    - Assumed MW discharge to the grid
    - Energy storage available
  - Simulation results show EV/battery has about 1.5 percent capacity factor
- Stakeholder feedback invited

Questions