# Electric Vehicle  DC Charging Overview for CE&T Partner Forum 26SE2023

## Rick Szymczyk, P. Eng, MBA

30+ years General Motors Manufacturing & Design

Started Upstartz in 2007, incorporated 10 years later

Led Toronto start-up, eCamion Engineering team to market  2017-2022

Currently serving as Ontario Tech University Automotive Centre R&D Manager upstartz energy development in parallel

Introduced to Stabiliti in 2018. Successfully integrated across several architectures.

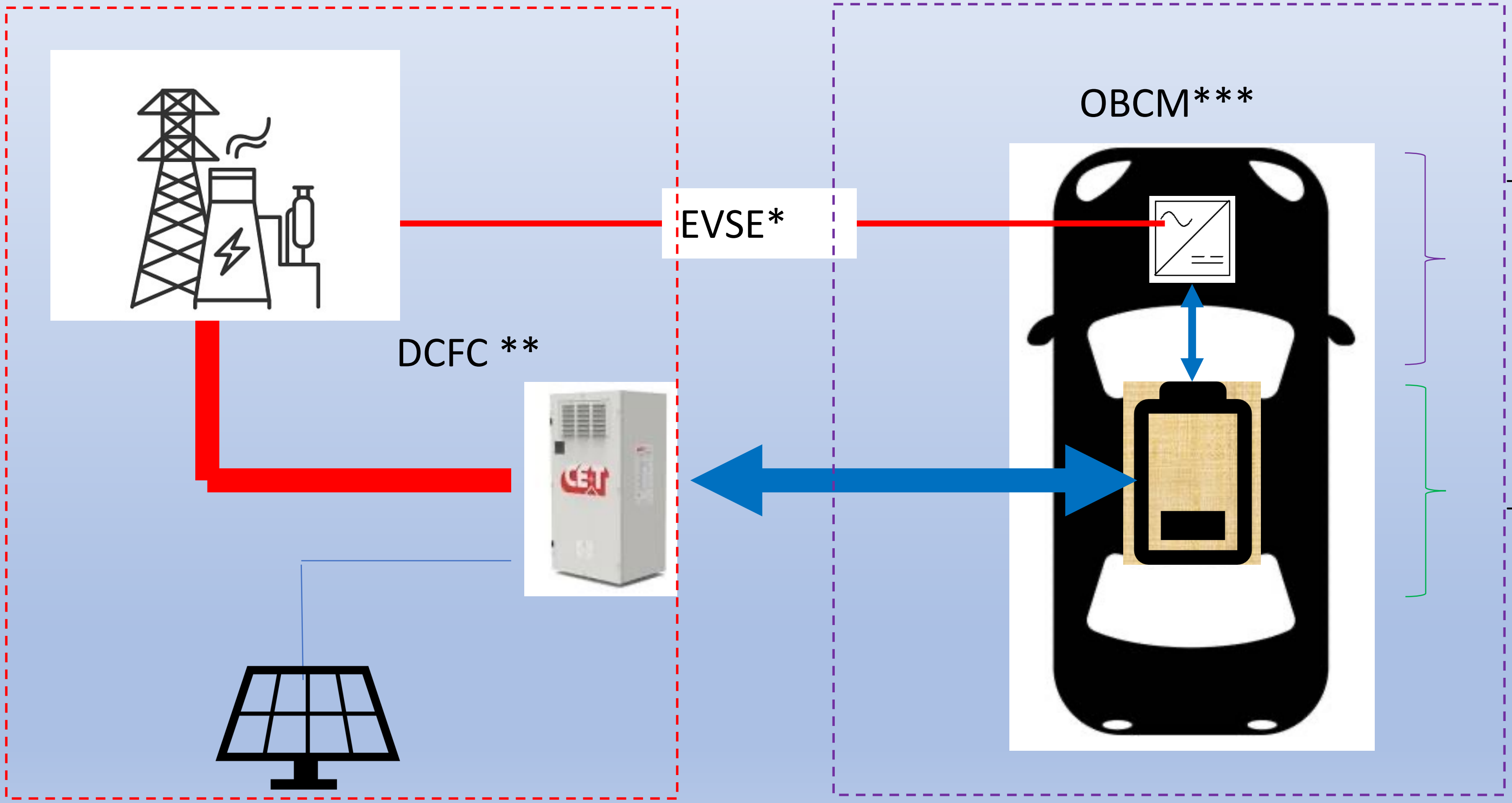
Constant relearning & reinvention!

# Agenda

- DC Charging rate characteristics
- Some recent developments in North America (NACS, OEM moves)
- Some Charging Economics & Market Challenges
- Some Technical Challenges
- Future Station & Measurement Requirements
- Q&A

# DC Charging rate Characterization

# Onboard Versus Offboard Charging



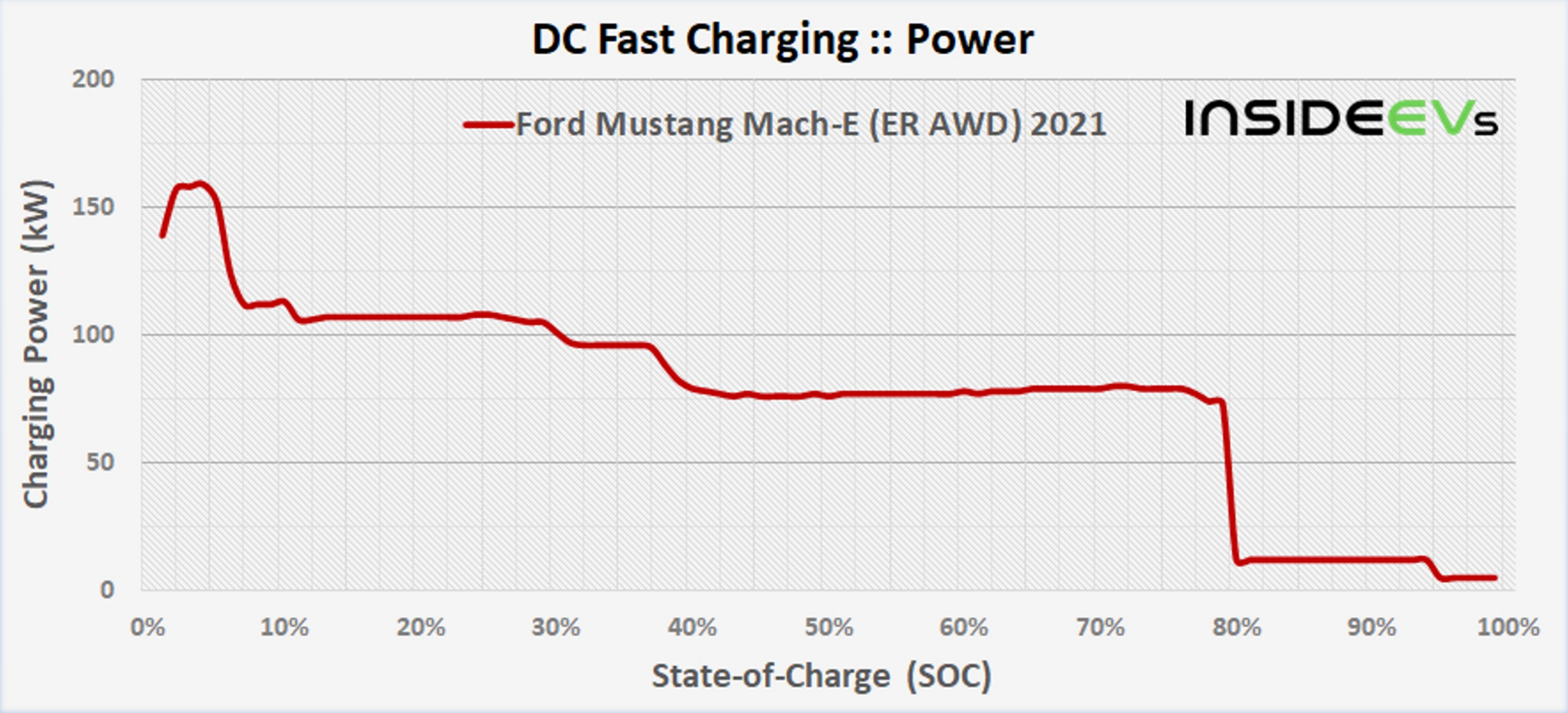

Utility Domain

OEM Domain

- <u>Onboard</u> Charging (Level 2)
  - Low Power (< 20 kW in N. America)
  - High Value (packaged inside the EV)
  - Long duration (overnight)
  - Simple, Reliable
  - Can also be controlled by EV/OEM
  - Currently Regulated by OEM but poised to change in the future
- <u>Offboard</u> Charging (Level 3)
  - Low or High Power
  - High Feature (Complex)
  - Part of Infrastructure
  - Complex
  - Regulated by UL/Utilities

* Electric Vehicle Service Equipment
** Direct Current Fast Charging
*** On Board Charging Module

# DC Charging rates can vary significantly

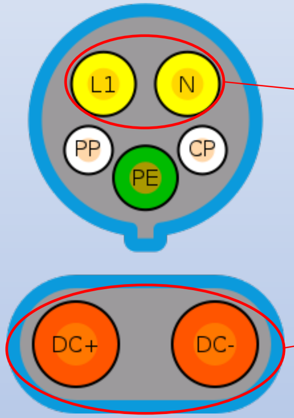



- EV Charging capacity
- Beware of overly simplistic proformas

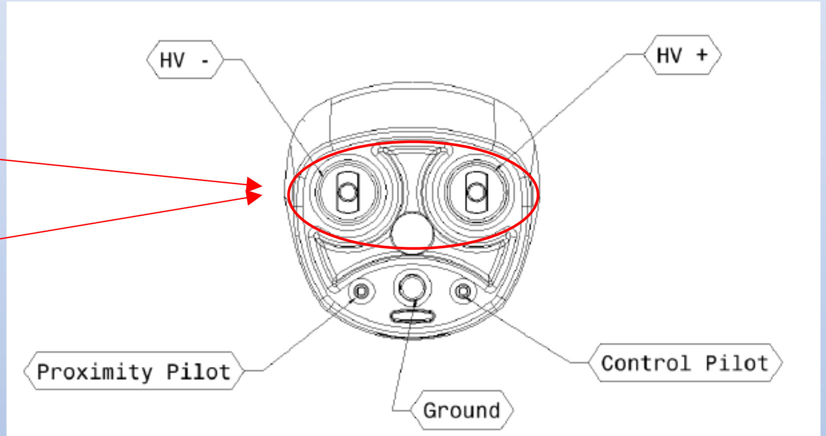
# Some recent Developments in North America

# NACS (aka Tesla Standard)

CCS




NACS
(Tesla)




Connector - 1,000V and 500V Configuration

Separate AC/DC Lines
Moving Latch
Combines Legacy AC + DC

Combined AC/DC Lines
No moving parts
Smaller footprint

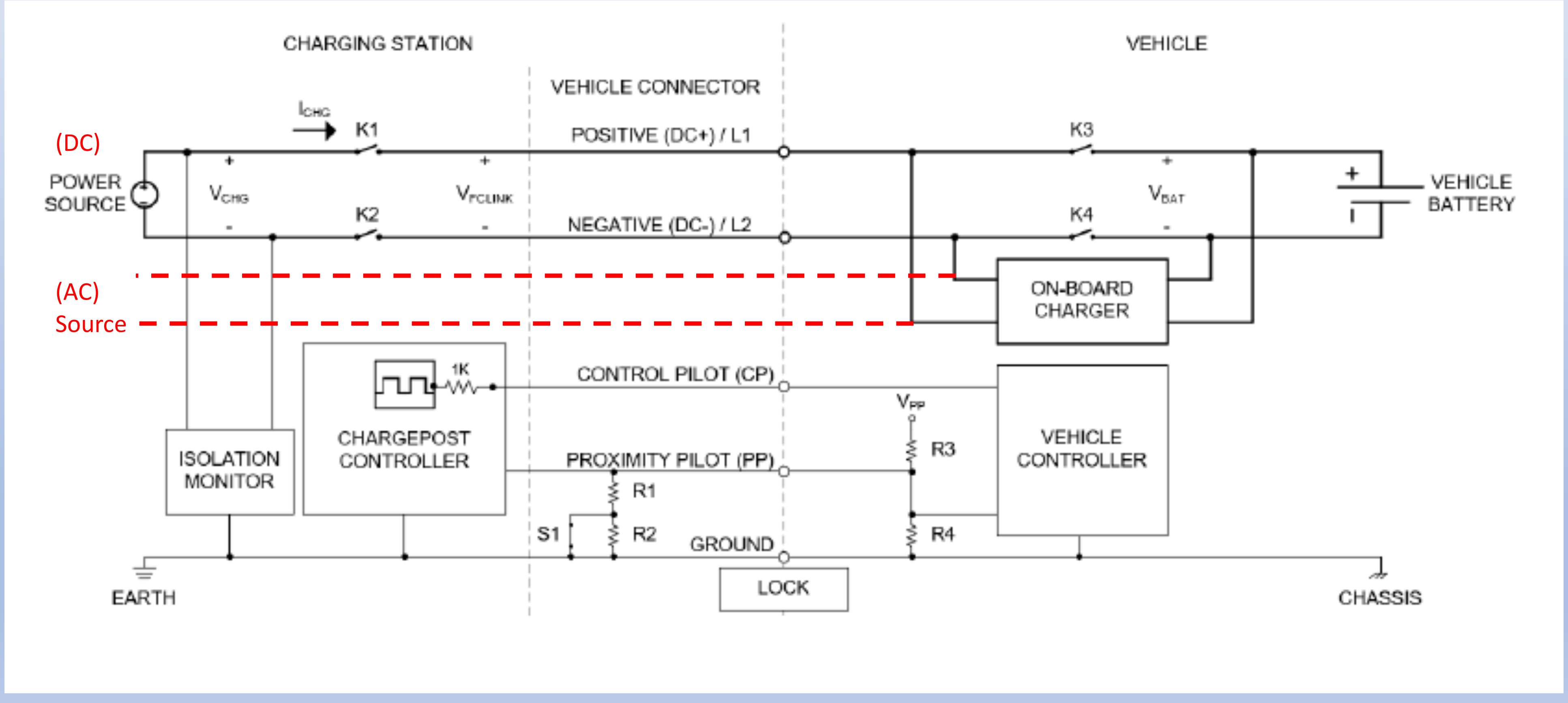
# NACS – Relevant Connections

EVSE

DC Supply

AC Supply

Signaling



# Some key Excerpts from NACS

## Voltage

The North American Charging Standard exists in both a 500V rated configuration and a 1,000V rated configuration. The 1,000V version is mechanically backwards compatible (i.e. 500V inlets can mate with 1,000V connectors and 500V connectors can mate with 1,000V inlets).

## Current

The North American Charging Standard shall specify no maximum current rating. The maximum current rating of the inlet or connector shall be determined by the manufacturer, provided that the temperature limits defined in section 8 are maintained.

*Tesla has successfully operated the North American Charging Standard above 900A continuously with a non-liquid cooled vehicle inlet.*

## Maximum Temperature

8.1.1 When subject to the temperature rise test of IEC 62196-1 section 24, the maximum interface contact temperature shall be 105°C.

*Modern thermoplastics are commonly rated to 120°C and higher. The IEC 62196 limit of 90°C artificially limits performance capabilities of EVs and EVSEs.*

8.1.2 The maximum temperature rise of the interface contacts shall be calculated by the maximum ambient temperature rating of the product and the maximum upper contact temperature of 105°C. E.g. if the product is rated to a 50°C ambient, the maximum allowable temperature rise shall be 55°C.

8.1.3 The maximum surface temperatures shall be in accordance with IEC 62196-1 section 16.5.

## Communication

**4.5 Communication between the EV and EVSE**

4.5.1 For DC charging, communication between the EV and EVSE shall be power line communication over the control pilot line as depicted in DIN 70121.

4.5.2 The North American Charging Standard is compatible with "plug and charge" as defined in ISO-15118.

## Future Updates supporting V2G/V2X

**4.6 Vehicle to X (V2X)**

4.6.1 The North American Charging Standard is compatible with Vehicle to X (i.e. Vehicle to load, Vehicle to home, vehicle to grid) power transfer. Future versions of this technical specification will specify the functional requirements and specifications required to achieve vehicle to X power transfer.

# V2x Technology

## GM's Ultium-based EVs will be able to power your home by 2026

Rebecca Bellan @rebeccabellan / 11:14 AM EDT • August 8, 2023 Comment


Image Credits: General Motors

Owners of all-electric Chevrolets and other GM brands will soon be able to use their cars as backup generators to power their homes during an outage or during peak demand days.

The Ultium Home products will be connected to the GM **Energy Cloud, a software platform** allowing customers to manage energy transfers.

GM Energy is working with **PG&E in pilot projects with Con Edison, Graniterock and New Hampshire Electric Cooperative** (NHEC).

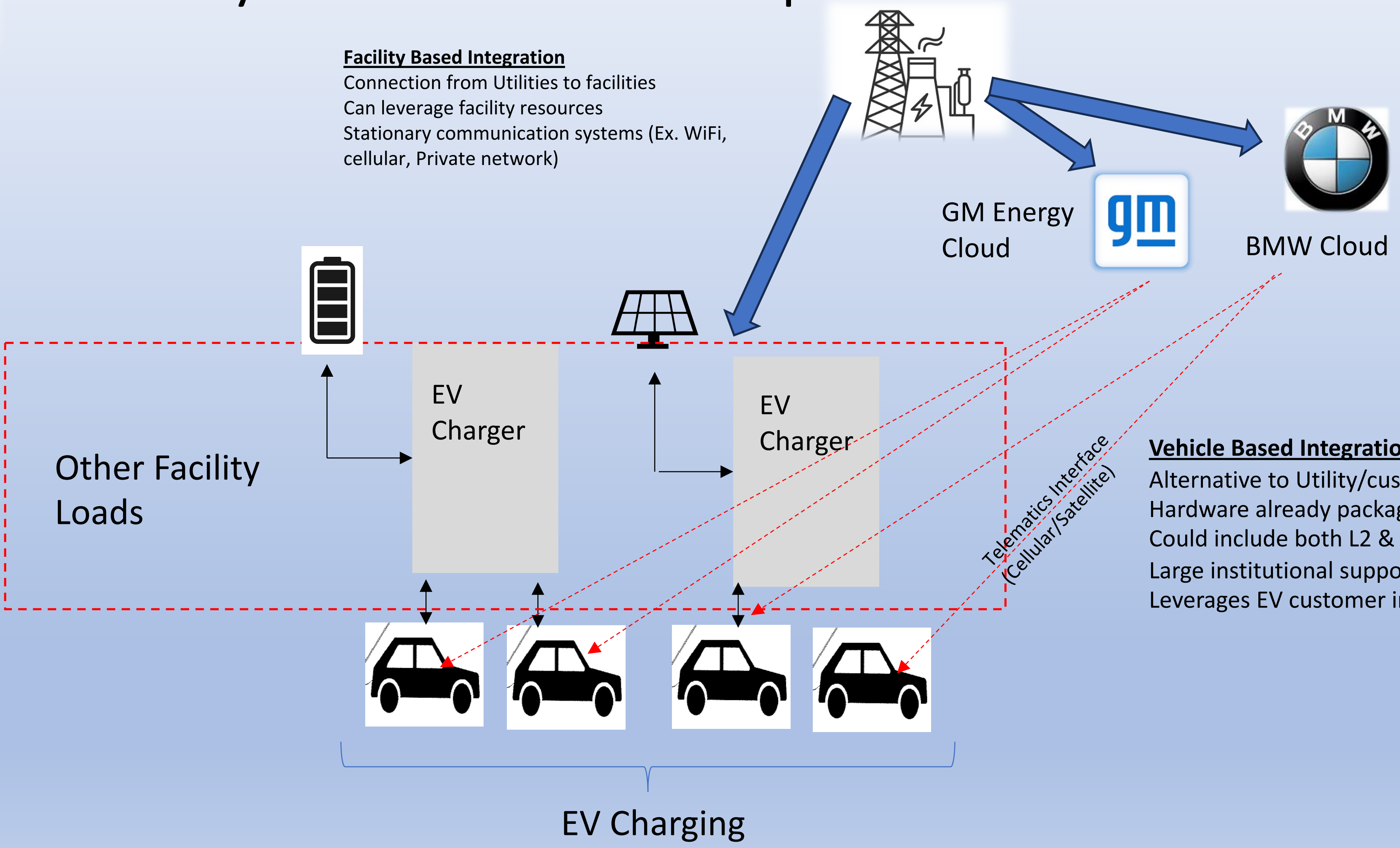
“As GM Energy’s ecosystem of connected products and services continues to expand, we’re excited to provide customers with options for **greater energy management beyond the vehicle,**”

“Our initial Ultium Home offerings represent an opportunity for customers to take **greater control over their personal energy independence and resiliency.**”

Ultium platform , “the heart of the EV product strategy” as the architecture includes the **proprietary batteries and the proprietary drive and power electronics.**

# Onboard vs Offboard Charging
# Key Market Development

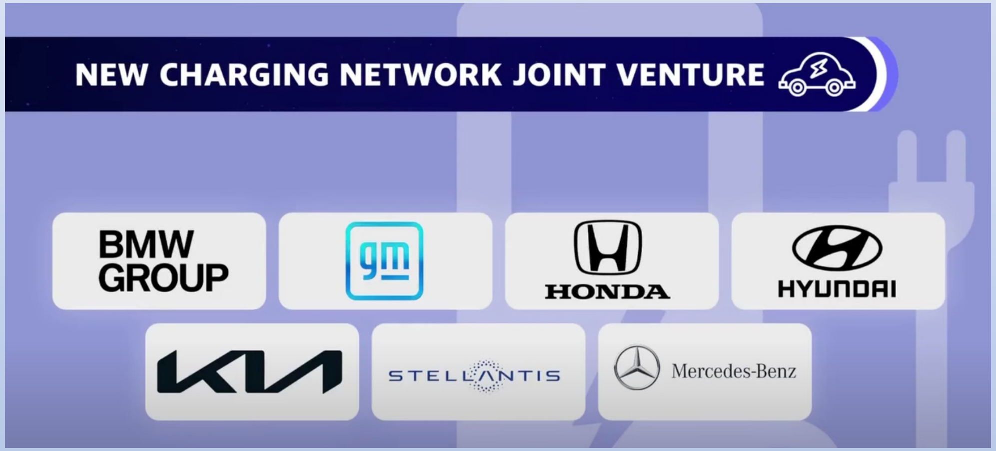
**Facility Based Integration**
Connection from Utilities to facilities
Can leverage facility resources
Stationary communication systems (Ex. WiFi, cellular, Private network)




**Vehicle Based Integration**
Alternative to Utility/customer connections
Hardware already packaged into EV's
Could include both L2 & L3 Charging
Large institutional support
Leverages EV customer interface

# How vehicle OEM's are responding

**Seven major automakers are teaming up on a North American EV charging network**


- 30,000 DC stations by CY2030
- Includes both CCS & NACS connectors
- Separate from GM & BMW's existing initiatives
- Renewable Energy Component (unclear if direct or indirect)
- First rollouts mid CY2024 in US. Canada to start later
- Funding from National Electric Vehicle Program (NEVI)

# Selected Charging Economics & Market Challenges

# Some opportunities to serve EV charging needs

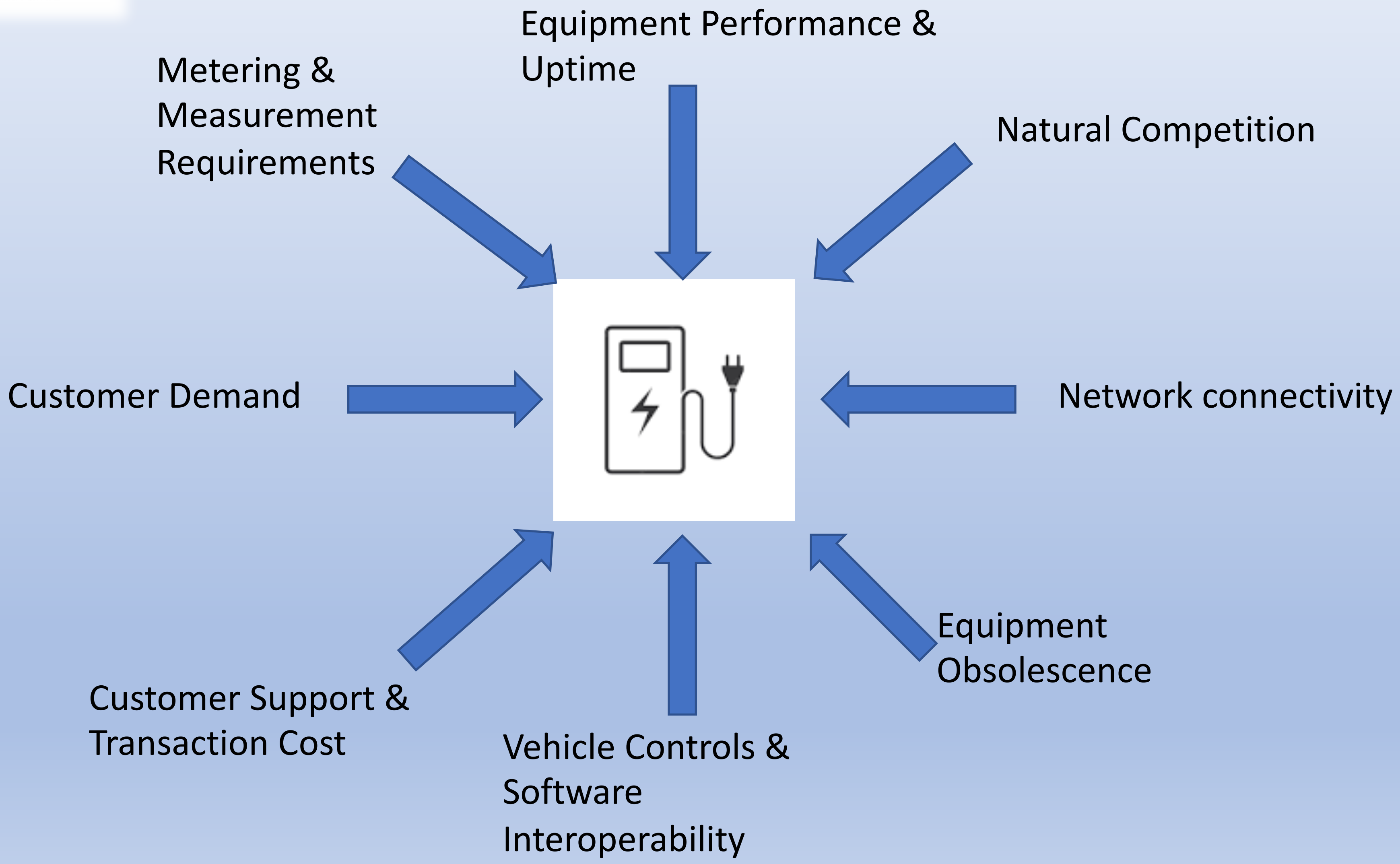
- Used Car sales represents 3x the number of new car sales
- 40% of used car purchasers will rely on some form of public charging
- 80% of daily driving is less than 60 km or approx. 12 kWh per day
- A 400 km range battery implies charging just twice per week
- Emphasis on development of an affordable, interoperable publicly available charging network that serves this type of customer
- Significant funding available from National Electric Vehicle Infrastructure Program (NEVI).

# National Electric Vehicle Infrastructure Program (NEVI)

- US Federal program (2021-2026) setting a path to deployment of 500,000 chargers by 2030
- $7.5B program allocated in 2 key parts across the country
  - $5B for EV charging infrastructure
  - $2.5B for Charging and (Low Carbon based refueling) infrastructure (Discretionary funding)
- Up to 80% funding available with key criteria including

  - Convenient, affordable, reliable, equitable network of EV chargers
  - Reduces GHG toward net zero by 2050
  - Focuses on US industries & family sustaining union jobs
  - Focuses on Interstate highways as priority
  - 40% of benefits to disadvantaged communities
  - Administered by US dept of Transport, FHWA (Federal Highway Administration)

# Business Pressures on EV Charging Providers



# P&L framework for DCFC

Revenue:

| | | |
|---|---|---|
| - Charging revenue $0.30-1.00/kWh | Market varies | Predominately variable |
| - Ancillary revenue (tbd) | Co-Hosting revenue | |
| - Advertising revenue (tbd) | Projected to increase | |

Costs:

| | | |
|---|---|---|
| - Energy | $0.10-.30/kWh + Sub Meter fees | Predominately Fixed |
| - Equipment Capital Cost | 10-12% + Future upgrade costs | |
| - Network Software fees | 20-$100/month + Future software update costs | |
| - Equipment Repair | 2-5%/year | |
| - Customer Service | Call Centre support | |
| - Site Maintenance | Snow removal/cleaning | |
| - Measurement recert | semi annual recert/tbd | |
| - Transaction fees | Fixed + Percentage | |
| - Communication Network fees | Cellular / local network fees | |
| - EGIA* fees | Mandatory? | |
| - Plugshare Fees | Based on selected service level | |
| - Insurance | Value Added service | |
| - Administrative & Legal fees | Revenue Sharing fees | |

* Electricity Gas & Inspection Act

# Market Reality in North America

## EV Charging Networks Aren't Making Money

by Matt Posky

April 25th, 2023 3:34 PM Share

Key Pressures:

- Low Volume & high Fixed Costs
- Price conscious customers
- High Cost of Energy (Power)
- Changing Standards
- Large Enterprises buying space
- High Operating Costs
- Nearly instant Obsolescence
- Pending regulatory changes
- High Transaction Costs
- Interoperability issues

CE+T POWER
Leading Conversion Technology for Power Resilience





# EV-charging industry is doing everything except making money

*"There's not a lot of money in electricity" says U.S. charging company CEO*

**Bloomberg**
May 04, 2021 • May 6, 2021 • 4 minute read • Join the conversation

# Charging Equipment availability

**Less than one in five federally funded car charging stations are operational**

Government invested $768M between 2016 and 2027 to buy and install nearly 90,000 chargers

Mia Rabson · The Canadian Press · Posted: Aug 30, 2023 2:58 PM EDT | Last Updated: August 30

Less than 20% of EV Charging Stations operational (Canada)

- Equipment durability
- Damage to equipment
- Software Incompatibility & interoperability
- Network connectivity
- Complexity/ Customer knowledge
- Payment process complexity
- Multiple Standards
- User Interface complexity & reliability

# Future Station & Measurement Requirements

# EV Station Requirements (California)

CALIFORNIA
AIR RESOURCES BOARD

ABOUT OUR WORK RESOURCES SERVICES RULEMAKING NEWS EQUITY

## Electric Vehicle Supply Equipment Standards Regulation Background and FAQs

Regulation summary and answers to frequently asked questions

Examples:

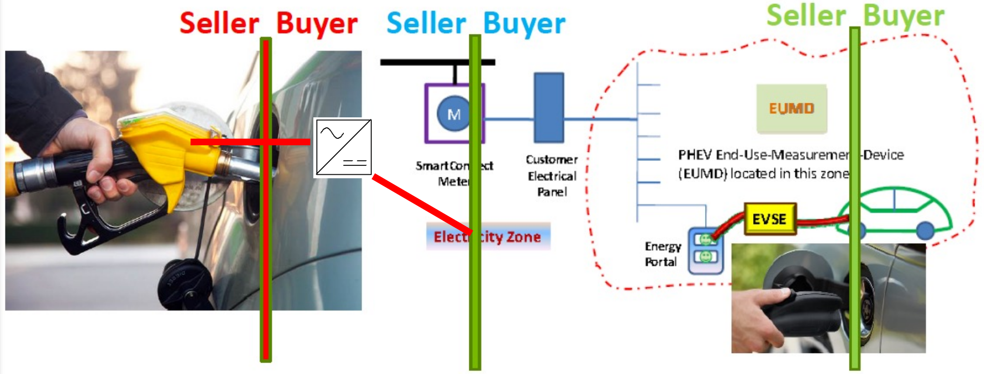
- Mandatory Subscription model prohibited
- Both Credit or Mobile pay to be supported
- Chip/Tap ready options to be required (est. $370+$271/yr.)
- Future Interoperability requirements for payment
- Per kWh rate required (drives metering)
- Graphical User Interface required
- Annual reporting requirements to CARB
- Compliance with EVITP (Training Program)
- Penalties for Non-compliance ($300-600/EVSE)
- etc, etc …

# NIST Handbook 44-3.40 Measurement Requirements for Commercial Dispensing of Electricity as a Fuel

**Weights and Measures Enforcement at State Level (not federal level)**

Line of demarcation for the point of sale of electricity for EV charging is at the tip of the charging cable (like liquid fueling), not at the feed circuit, as is the case for utility service

- NIST HB44-3.40 was released in 2016, adopted by most states, enforced only in California as of January 2021
- Type approval certification of 'system level' dispensed energy accuracy and billing information is required for **ALL** commercial EV charging stations before deployment
- Only three manufacturers have type approved stations as of May 2021 (Evercharge, ChargePoint, BTCPower)




*Comparison of the line of demarcation at the point-of-sale for liquid fuels, utility distribution of electricity and commercial dispensing of electricity as a fuel (at the edge of the vehicle).*

Argonne NATIONAL LABORATORY

# Measurement Canada Requirements

Government of Canada | Gouvernement du Canada

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MENU

Canada.ca > Measurement Canada

## Electric vehicle charging stations

**Note**: see Electric Vehicle Supply Equipment (EVSE) Temporary Dispensation Program

### Level 3+ charging devices

- In October, we will launch consultations to support the finalization of a framework that will allow kilowatt-hour (kWh) billing for Level 3+ EV charging devices already existing in the marketplace.
- Furthermore, before the end of the calendar year, we aim to enact a temporary dispensation mechanism to allow device owners and operators of Level 3+ EV charging devices already in the marketplace to bill customers based on kWh consumed rather than time. This mechanism will be informed by the forthcoming consultations and will allow us to continue working simultaneously with international competent authorities to develop technical regulations for level 3+ fast chargers. The timeframe within which this mechanism will be valid will be determined based on market conditions and the timing of future specifications for type approvals, but like the 2030 date for Level 1 and Level 2 EV charging devices, the intent will be to provide those in market with sufficient time to adapt to the final set of specifications for type approval.

California: Currently Requires Credit Card & Touch Screens for new DCFC

CY 2030 to retrofit previous installations.

Charge by kWh per California Handbook 44.

Canada: Consultations period for L1/L2 over, L3 consultations started

# Measurement Canada – Announcement

*"In the next 18 months, we expect to allow existing and new electric vehicle (EV) charging stations that meet established technical standards to charge based on kilowatt-hours (kWh) consumed. We will do this by continuing to work closely with industry and monitoring requirements other countries are developing, as well as advances and innovations in EV charging station technologies. The requirements will be performance-based to minimize costs and regulatory burden for EV charging station operators, while ensuring consumers receive accurate and reliable measurement, and protection against unfair practices."*

# Excerpt from Handbook 44

## A. Application

**A.1. General.** – This code applies to devices, accessories, and systems used for the measurement of electricity dispensed in vehicle fuel applications wherein a quantity determination or statement of measure is used wholly or partially as a basis for sale or upon which a charge for service is based.

**A.2. Exceptions.** – This code does not apply to:

(a) The use of any measure or measuring device owned, maintained, and used by a public utility or municipality only in connection with measuring electricity subject to the authority having jurisdiction such as the Public Utilities Commission.

(b) Electric Vehicle Supply Equipment (EVSEs) used solely for dispensing electrical energy in connection with operations in which the amount dispensed does not affect customer charges or compensation.

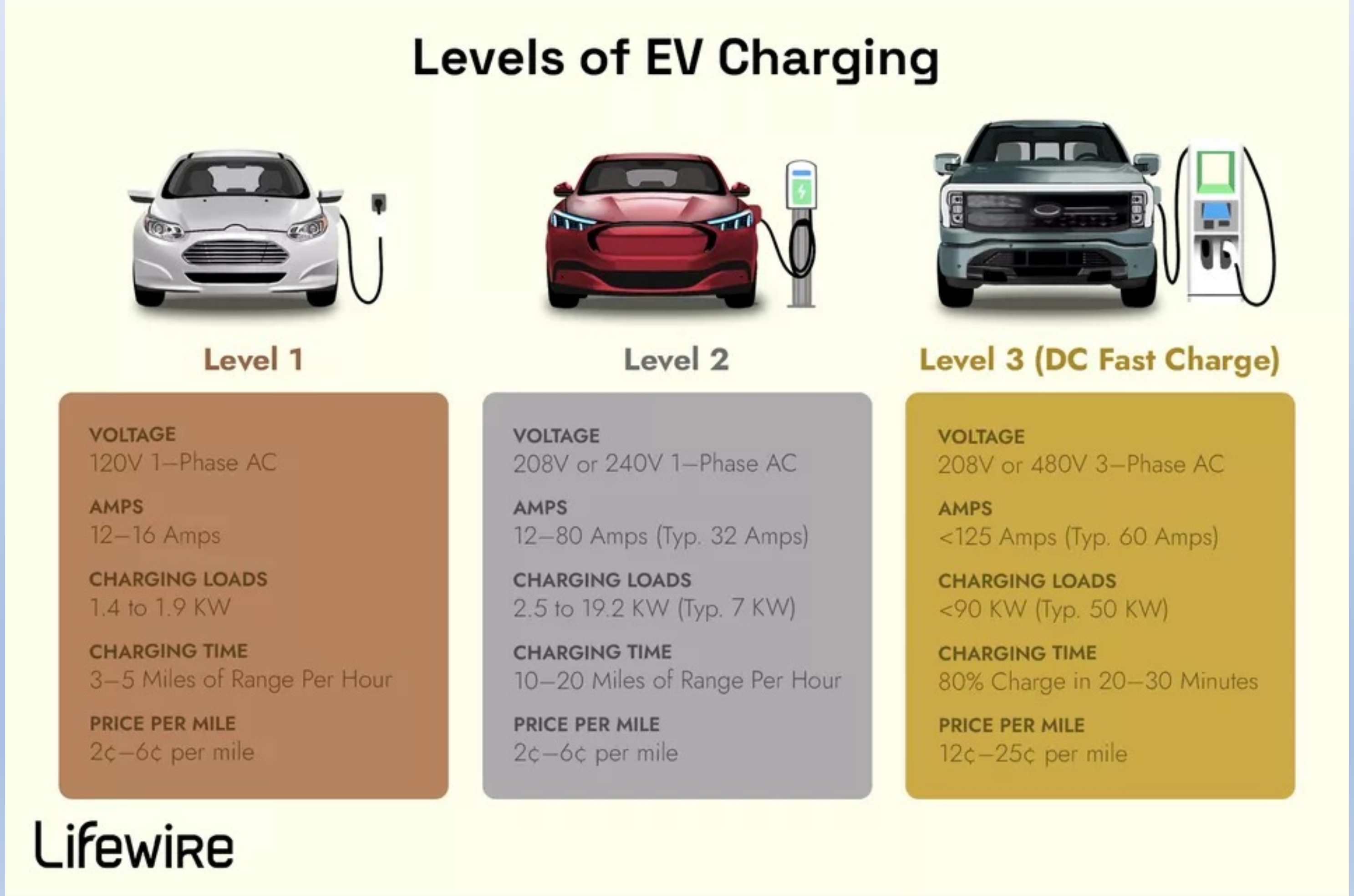
(c) The wholesale delivery of electricity.

Thank You

Questions & Feedback

# Backup

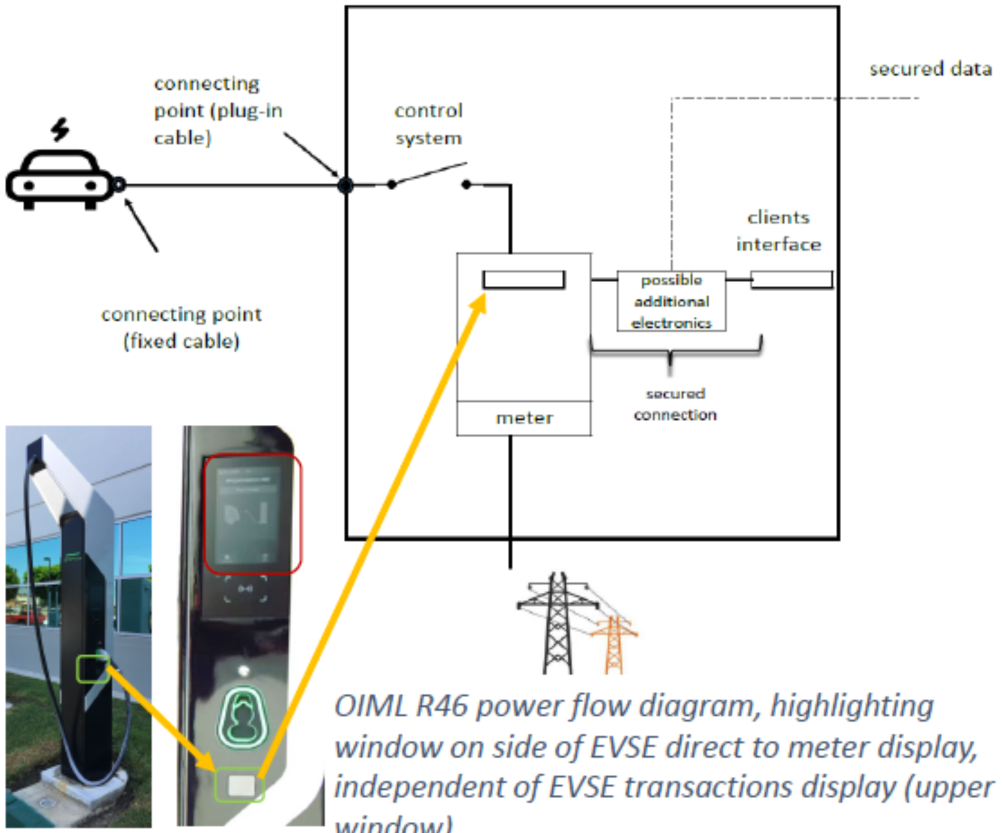
# Level 1-3 Charging – Specs!



# Differences Between US and Other Regions on Transaction Record Pathway and Certification

## Three Regional Levels of EV Charging Accuracy and Transaction Certification

- In North America NIST HB44-3.40 is enforced, based on type approval of the dispenser as a system. Meter is an embedded device.
- Europe-Germany enforces PTB (NIST equivalent) tracable accuracy requirements via VDE-AR-E-2418-3-100 evaluation process for meter type approval, independent of the EVSE (meter is an accessory to the EVSE)
- OIML R46 EV charging annex, is an international metering treaty that bridges the difference between PTB/VDE and HB44 by allowing both methods- direct meter or measurement functions as embedded.




*OIML R46 power flow diagram, highlighting window on side of EVSE direct to meter display, independent of EVSE transactions display (upper window)*

# ‘electric vehicle wh per mile ratings’

| Score | Wh/mile | Economy figures kWh/100 miles |
|---|---|---|
| Excellent | 190-225 | 19-23 |
| Good | **226-260** | 24-26 |
| Average | 261-295 | 27-30 |

1 more row

https://www.buyacar.co.uk › cars

Electric car efficiency explained: miles per kWh - BuyaCar

Search for: What is a good Wh per mile?

Which EV has best miles per kWh?

**The most efficient electric cars in 2022**

- Tesla Model 3, Standard Range Plus: 4.56 miles per kWh.
- Fiat 500e: 4.54 miles per kWh.
- Tesla Model 3, Long Range: 4.54 miles per kWh.
- Hyundai Ioniq Electric: 4.19 miles per kWh.
- BMW i3: 4.16 miles per kWh.
- Mini Electric: 4.10 miles per kWh.

Wh per Mile – How much energy you consume to go a mile.

KWh / 100 miles: Same * 100

Miles per kWh – Just the inverse of the above.

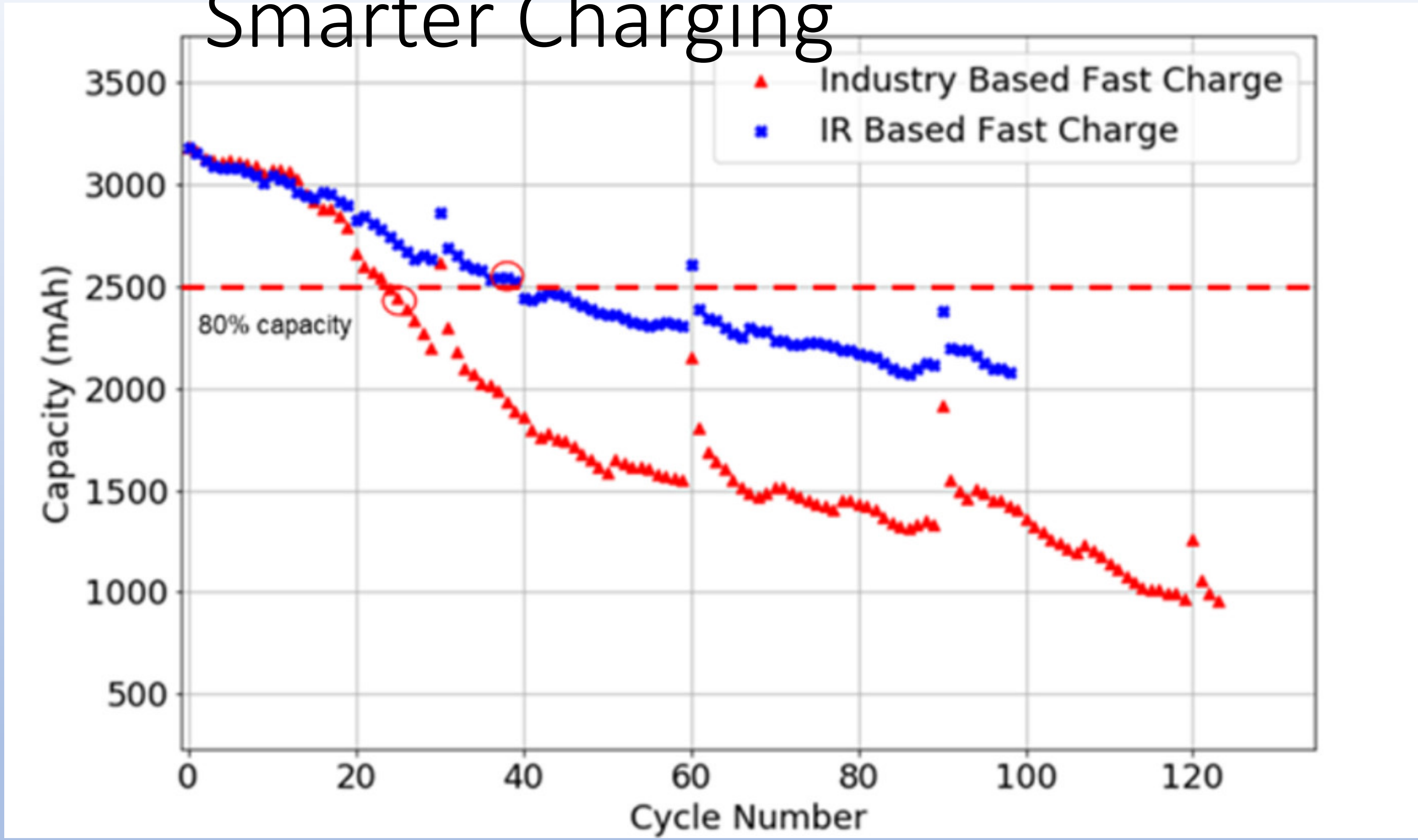
# Recent ABB Terra 350 Exprience

| Specifications | Terra HP 175 | Terra HP 350 |
|---|---|---|
| **Electrical** | | |
| Max output power | 175 kW peak<br>160 kW continuous | 350 kW peak<br>320 kW continuous |
| AC Input voltage range | UL: 3-phase, 480Y/277 $V_{AC}$ +/- 10% (60 Hz)<br>CSA: 3-phase, 600 $V_{AC}$ +/-10% (60 Hz) | |
| AC input connection | L1, L2, L3, GND (no neutral) | |
| Nominal input current and input power rating | UL: 231 A, 192 kVA<br>CSA: 185 A, 192 kVA | UL: 2x231 A, 384 kVA<br>CSA: 370 A, 384 kVA |
| Recommended upstream circuit breaker(s) | UL: 1 x 300 A<br>CSA: 1 x 250 A | UL: 2 x 300 A<br>CSA: 2 x 250 A |
| Power Factor | ≥ 0.97 | |
| Current THD | IEEE 519 Compliant; <8%; option for 5% | |
| DC output voltage | 150 – 920 VDC | |
| DC output current | 375 A CCS-1<br>200 A CHAdeMO | 500 A CCS-1<br>200 A CHAdeMO |
| Efficiency | 95% at full load | |
| **Interface and Control** | | |
| Charging protocols | CCS-1 and CHAdeMO | |
| User interface | 7" high brightness full color touchscreen display<br>Option for 15" display | |
| RFID system | ISO/IEC 14443A/B, ISO/IEC 15393, FeliCa™1,<br>NFC, Mifare, Calypso (option: Legic) | |
| Network connection | GSM/3G/4G; 10/100 base-T Ethernet | |
| Communication | OCPP 1.5 and OCPP 1.6 enabled | |
| Support languages | English (others available on request) | |
| **Environment** | | |
| Operating temperature | -35 °C to +55 °C<br>(de-rating characteristics apply) | |
| Storage Temperature | -10 °C to +70 °C | |
| Protection | IP 54, outdoor use | |
| Humidity | 5% to 95% | |
| Altitude | 2000 m / 6560 ft | |
| **General** | | |
| Charge cable | 3.2 m (10 ft 6 in) CHAdeMO<br>3.2 m (10 ft 6 in) or 3.8 m (12 ft 6 in) for CCS-1 | |
| Dimensions (H x W x D) | Power cabinet: 2030 x 1170 x 770 mm / 79.9 x 46.1 x 30.3 in<br>Charge post: 2390 x 620 x 440 mm / 94 x 24.4 x 17.3 in | |
| Weight | Power cabinet: 1340 kg / 2954 lbs<br>Charge post: 250 kg / 551 lbs | |
| Compliance and safety | UL/cUL UL 2202, NEC Article 625, EN 61851, EN 62196;<br>CHAdeMO 1.2; DIN 70121, ISO 15118;<br>IEC 61000-6-3 EMC Class B; BA Rule 49 CFR Part 661.5 | |

Spec review details…

- Derating > 40C reduces output by 85% affecting Fast Charging Service
- Storage Temp @ -10C cause damage if stored outdoors?
- IP54 confirm outdoor protection
- Touch Screen – Confirm operation at extreme cold temperatures
- OCPP 1.6 is lower than latest OCPP 2.01
- Reach Study required for 10’6” CCS cable

# Smarter Charging




[*Internal resistance-based fast charging vs. standard method - UC Riverside research*]()

# Not just Range Anxiety

> 10 types of EV Charging Anxiety Identified

*Some examples include:*
*Charger/vehicle Interoperability*
*Equipment availability*
*Amenities available*
*Reasonable pricing compared to the alternatives*
*Time required*
*Ease of use*

# Interoperability - SAE

SAE Recommended Practice SAE J2847-2 establishes requirements and specifications for communication between plug-in electric vehicle (PEV) and the DC EVSE. Where relevant, this document notes, but does not formally specify, interactions between the vehicle and vehicle operator.

This document applies to the off-board DC EVSE for conductive charging, which supplies DC current to the rechargeable energy storage system (RESS) of the electric vehicle. Communications can be on the control pilot for PLC communication or wireless network (WiFi modem). The details of powerline communications (PLC) are found in SAE J2931/4.

A typical method of DC charging is shown in Figure 5. This configuration allows DC charging with the VSC and ISC. Figure 5 is for illustration only and is not intended to constrain EVSE or EV design.

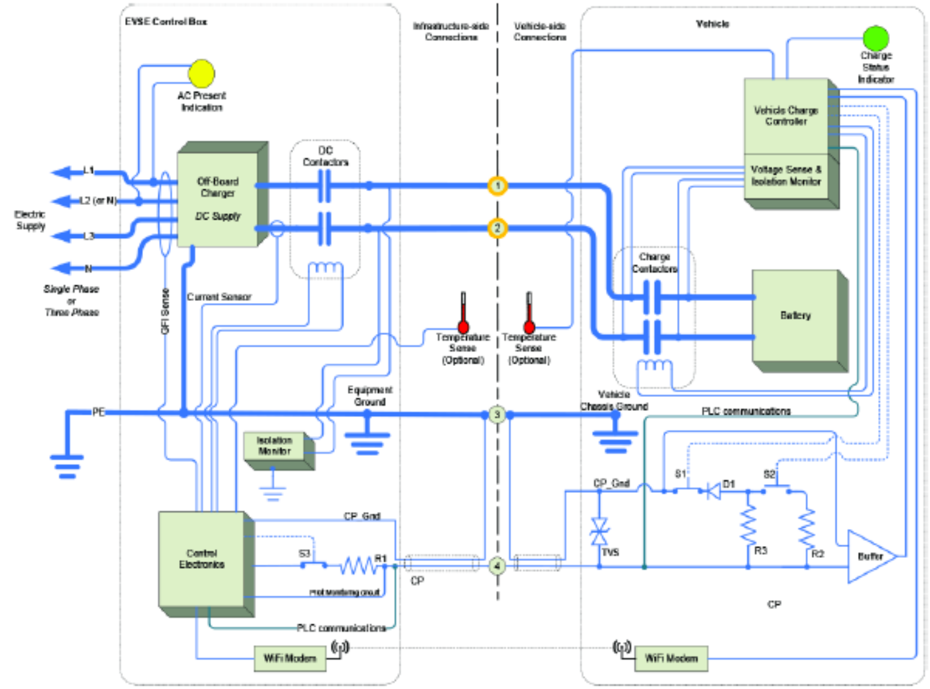


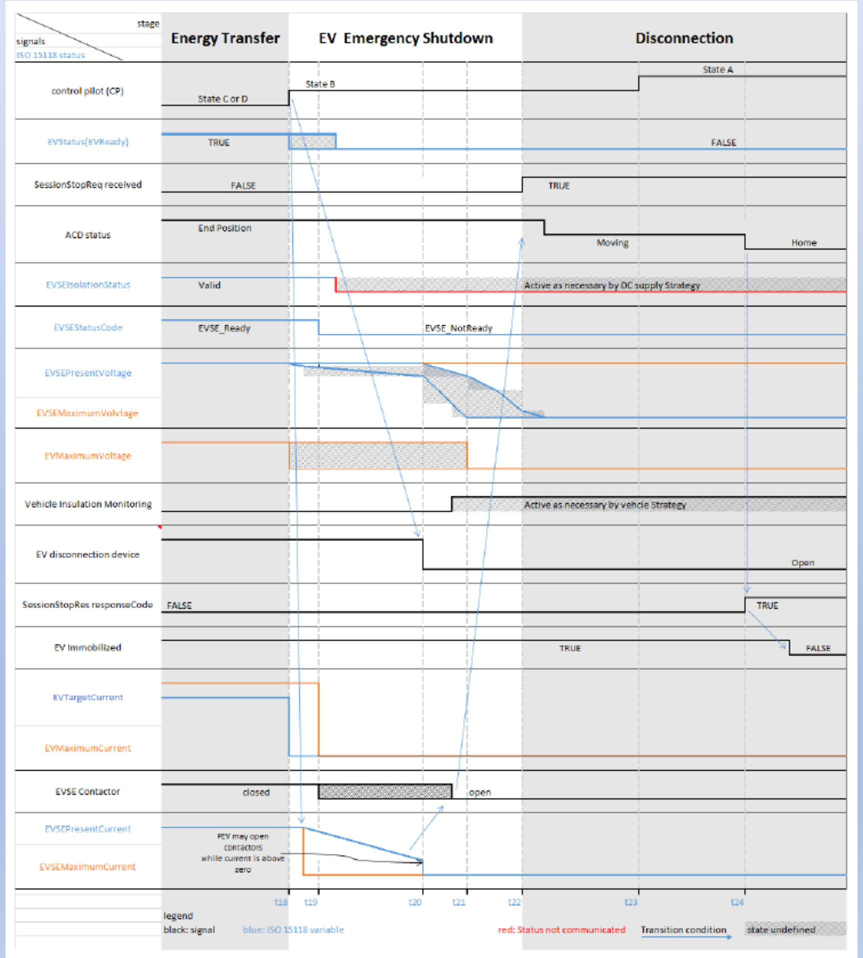

*Figure 5 - DC system configuration*

DC Charging is Complicated:

Things that (Can) go wrong:

- Software errors
- Equipment issues
- Customer experience
- Network issues
- Interoperability issues
- Hardware damage/wear
- Dirt/Water intrusion
- Temperature ranges

# Charging - It’s Complicated!




Complicated and planning to change!

Much like compatibility between computers.

# Factors Influencing Driving Range

Key Factors influencing Range/Lifecycle:

Driving Speed/Behaviour: 15% drop between 65 & 75 MPH

Ambient Temperature/Wind: Range can drop 50% in cold temperatures

Loading: Higher Mass = Higher power required to accelerate

HVAC Settings: Ex. 41% drop in -7C temperatures. Comfort versus Range.

Tire Pressure: Higher Pressure = Improved Range (possibly reduced handling)

Depth of Discharge: Charging to highest capacity/ Discharging to lowest capacity reduces lifecycle.

Lifecycle: 2% Range loss per year. Worse when DC Fast Charging is used.

# How long to charge? Well, it depends!

Key Factors influencing EV Charging rate (DC):

Battery State of Charge (SOC): Rate reduces towards 100% SOC

Vehicle

- Temperature: Outside 25C, rates will be reduced especially in cold ambient
- Battery Lifecycle: Older batterie will charge more slowly on average
- Vehicle HVAC Needs: Power can be diverted to vehicle not battery
- Charger Equipment: Power electronics can become too hot/cold

Infrastructure

- Customer Settings: Customer can select maximum charging level through EV User Interface
- Utility/facility/adjacent requests to curtail: Depends on location/time situation
- Pricing regime: Pricing schemes can provide curtailment

Rate determined/negotiated between Charger and Vehicle. Changes every second. Any can refuse if outside required/agreed upon level. Lowest rate is the chosen rate.

Be cautious when developing Pro Formas