Virtual Odometer Proposal to Account for V2X Usage

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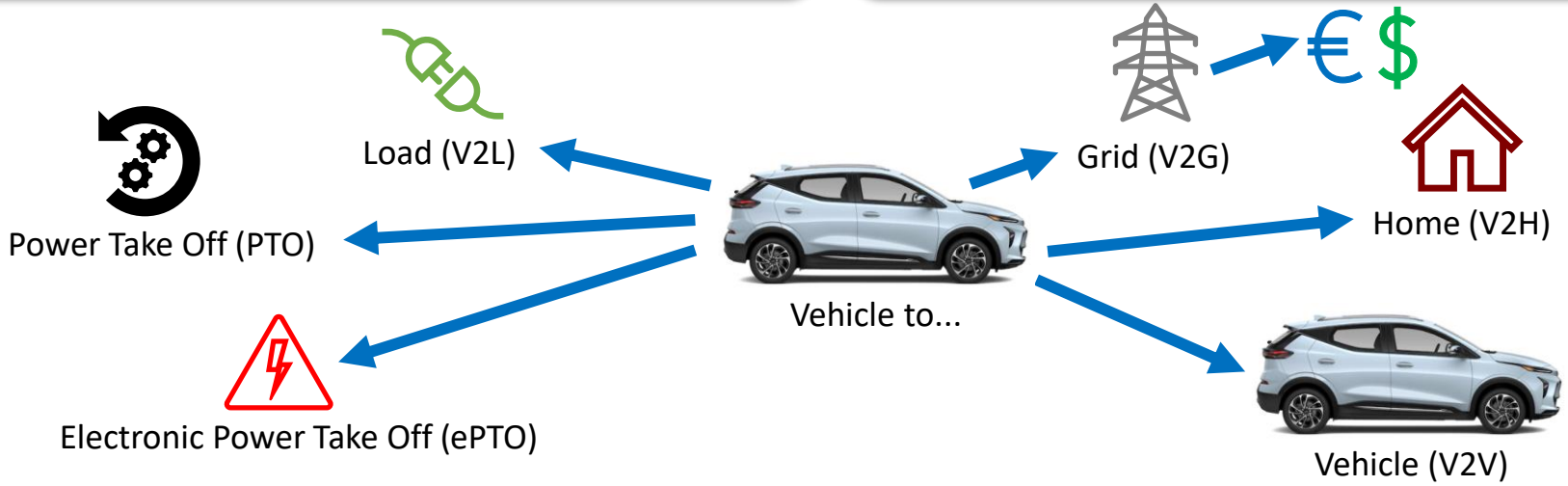
Vehicle to X (V2X) Definition

We will define V2X as the **transfer of energy** from a vehicle to an **offboard device**, or for an **offboard use**, while the vehicle is **stationary**

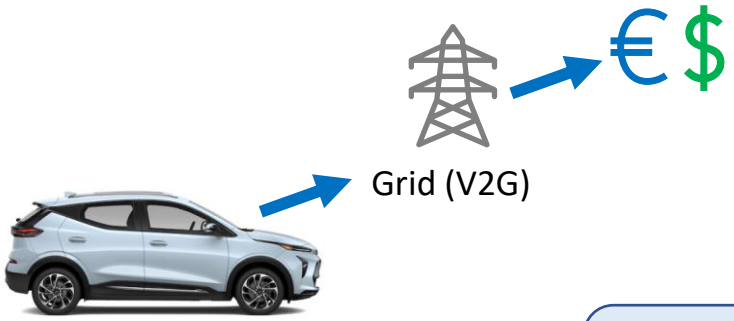
V2X enables the vehicle to become a **power source** in addition to a mode of transportation



Note: Please do not confuse this V2X definition with the unrelated V2X definition in SAE J2735 for vehicle to vehicle or vehicle to infrastructure communication.

Vehicle to Grid (V2G)

California Energy Commission: "[Vehicle-grid integration] is a key tool for **achieving California's decarbonization and electric vehicle adoption goals**."*



Customers will have a **financial incentive** to buy/sell energy to the grid

* https://www.energy.ca.gov/programs-and-topics/programs/vehicle-grid-integration

Why Track V2X Usage?

More Battery Throughput and Wear

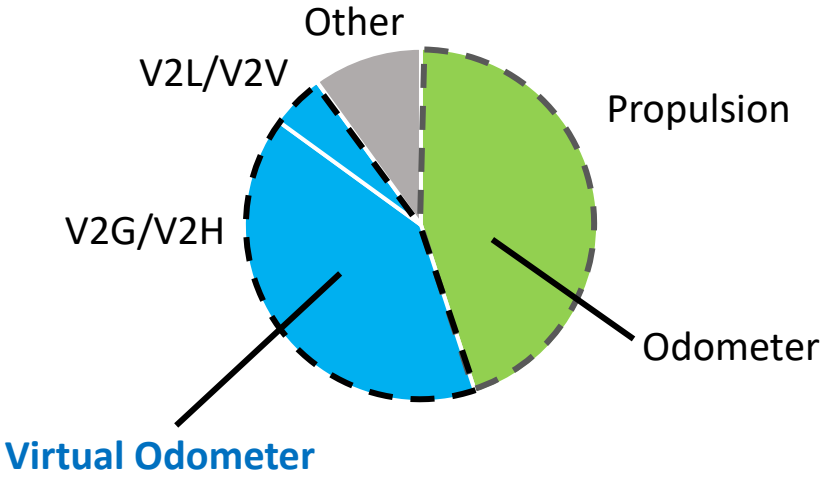
V2X causes wear and tear comparable to propulsion use cases for some customers

Stricter Regulations

California Code of Regulations Section 1962.5

- Customer-facing battery State of Health Metric
- Warranty tied to State of Health Value

Example Discharge Energy Throughput



Opportunity

- Create a **new customer-facing metric** to account for high voltage (HV) wear and tear from V2X, specifically on the HV battery
- Let's create a **"Virtual Odometer"** to show the customer this V2X usage
- Encourage the **"Virtual Odometer"** to be encompassed in **propulsion warranty**

Virtual Odometer vs Alternatives

Conveying V2X usage on a Virtual Odometer in units of "kilometers" is the best choice

Preferred Option

Add in V2X Usage to Existing Distance Domain (Odometer)

- United Nations Technical Committee proposed an "equivalent virtual distance"* to account for V2X energy supplied by the vehicle
- "Equivalent virtual distance" + driven distance = total distance

Less Preferrable Option

Replace Distance (Odometer) with Novel Energy (kWh) Metric

- Force all warranty/maintenance to be based on energy throughput and calendar life
- **A kWh-based metric can cause confusion for the customer**

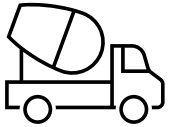
Less Preferrable Option

Add Novel Energy (kWh) Metric in addition to Distance (Odometer) and Time (Calendar)

- Added complexity: Three metrics for warranty/maintenance instead of two
- Both Distance and Energy are use-based degradation

* https://unece.org/sites/default/files/2021-10/GRPE-84-01e%20-%20track_0.pdf

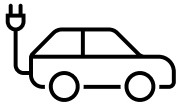
Measuring V2X Usage in “Kilometers”



ICE Vehicle with PTO

Conventional Indicators of Vehicle Use/Wear: Distance (Odometer) and Time

- Engine hours are easy to measure
- Engine power can only be estimated
- Maintenance procedures convert hours of operation to km



Electric Vehicle with V2X

V2X “Wear and Tear” can be expressed in distance and fit within the existing framework for warranty/maintenance

- Accurate sensors → *measure* power
- V2X loads can vary greatly

V2L ↔ V2V DCFC ePTO

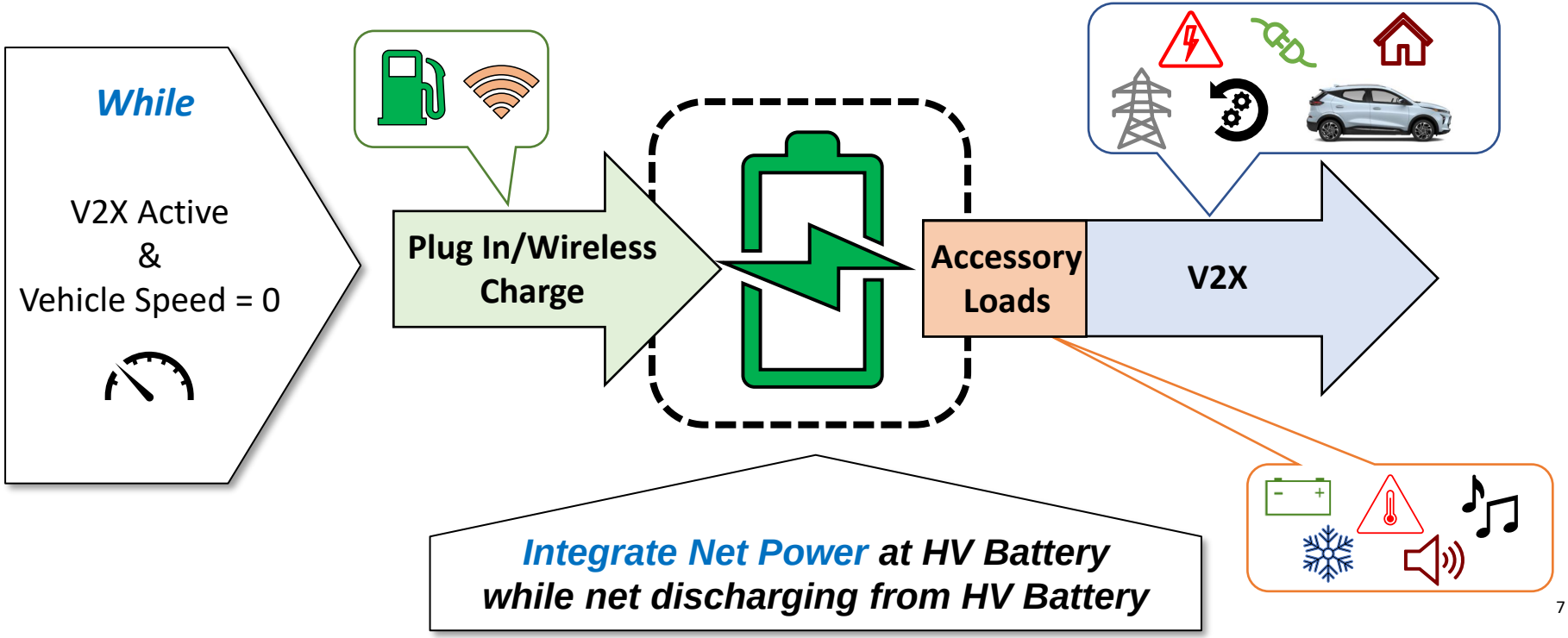
~1kW ~100kW

- Convert energy to km

“Virtual Odometer” Energy Metric

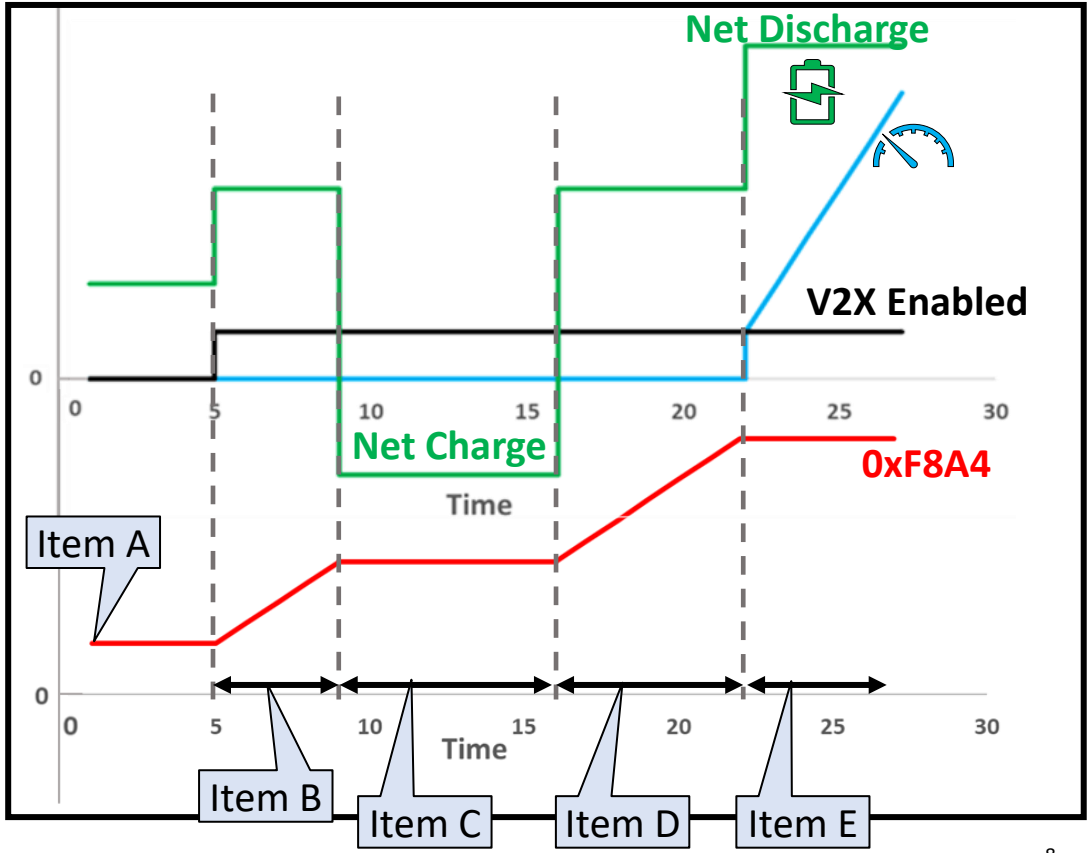
“Virtual Odometer Reading” = ***[What kWh metric?]*** X [What km/kWh conversion?]

$$\textit{Virtual Odometer Lifetime V2X Discharge Energy (kWh)}$$



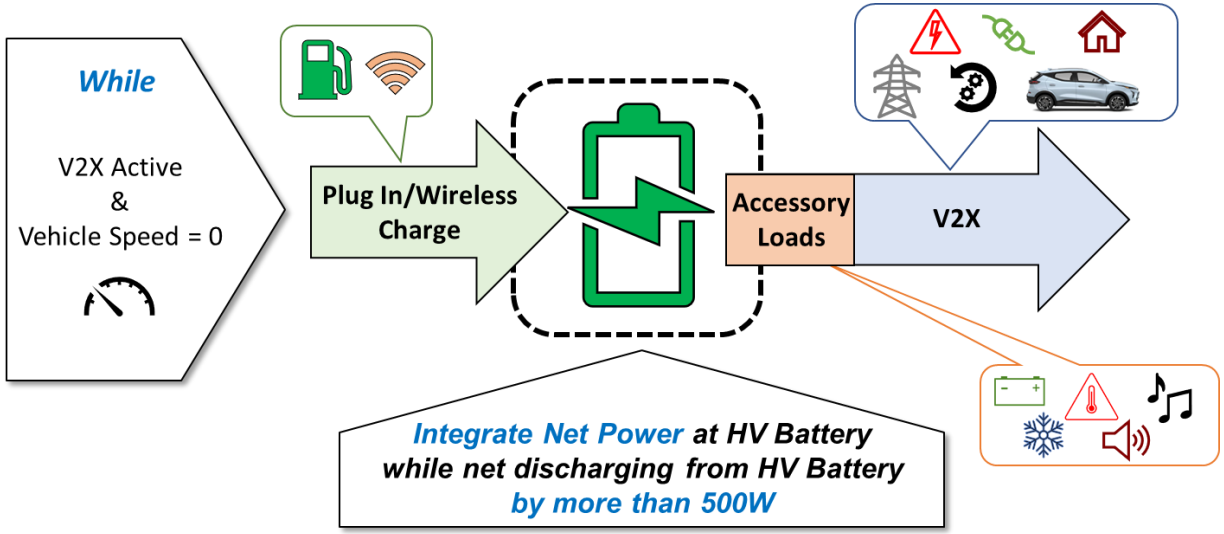
0xF8A4 → "Total Lifetime Discharge Energy in V2X”

Item A	0xF8A4 hold value from last V2X event
Item B	0xF8A4 increments up
Item C	0xF8A4 holds value • Example: PIC > V2X loads • Net energy into HV Battery
Item D	0xF8A4 increments up
Item E	0xF8A4 holds value • Vehicle no longer stationary • Driving Odometer increments up • We do not want to “double count” V2X and driving odometer miles



Possible Adjustments Based on Regional Certification Requirements

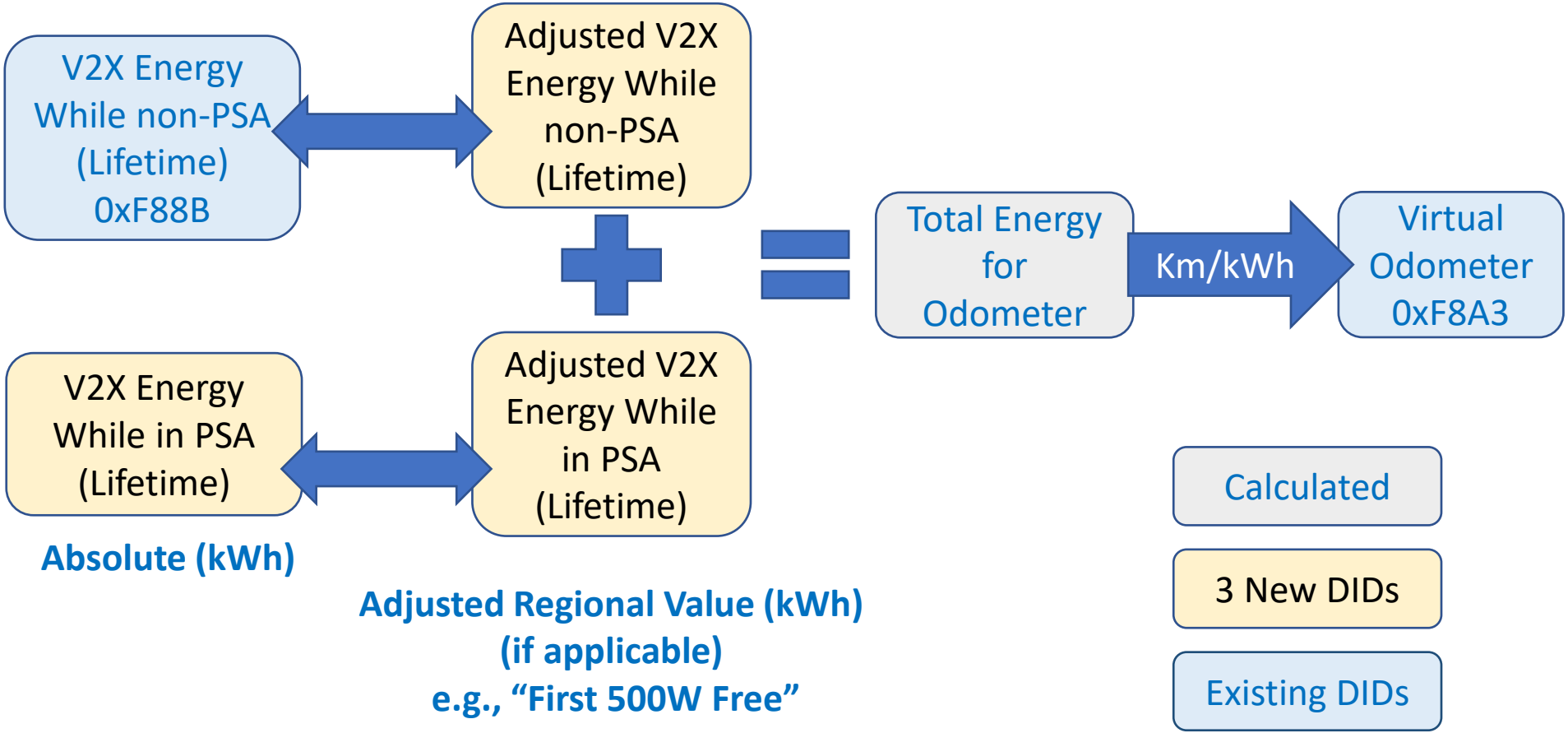
Example: **"Below 500W Free"**



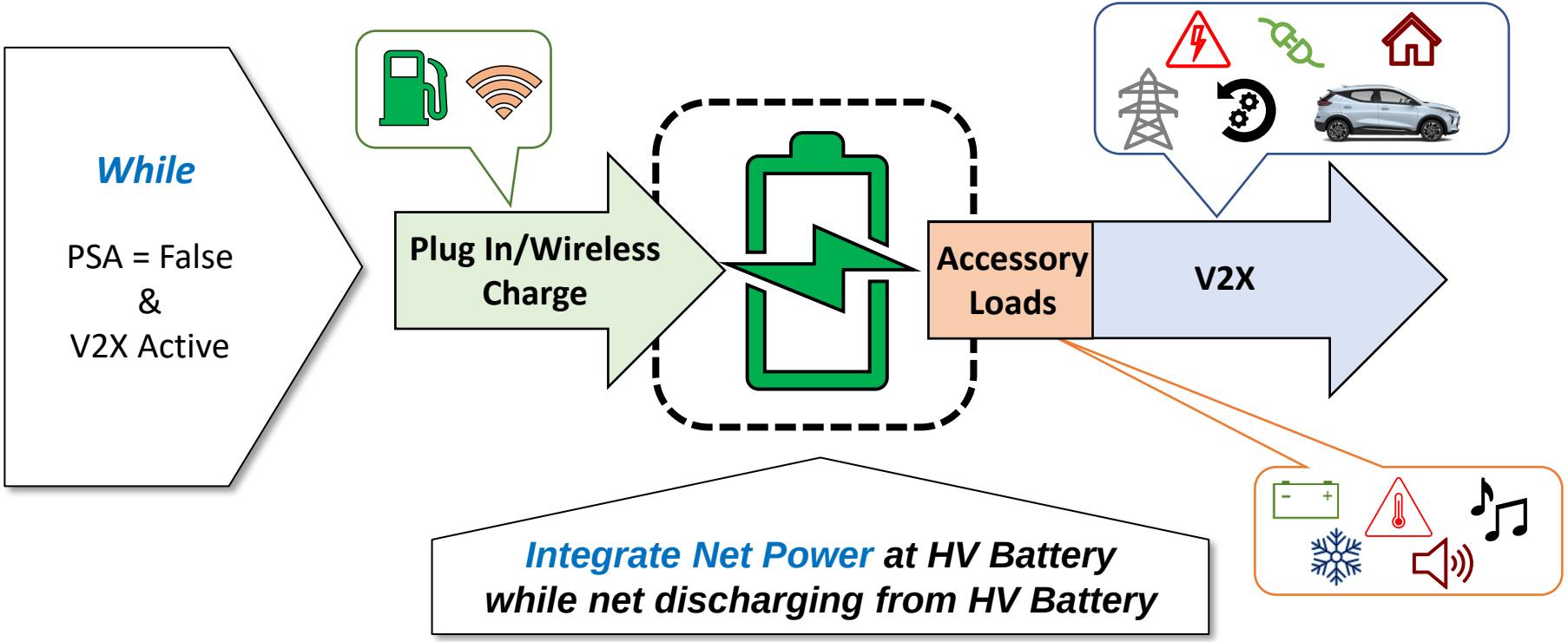
Only count battery power if it exceeds 500W

Does not count low power V2X usage towards the virtual odometer

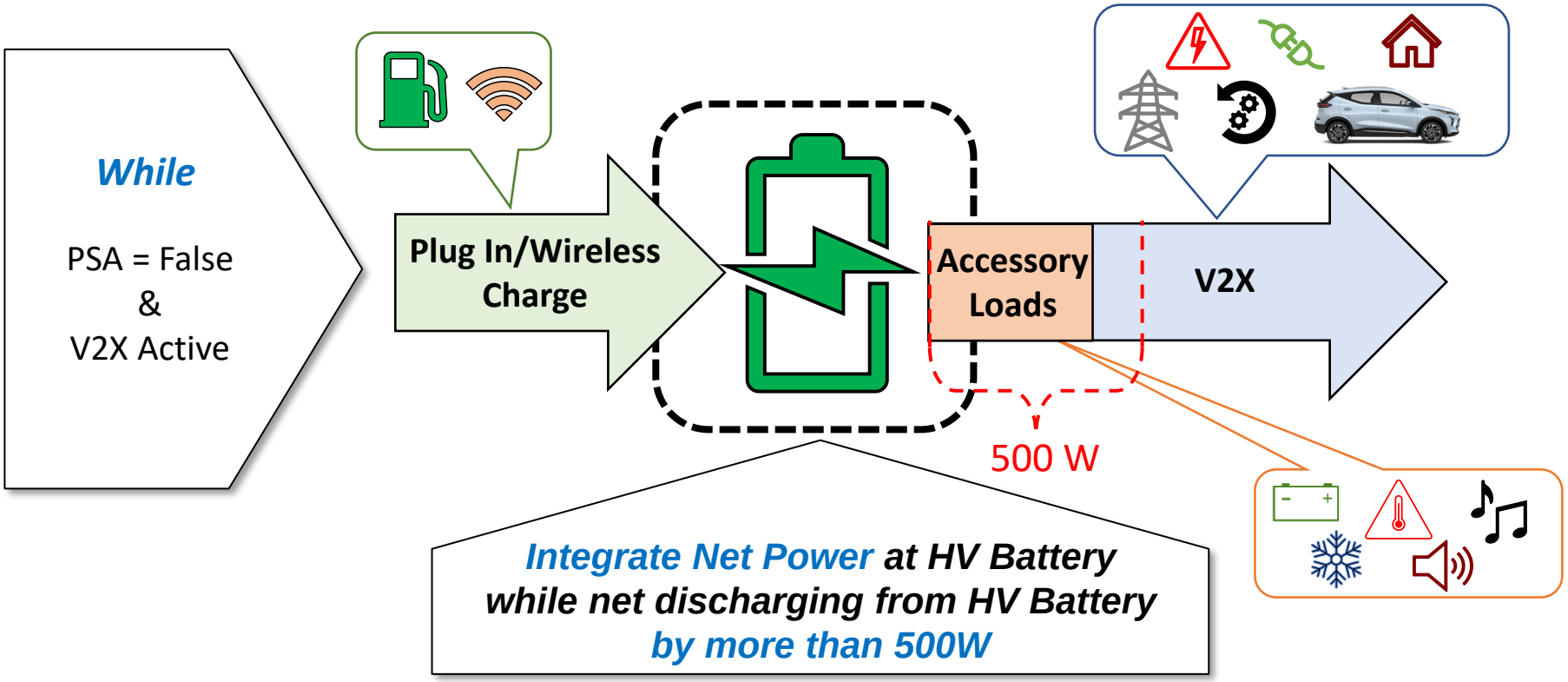
0xF88B DID vs Region-Adjusted Energy Calculations



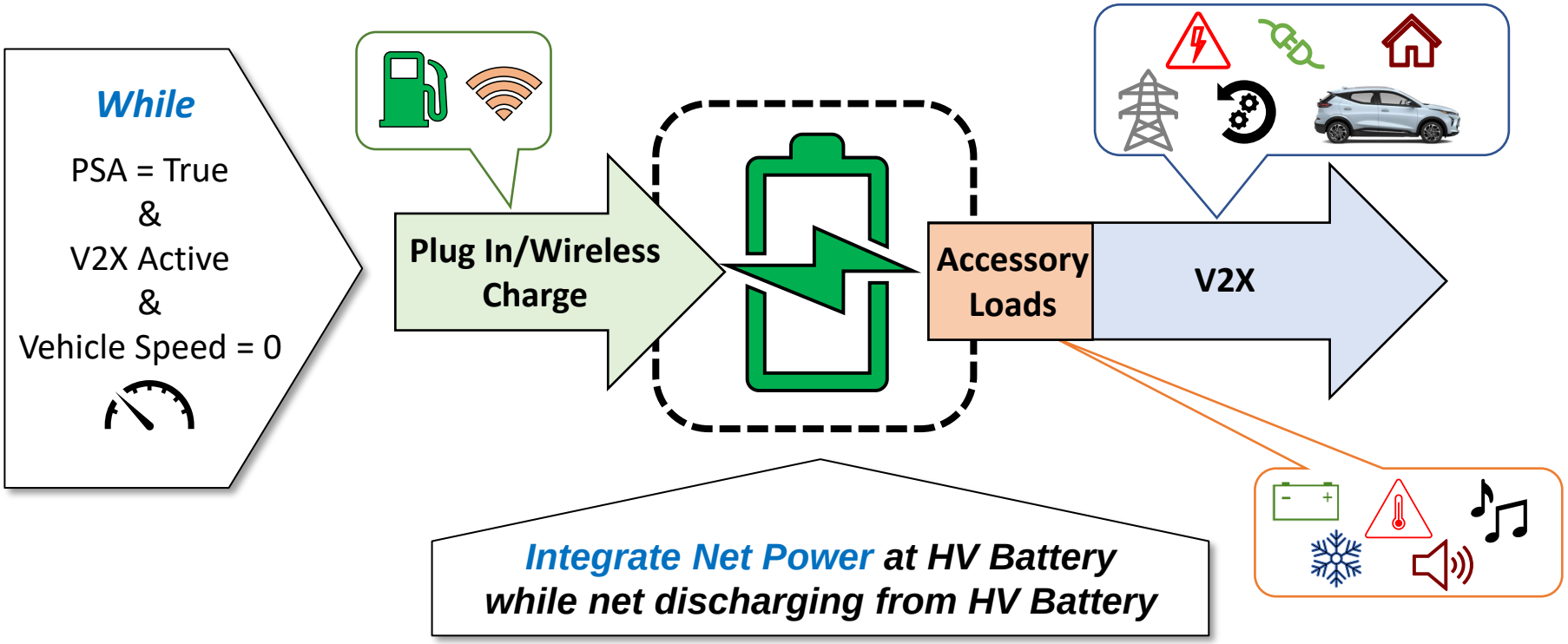
V2X Energy While non-PSA (Lifetime) – 0xF88B



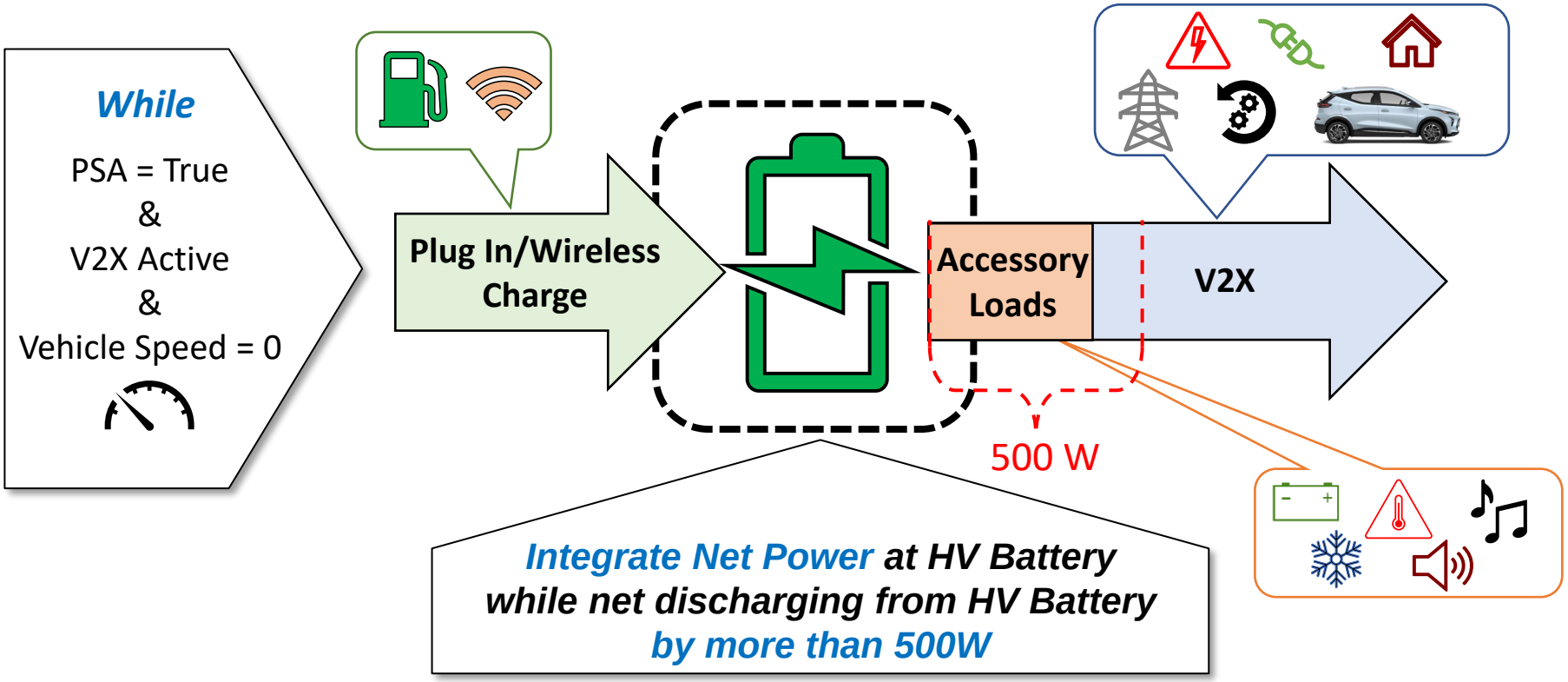
Adjusted V2X Energy While non-PSA (Lifetime) – 500W Threshold



V2X Energy While in PSA (Lifetime)

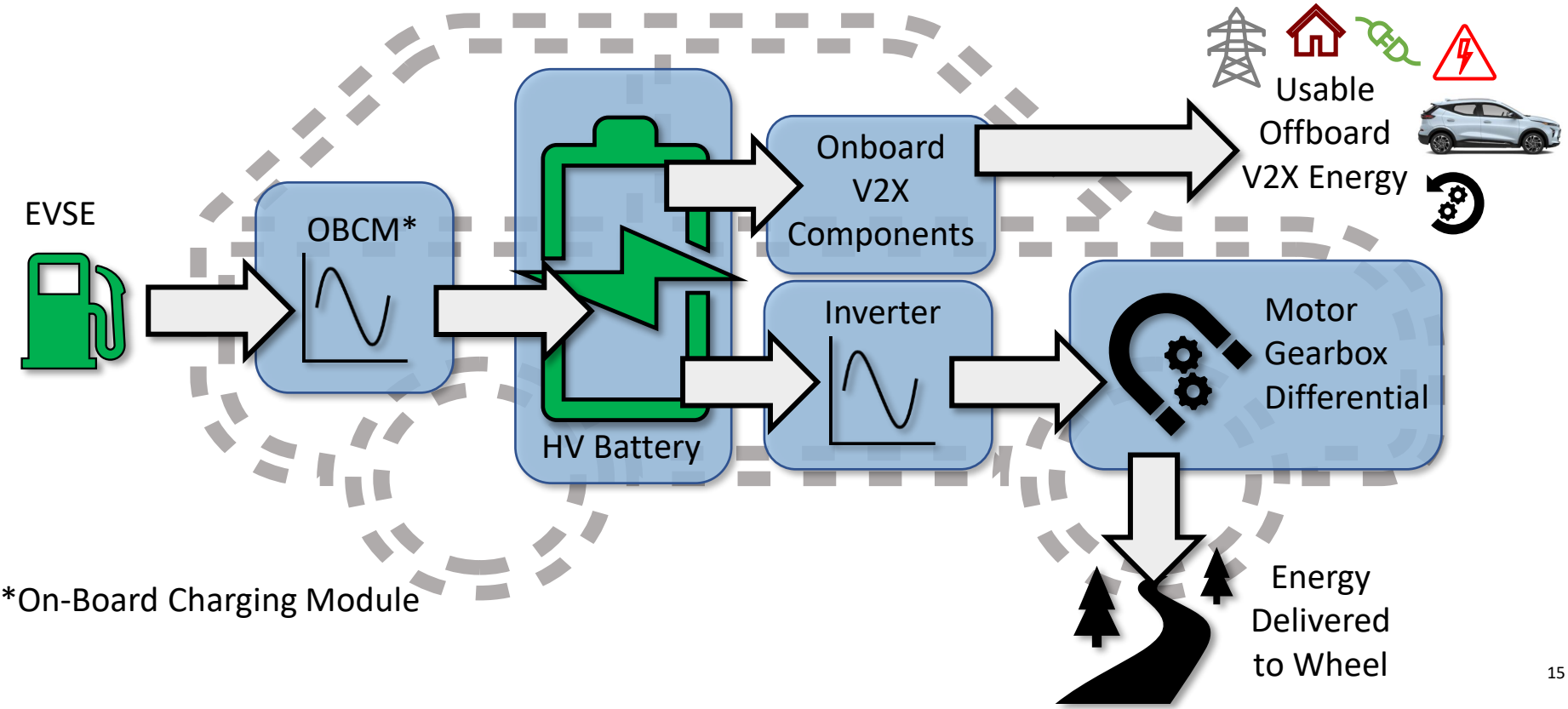


Adjusted V2X Energy While in PSA (Lifetime) – 500W Threshold



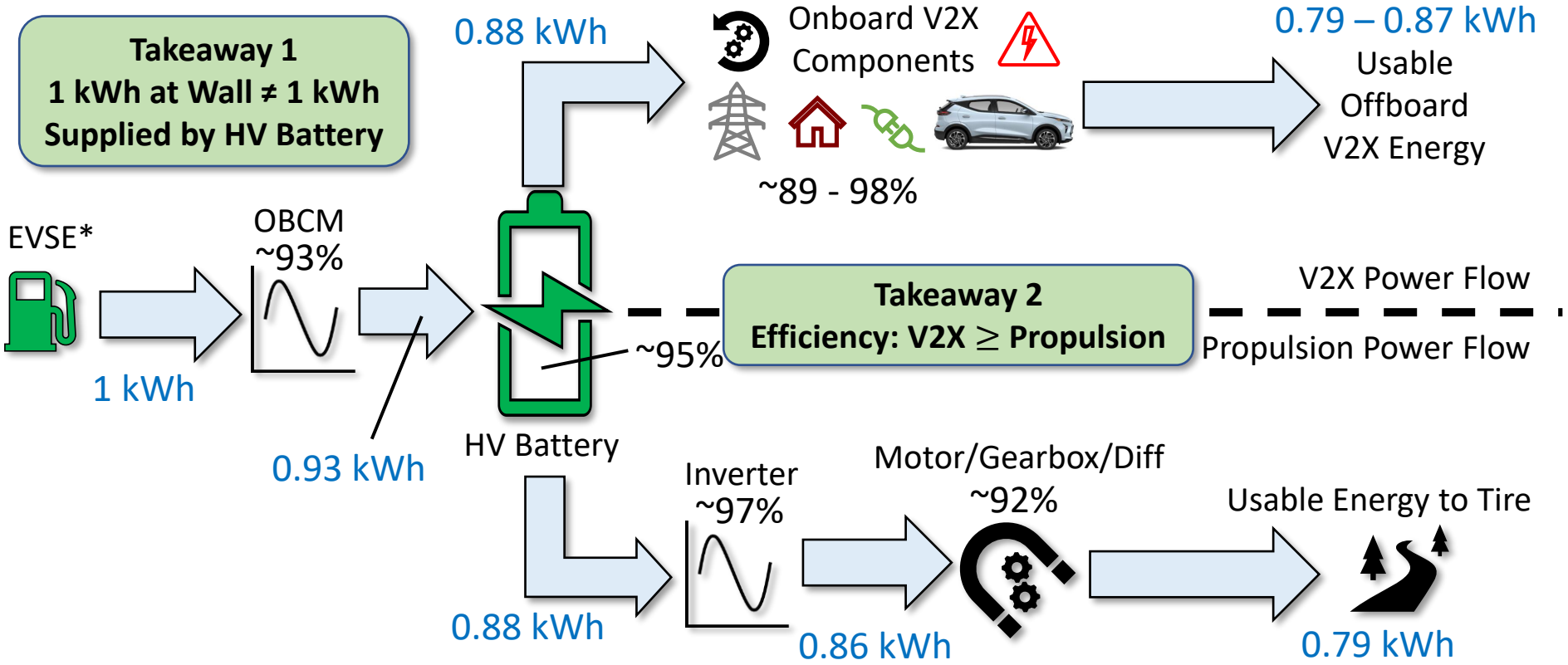
Power Flow within an Electric Vehicle: V2X vs Propulsion

"Virtual Odometer Reading" = [What kWh metric?] X ***[What km/kWh conversion?]***



*On-Board Charging Module

Deployment Efficiency Comparison: V2X vs Propulsion



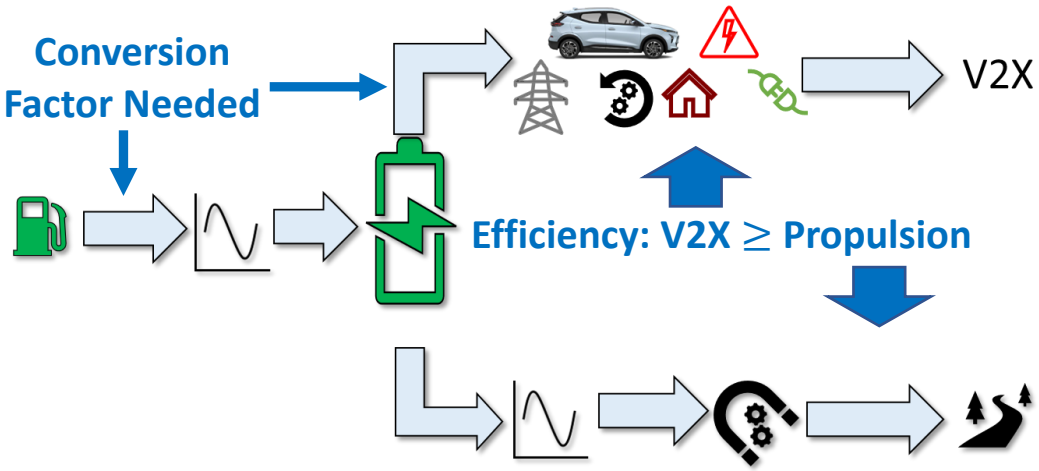
*Certification testing done with AC EVSE

Conversion Factors and km/kWh: Driving to V2X

"Virtual Odometer Reading" = [What kWh metric?] X ***[What km/kWh conversion?]***

1 kWh at Wall ≠ 1 kWh out of HV Battery

- Certification Efficiency measures energy supplied by the AC EVSE
- V2X Virtual Odometer will measure energy at the output of the HV Battery
- **Conversion Factor Needed**
  - **see next slide**



V2X Efficiency ≥ Propulsion Efficiency

Let's assign the same "km/kWh" to V2X and Driving

- This will **simplify the calculation** of virtual odometer and **ease adoption** of this new metric
- This will be a slight **benefit to customers** who opt to use V2X
- Their virtual odometers will increment up "slower" than if system efficiencies of driving vs V2X were considered

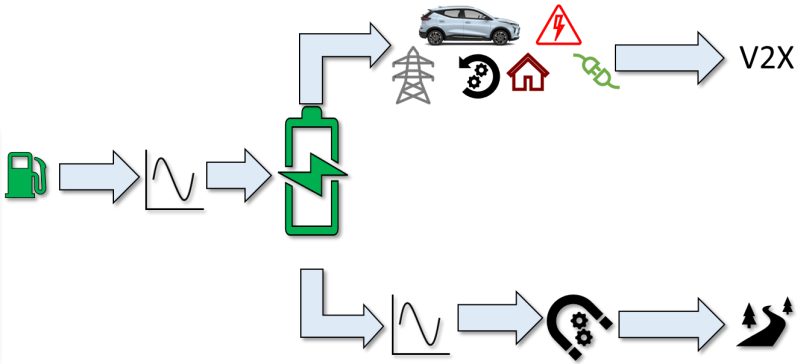
“Virtual Odometer” Calculations

$$Virtual\ Odometer_1(km) = \frac{Lifetime\ V2X\ Discharge\ Energy_2\ (kWh) * 1000\ \left(\frac{Wh}{kWh}\right)}{Virtual\ Odometer\ Consumption\ \left(\frac{Wh}{km}\right)}$$

In which…

$$Virtual\ Odometer\ Consumption\ \left(\frac{Wh}{km}\right) = \frac{Certified\ Energy\ Consumption_3\left(\frac{Wh}{km}\right) * UBE\ Measured\ at\ Certification_4\ (kWh)}{Wall\ Energy\ Measured\ at\ Certification_5\ (kWh)}$$

1. DID: 0xF8A3 “Total Lifetime Virtual Distance”
2. "Total Lifetime Discharge Energy in V2X” -> Multiple DIDs
3. DID: 0xF8A6 “Certified Energy Consumption”
4. DID: 0xF8A8 “Usable Battery Energy Measured at Certification”
5. Wall Energy Recharged at Range Certification Test



“Virtual Odometer” Calculations: High Efficiency EV Example

Lucid Air Grand Touring*
Charge Depleting UDDS: 622 miles or 1001 km
Charge Depleting Highway: 630 miles or 1013.9 km
Recharge Event: 130.3 kWh

Highest efficiency vehicles will see the virtual odometer increment up at the fastest rate per unit of V2X energy expended

$$\textit{Certified Energy Consumption} = \frac{130.3\ kWh * 1000\ \frac{Wh}{kWh}}{0.55 * 1001\ km + 0.45 * 1013.9\ km} = 129.42\ \frac{Wh}{km}$$

$$\textit{Virtual Odometer Consumption}\left(\frac{Wh}{km}\right) = \frac{\textit{Certified Energy Consumption}\left(\frac{Wh}{km}\right) * \textit{UBE Measured at Certification}\ (kWh)}{\textit{Wall Energy Measured at Certification}\ (kWh)}$$

$$\textit{Virtual Odometer Consumption}\left(\frac{Wh}{km}\right) = \frac{129.42\left(\frac{Wh}{km}\right) * 112^{**}\ (kWh)}{130.3\ (kWh)} = 111.24\left(\frac{Wh}{km}\right)$$

*https://dis.epa.gov/otaqpub/display_file.jsp?docid=56621&flag=1
**https://ev-database.org/car/1316/Lucid-Air-Grand-Touring

“Virtual Odometer” Calculations: High Efficiency EV Example

Lucid Air Grand Touring
Charge Depleting UDDS: 622 miles or 1001 km
Charge Depleting Highway: 630 miles or 1013.9 km
Recharge Event: 130.3 kWh

$$\textit{Virtual Odometer Consumption} = 111.24\left(\frac{Wh}{km}\right)$$

$$\textit{Virtual Odometer}\ (km) = \frac{\textit{Lifetime V2X Discharge Energy}\ (kWh) * 1000\left(\frac{Wh}{kWh}\right)}{111.24\left(\frac{Wh}{km}\right)}$$

11 kWh/day
V2H Use

Virtual Odometer

99 km/day
Kilometers Gained

“Virtual Odometer” Calculations: EV Examples Across the Industry

Lucid Air Grand Touring

Charge Depleting UDDS: 1001 km*
Charge Depleting Highway: 1013.9 km*
Recharge Event: 130.3 kWh*
Usable Battery Energy: 120 kWh**

Virtual Odometer Consumption

$$111.24\left(\frac{Wh}{km}\right)$$

11 kWh/day V2H Use = **99 km/day Virtual Odometer**

MY21 Tesla Model Y Performance

Charge Depleting UDDS: 658.2 km*
Charge Depleting Highway: 605.1 km*
Recharge Event: 92.2 kWh*
Usable Battery Energy: 75 kWh**

Virtual Odometer Consumption

$$145.36\left(\frac{Wh}{km}\right)$$

11 kWh/day V2H Use = **76 km/day Virtual Odometer**

* https://dis.epa.gov/otaqpub/ ** https://ev-database.org/

“Virtual Odometer” Calculations: EV Examples Across the Industry

Lucid Air Grand Touring

11 kWh
Battery Throughput

=

99 km
Virtual Odometer

MY21 Tesla Model Y Performance

11 kWh
Battery Throughput

=

76 km
Virtual Odometer

- Energy throughput from V2X drives wear and tear on the battery
- More efficient vehicles use less energy per kilometer
- 1 unit of V2X energy = higher equivalent driven distance for a higher efficiency vehicle
    - Higher propulsion efficiency = More virtual kilometers per kWh of V2X energy

* https://dis.epa.gov/otaqpub/ ** https://ev-database.org/

Customer Benefits from the Virtual Odometer

- **Informing** the customer through **transparent metrics** displayed on the center stack or instrument panel
- **Appropriate used vehicle pricing**
  - **Higher confidence** in buying a used vehicle from understanding past propulsion and V2X use
- **Warranty** can be tied to the Virtual Odometer in metrics the customer is accustomed to (Odometer/km)
- **Less risk to manufacturers** due to V2X usage being accounted for in warranty
  - **Less risk = more adoption of V2X capability** across the industry
- **Appropriate new vehicle pricing** by eliminating the need for auto manufacturers to overdesign the vehicles for excessive V2X usage

Battery SOH

Virtual Odometer

Warranty Odometer: Virtual + Driven

Warranty Proposed Addition

Section 1962.8, Title 13, California Code of Regulations

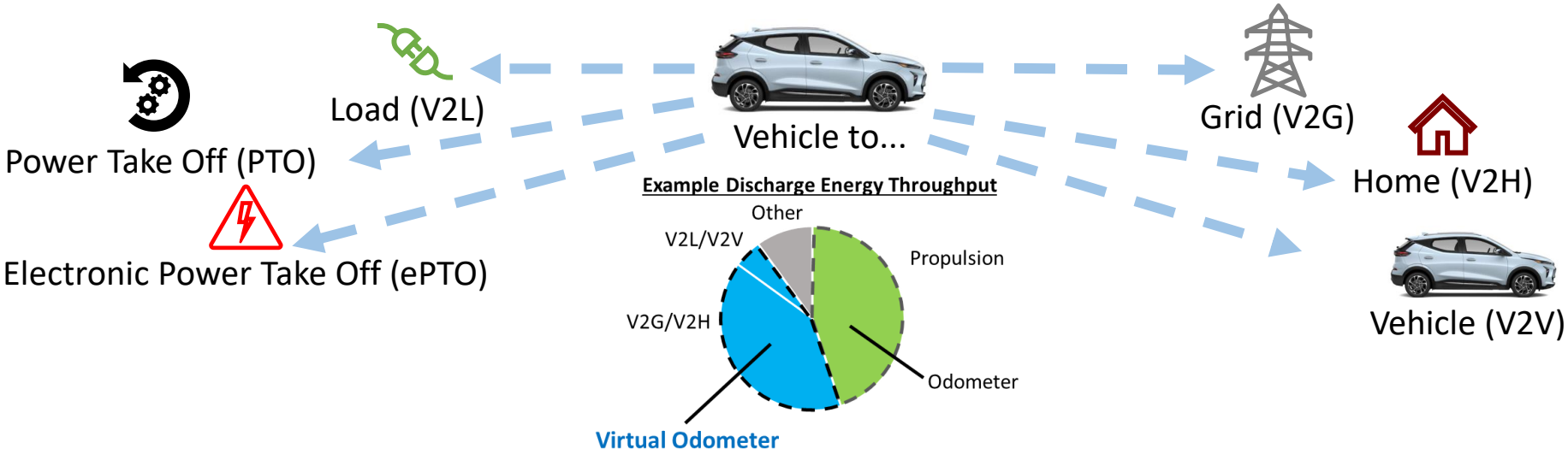
(3) Battery Warranty. The vehicle manufacturer of each battery electric vehicle and plug-in hybrid electric vehicle shall warrant to the ultimate purchaser and each subsequent purchaser that the vehicle's battery is free from defects in materials and workmanship which cause the battery state of health, as described in CCR, title 13, section 1962.5(c)(4)(A)4.c. and d., to deteriorate to less than 70% for a **warranty period** of eight years or ***100,000 miles****, whichever first occurs, for 2026 through 2030 model years, and 75% for a **warranty period** of eight years or ***100,000 miles****, whichever first occurs, for 2031 and subsequent model years.

Proposed Addition

*For purposes of the mileage limits provided in CCR 1962.8, the miles are defined as the **sum of the driven odometer and the virtual odometer**

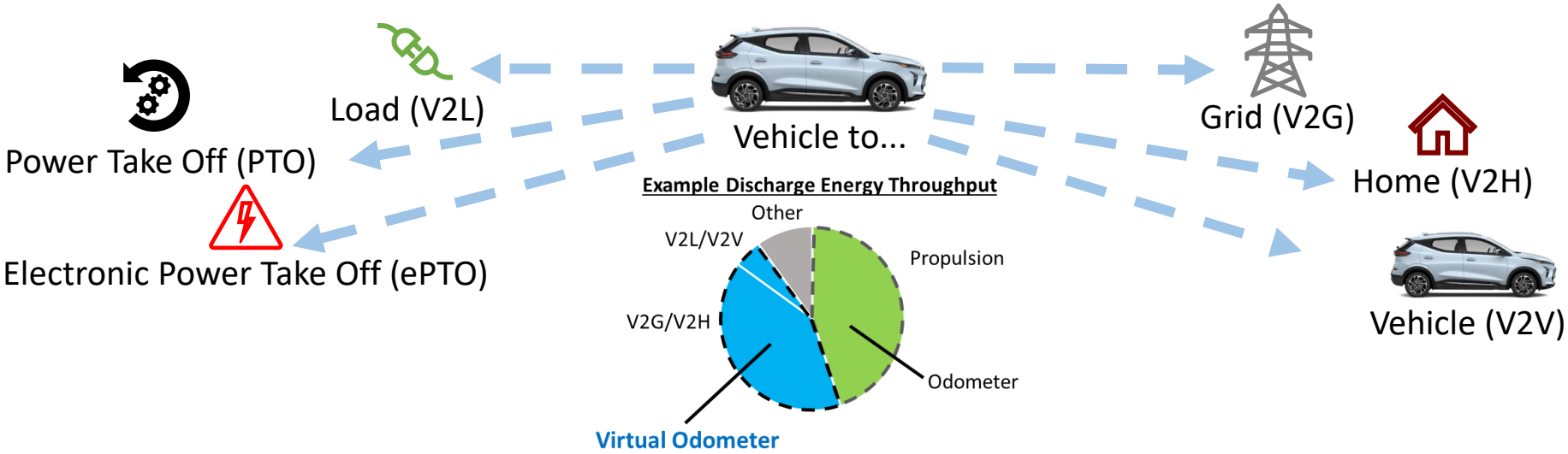
- (provided in DID 0xF4A6 and ITID 0xF8A3 respectively)

Closing Remarks



- V2X features will drive a significant amount of HV battery throughput and resulting wear and tear
- Customer-facing metrics are needed to convey historical V2X usage
- We believe our **"Virtual Odometer"** methodology to be a **fair**, **transparent**, and **easily adoptable** metric

Future Work



Data Security of Virtual Odometer:

- Plan how to manage part replacements
  - Reset of V2X energy and virtual odometer calculations

On-Board Diagnostics Symposium-Americas: Sept 12-14

Contact Info

Thank you!

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