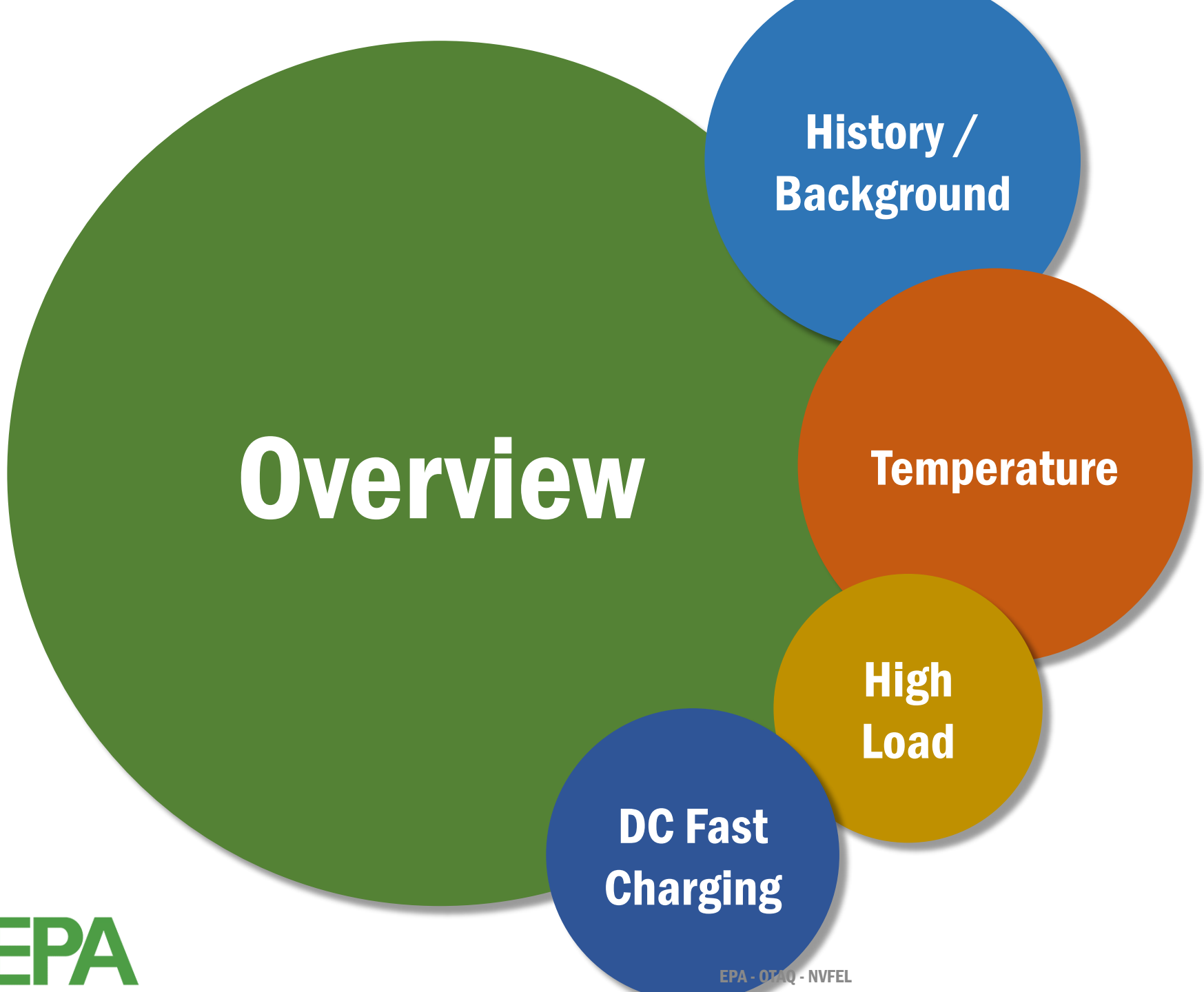
Exploratory EV Testing

EPA – OTAQ – NVFEL
Ann Arbor, MI

MSTRS Spring Meeting
May 30, 2024


Overview
History / Background
Temperature
High Load
DC Fast Charging

History

Early 2021: Are there significant temperature effects on EV vehicle and/or battery efficiency at ‘extreme’ temperatures for modern, actively managed EV power systems?

- 20F (-7C) – 95F (36C) @ NVFEL Hot and Cold Test Facilities
- Onboard vehicle CAN signal monitoring + off-board power analyzer
- EVSE recharge monitoring
- SMCT / SMCT+ EV-centric drive cycles (in conjunction with SAE MCT exploration)

Vehicles acquired through cooperative sharing agreement with Transport Canada / Environment Canada

History

Early 2024: Five vehicles tested on multiple drive cycles, load profiles, and temperatures (with replicates).

~120 tests performed to date (~1000 hrs).

- Does extreme temperature affect vehicle/battery performance?
- Do CAN vehicle signals vary within the same manufacturer?
- Unique HVAC strategies (heat pumps)?
- Battery SOC?
- High load / towing?
- DC fast charging?
- Battery chemistry?

Background

Background – SMCT / Main Test Cycle

SMCT / SMCT+
Cycle 1: UDDS, UDDS
Cycle 2: HWY, US06, HWY, UDDS
Cycle 3: UDDS, **(SC03)**
Constant Speed Cruise (CSC): 1 hr repeats until vehicle cannot maintain 65mph
Cycles are separated by up to 30min soak

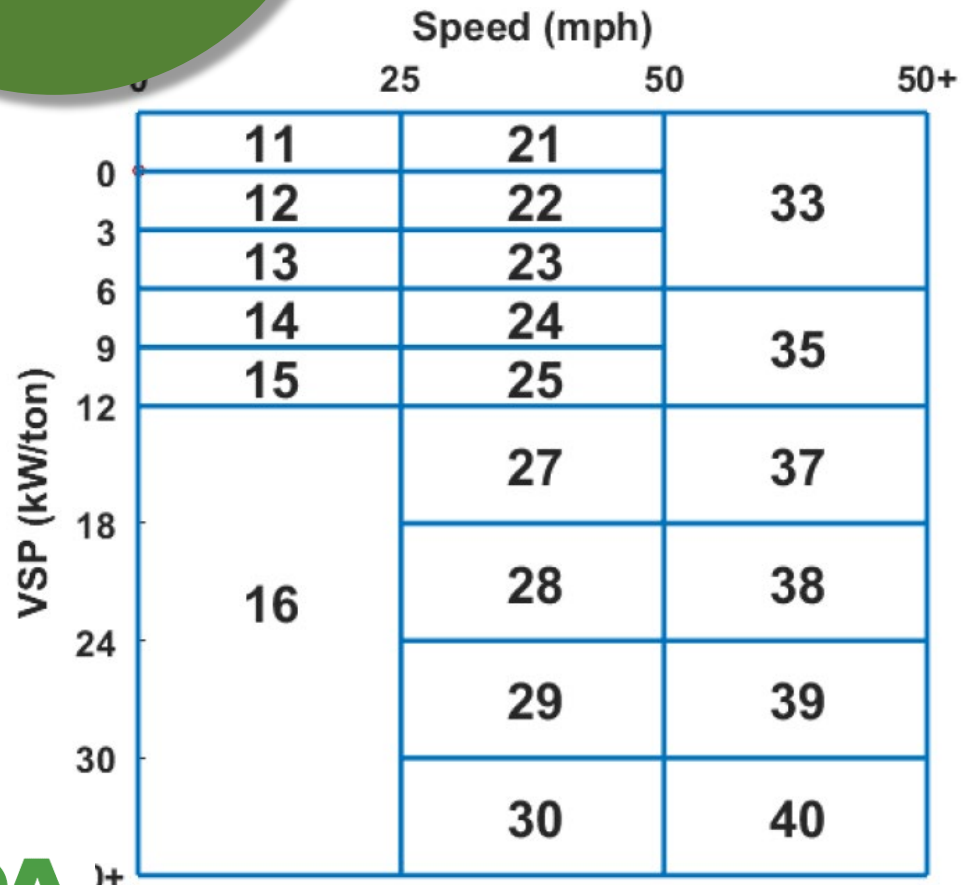
*SC03 added to test cycle in early 2023 to allow for additional cycle analysis

HVAC at 72F medium speed automatic control, no seat heating or cooling Some tests performed with HVAC disabled

EVSE power delivery / recharge data collected at soak temperatures (72F, 20F)

Background

Operating Modes



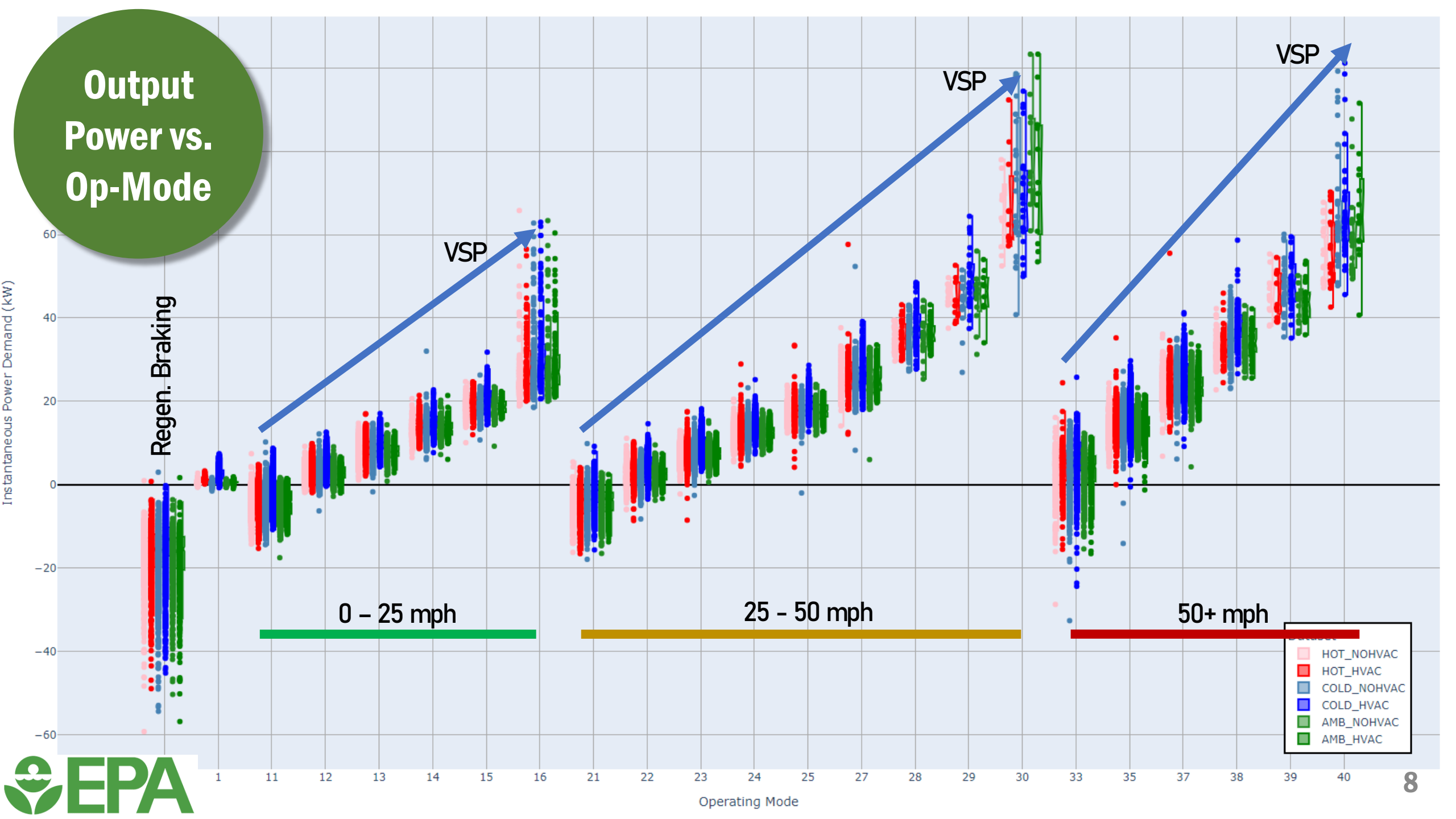
How do we compare data across cycles (or using real-world driving)?

Operating mode – data binning based on vehicle specific power (VSP) and current speed. VSP is calculated based on vehicle load (ABCs, grade, speed, etc.)

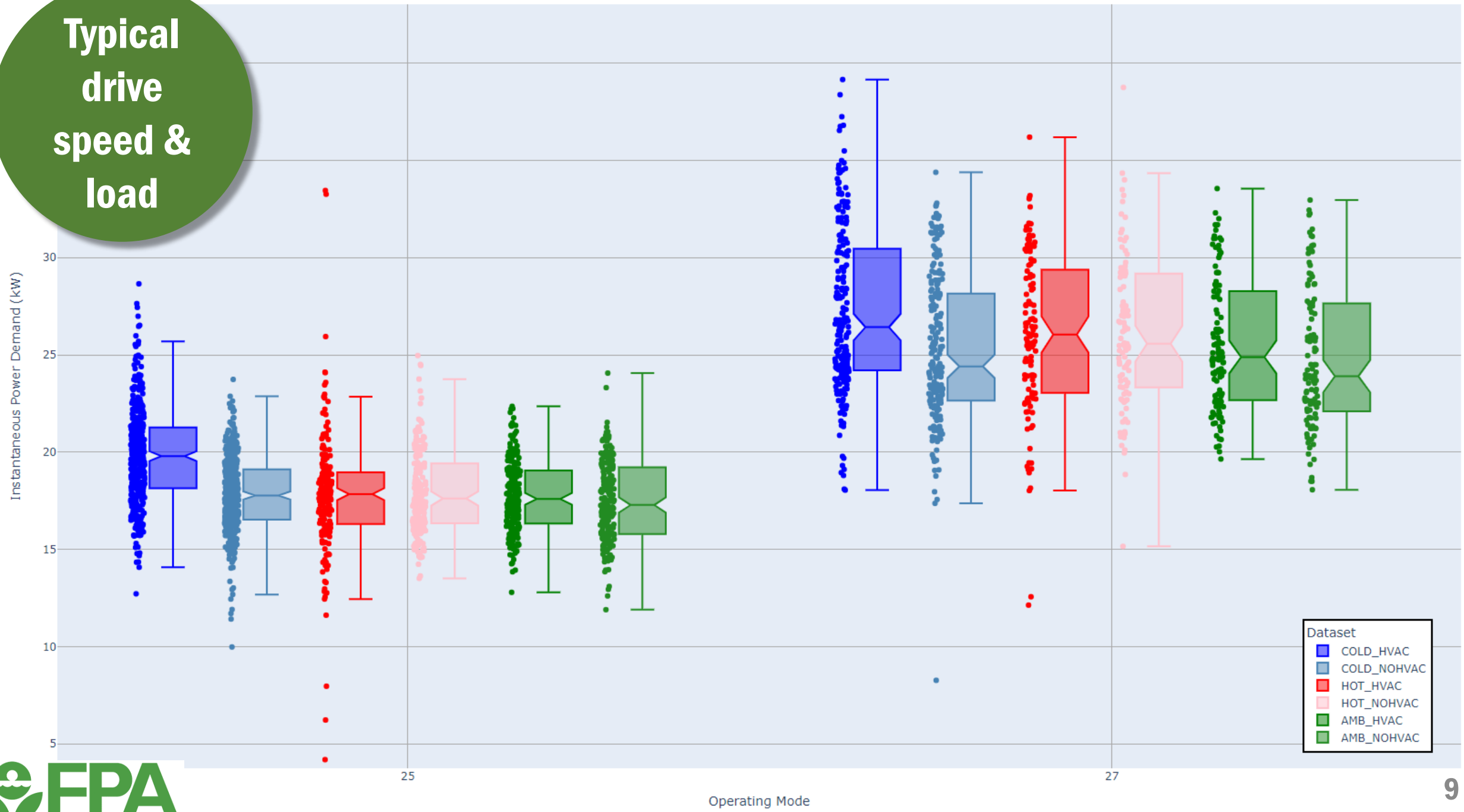
- Used extensively in EPA-OTAQ models (MOVES, etc)
- Additional operating modes may be included for EV-specific operation (e.g. regenerative braking)

Does temperature affect efficiency?

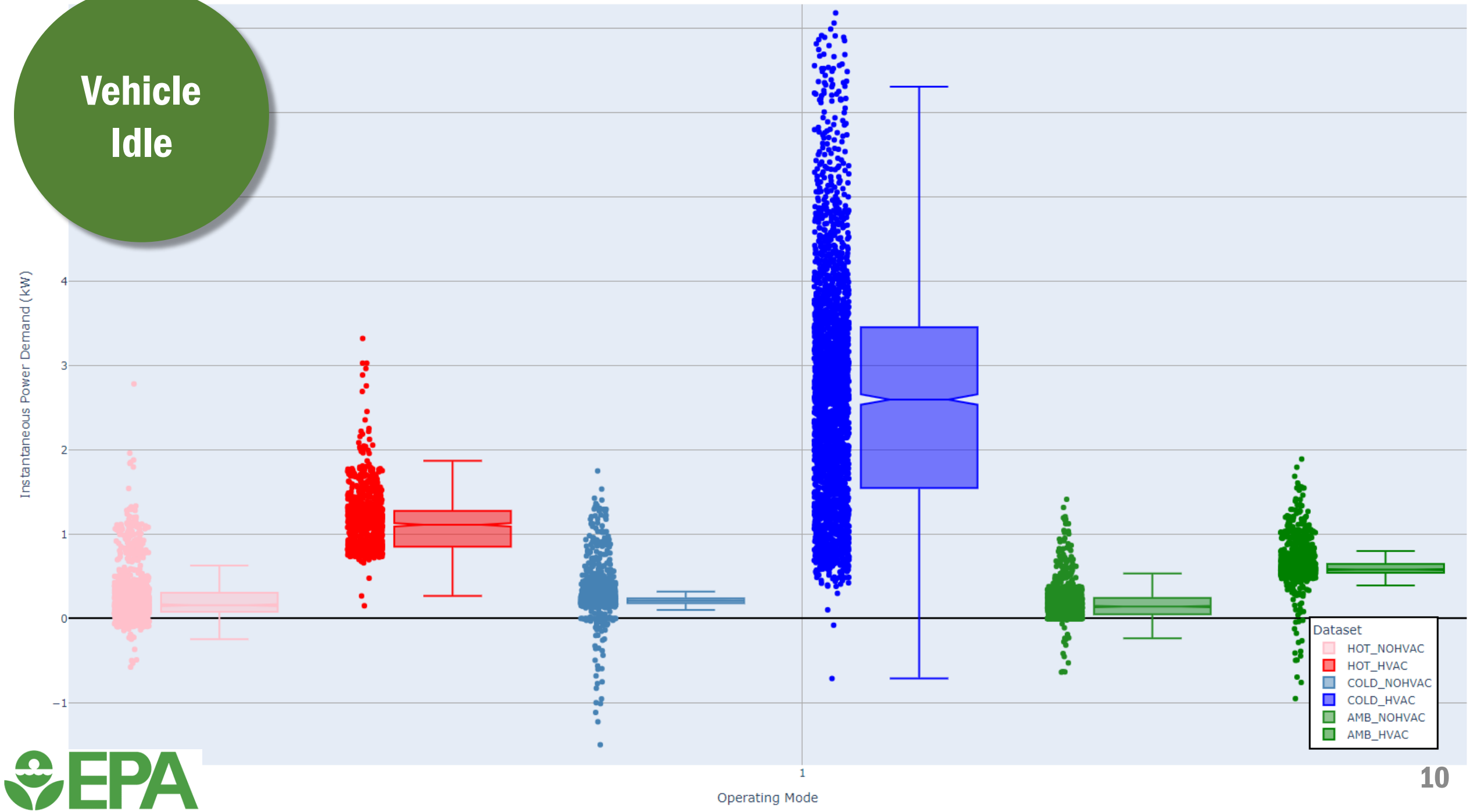
Output Power vs. Op-Mode



Typical drive speed & load

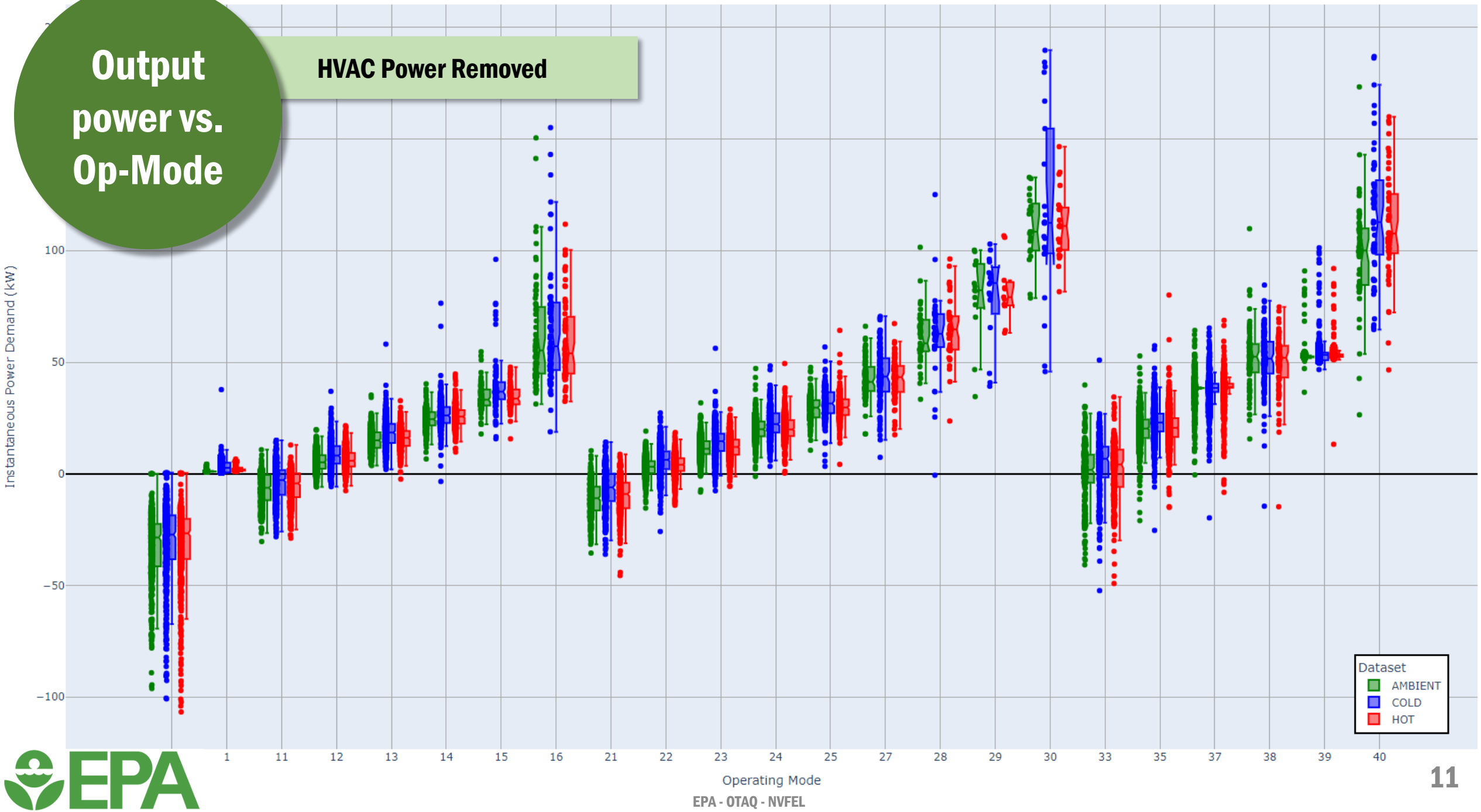


Vehicle Idle



Output power vs. Op-Mode

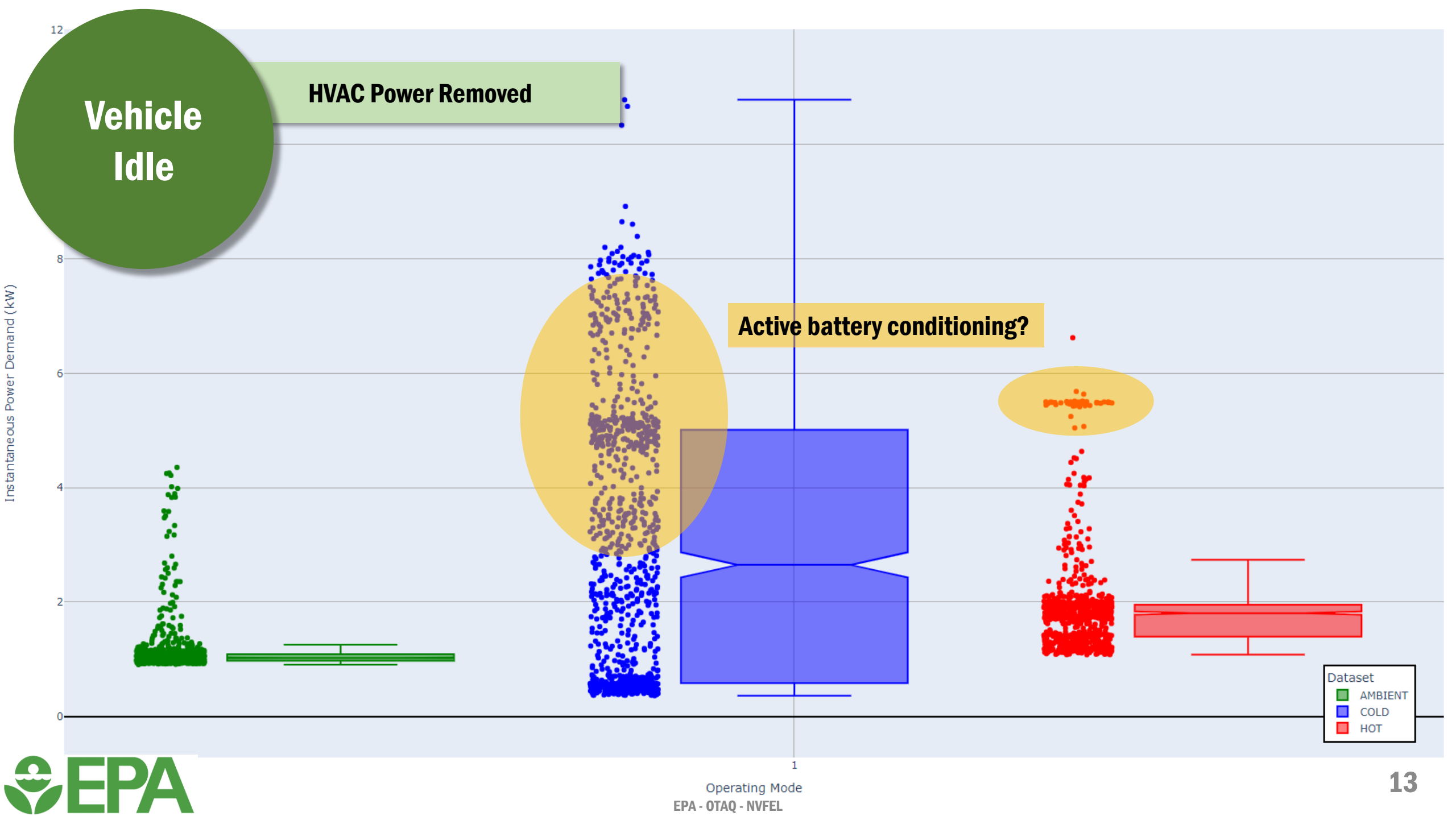
HVAC Power Removed



Typical drive speed & load

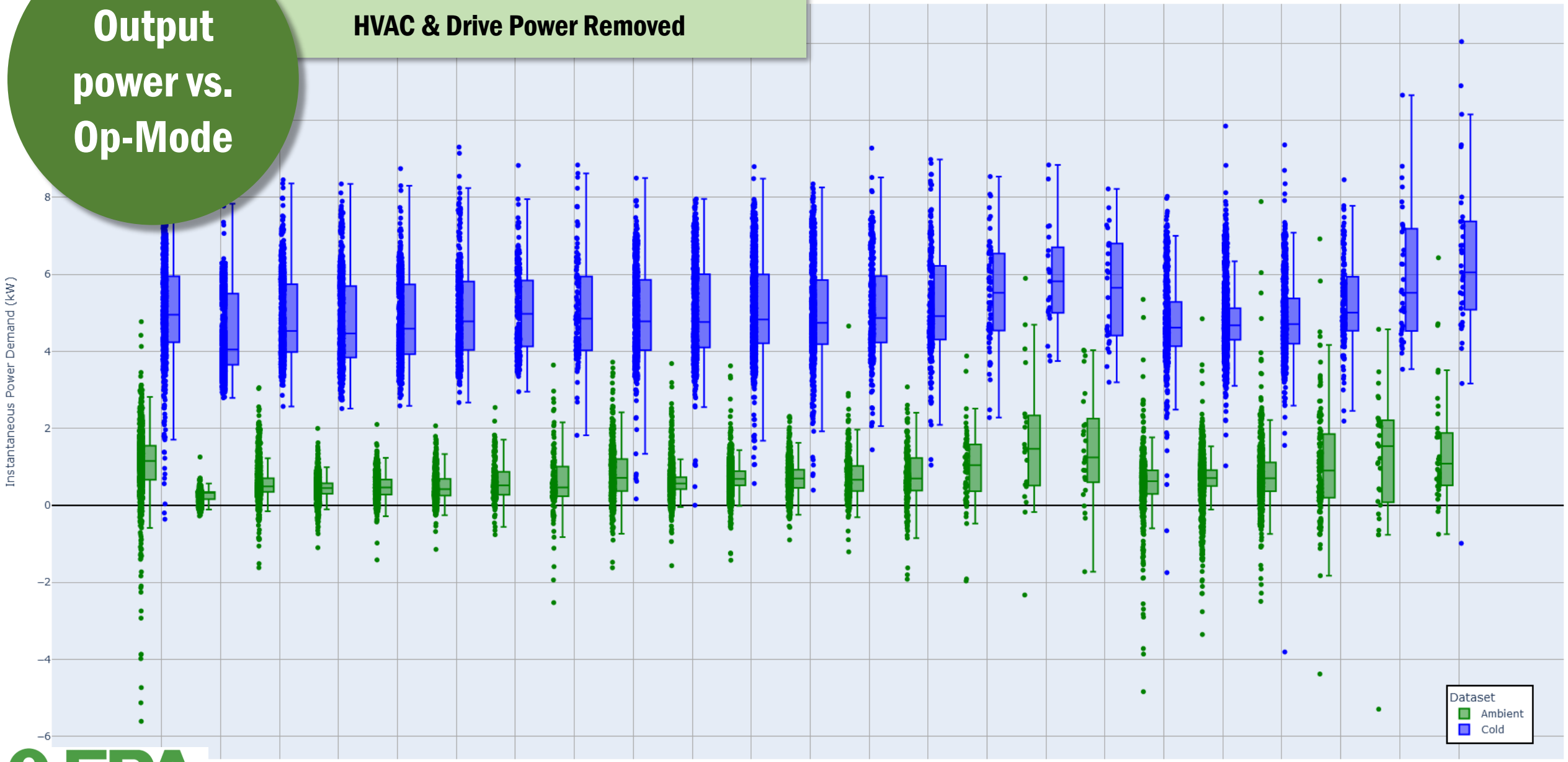
HVAC Power Removed

Vehicle Idle



Output power vs. Op-Mode

HVAC & Drive Power Removed



Takeaways

HVAC power accounts for differences in temperature efficiency

Active battery conditioning and/or quiescent power effects can be seen in some circumstances, but not at statistically significant levels during vehicle operation.

Regulatory drive cycles do not represent high power operation

Lack of high speed/power operation in regulatory drive cycles hampers the statistical power of modeling vehicle performance in higher regimes.

The large majority of the SMCT/+ operation time provides very little meaningful data.

Differences in onboard signals make analysis cumbersome

Even within the same vehicle manufacturer, differences in onboard CAN data reporting creates hurdles for analyzing and comparing vehicle operation data. Standard CAN signals (similar to OBD) would greatly improve understanding.

Heat pump analysis inconclusive due to lack of data quality.

Efficiency does NOT mean range!

This analysis focuses on the relationship between temperature, vehicle specific power, and the output power delivered by the high voltage battery systems of electric vehicles.

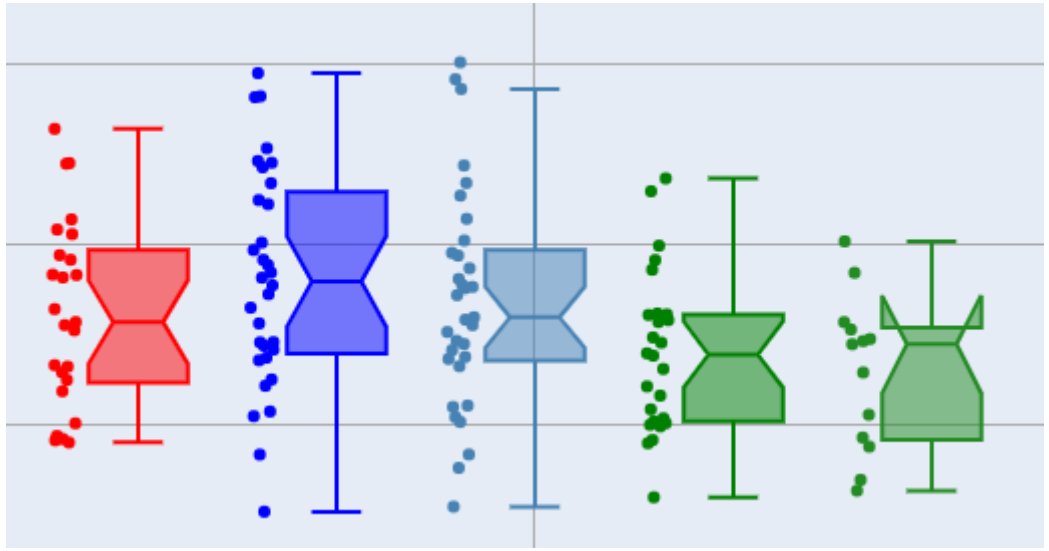
The efficiency of power delivered to the vehicle drive system at various temperatures does not necessarily imply an increase or decrease of usable battery energy (UBE) at different temperature ranges.

Vehicle power efficiency is only one factor that can affect the overall range of an electric vehicle, including battery management techniques, state of charge, state of health, and other UBE effects.

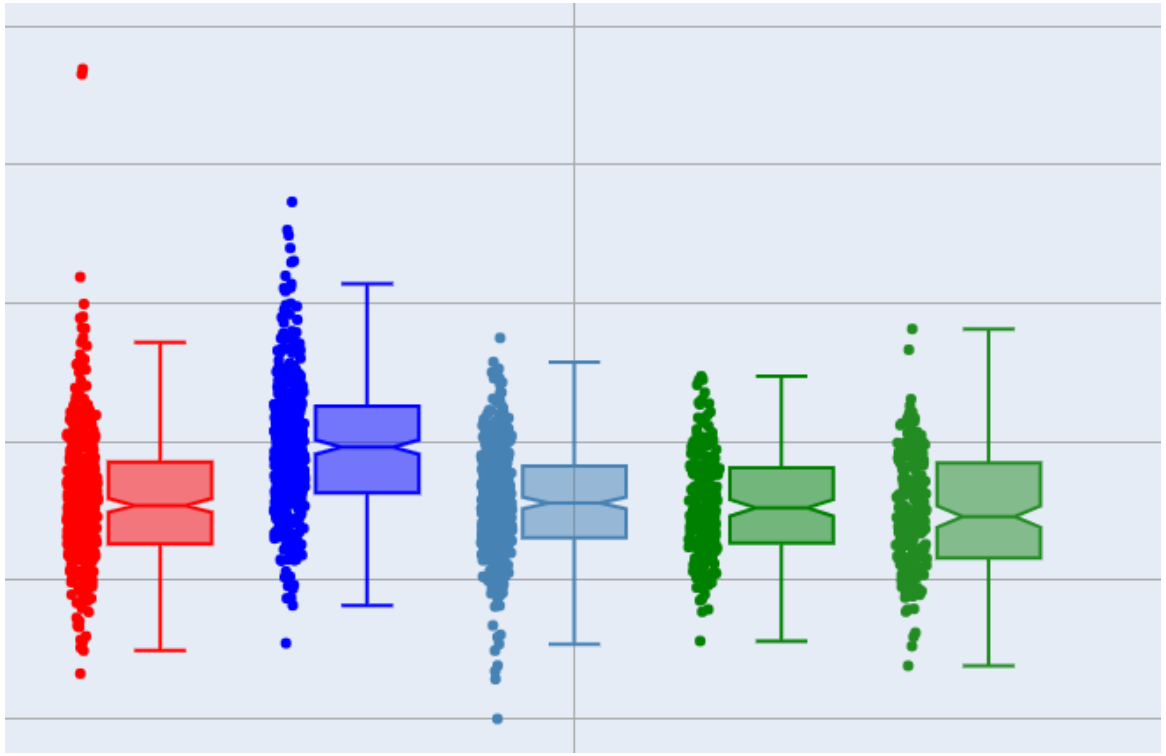
NVFEL is interested in investigating UBE in future programs, including approaches to measuring state of charge and/or state of health across manufacturers.

High Load

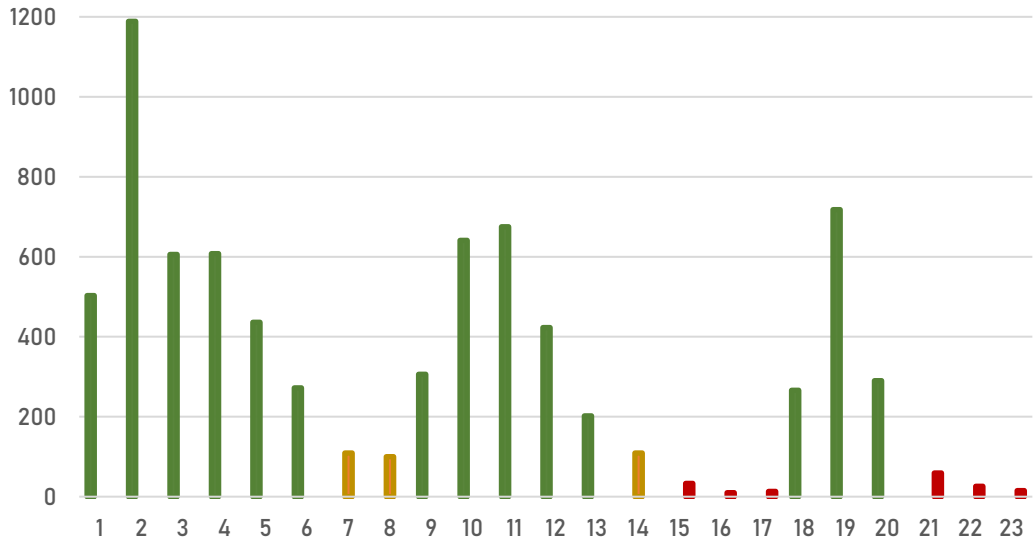
Statistical Power



Op. Mode 39 – High Speed / High Power

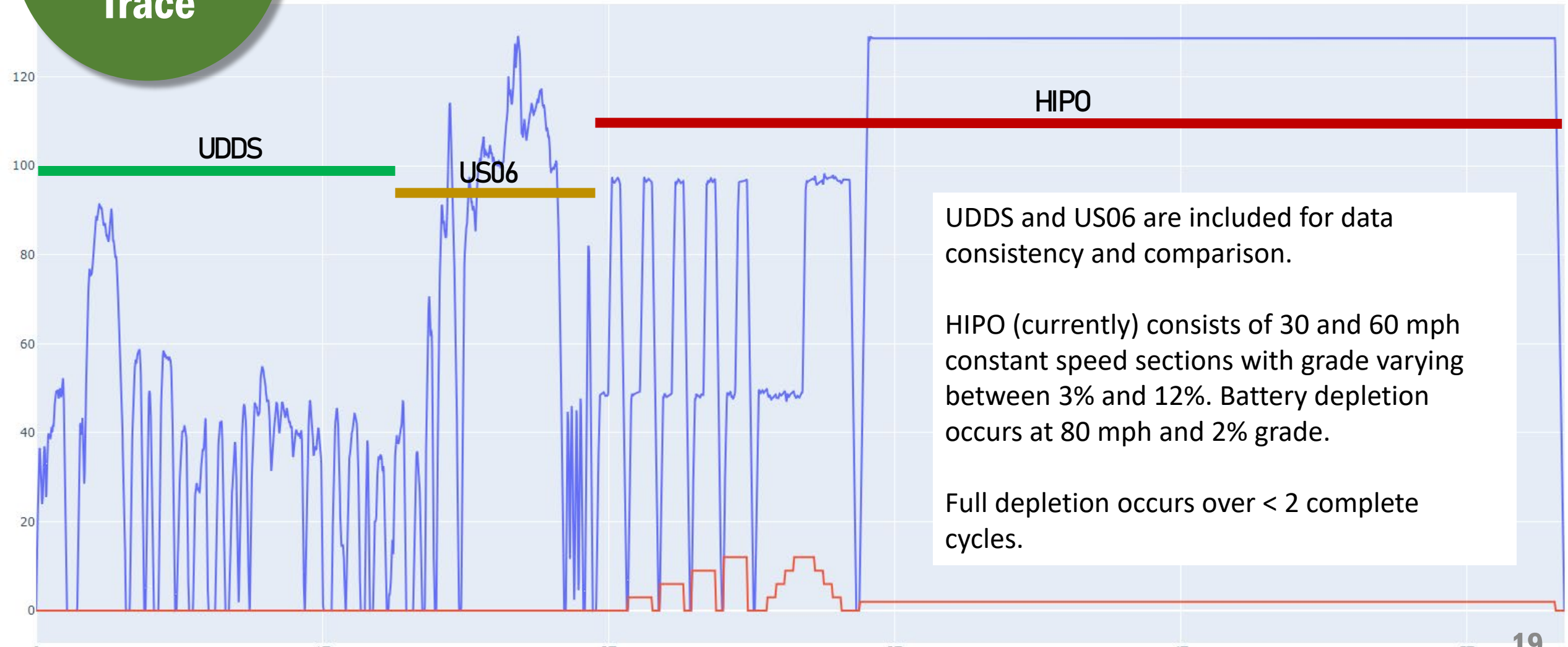


Op. Mode 25 – Medium Speed / Medium Power



HIPO Drive Trace

High Power Operation Cycle (HIPO)

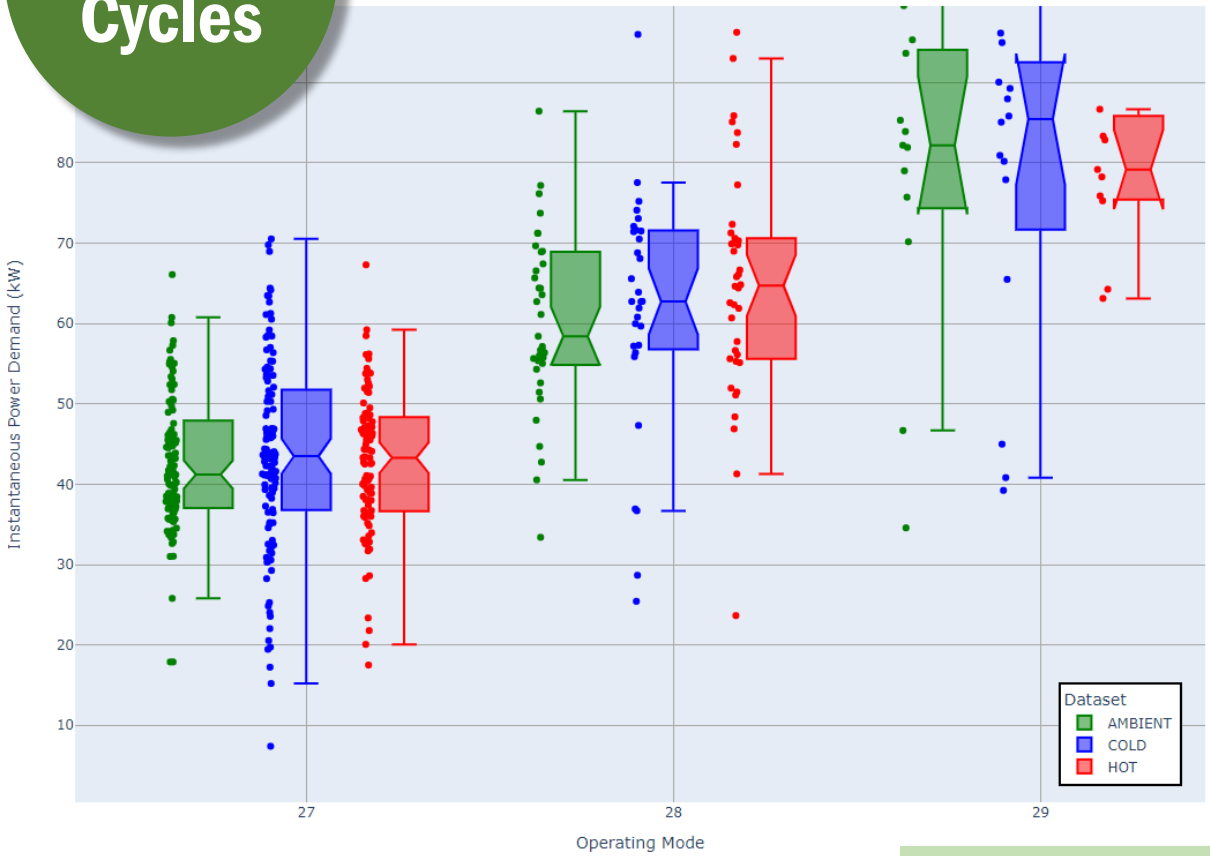


UDDS and US06 are included for data consistency and comparison.

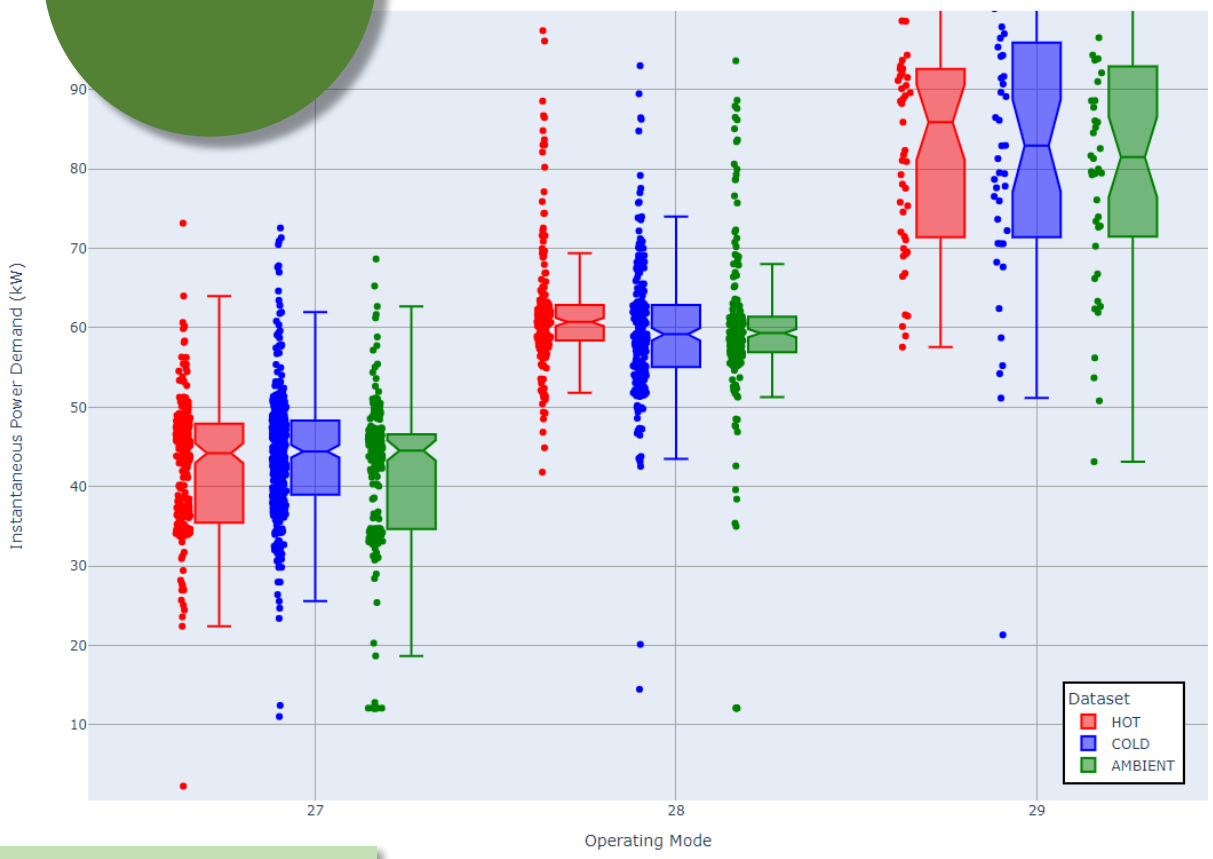
HIPO (currently) consists of 30 and 60 mph constant speed sections with grade varying between 3% and 12%. Battery depletion occurs at 80 mph and 2% grade.

Full depletion occurs over < 2 complete cycles.

Reg. Cycles

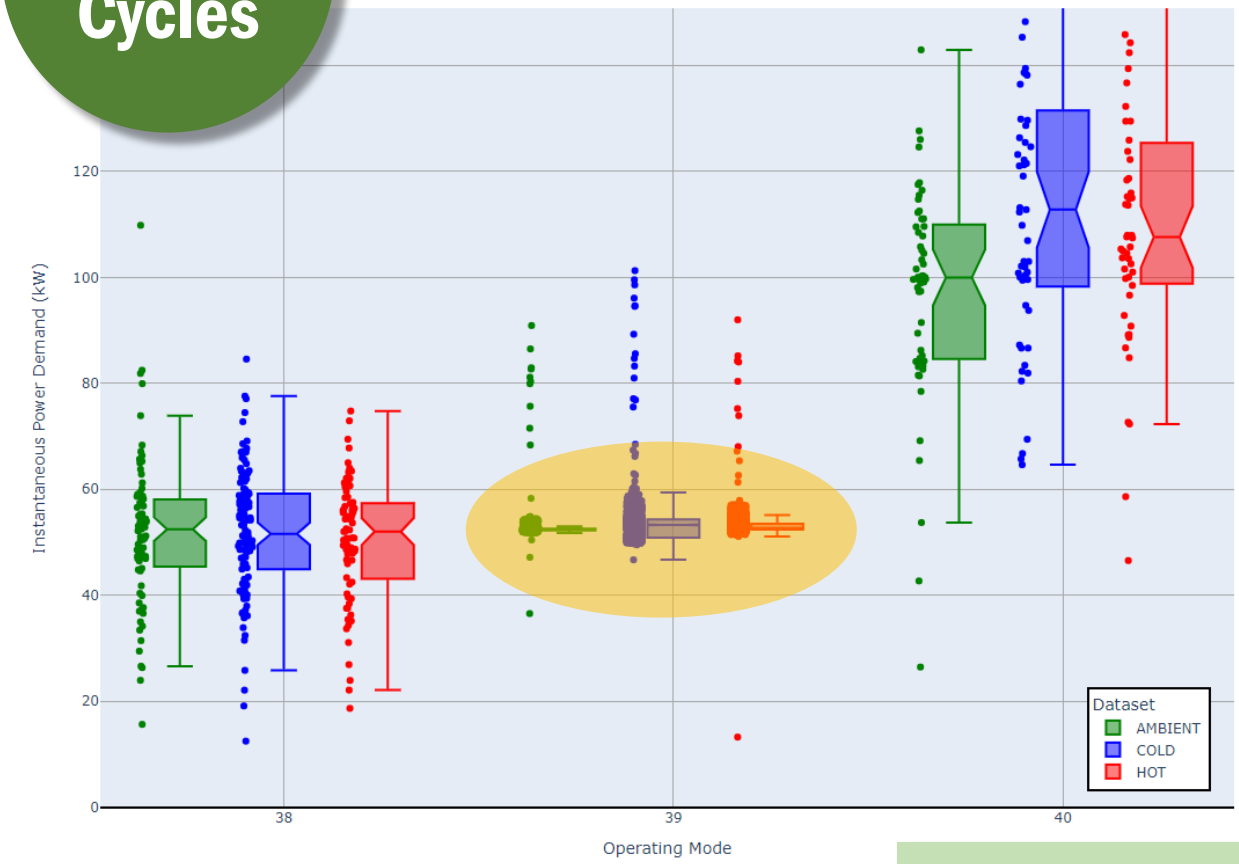


HIPO

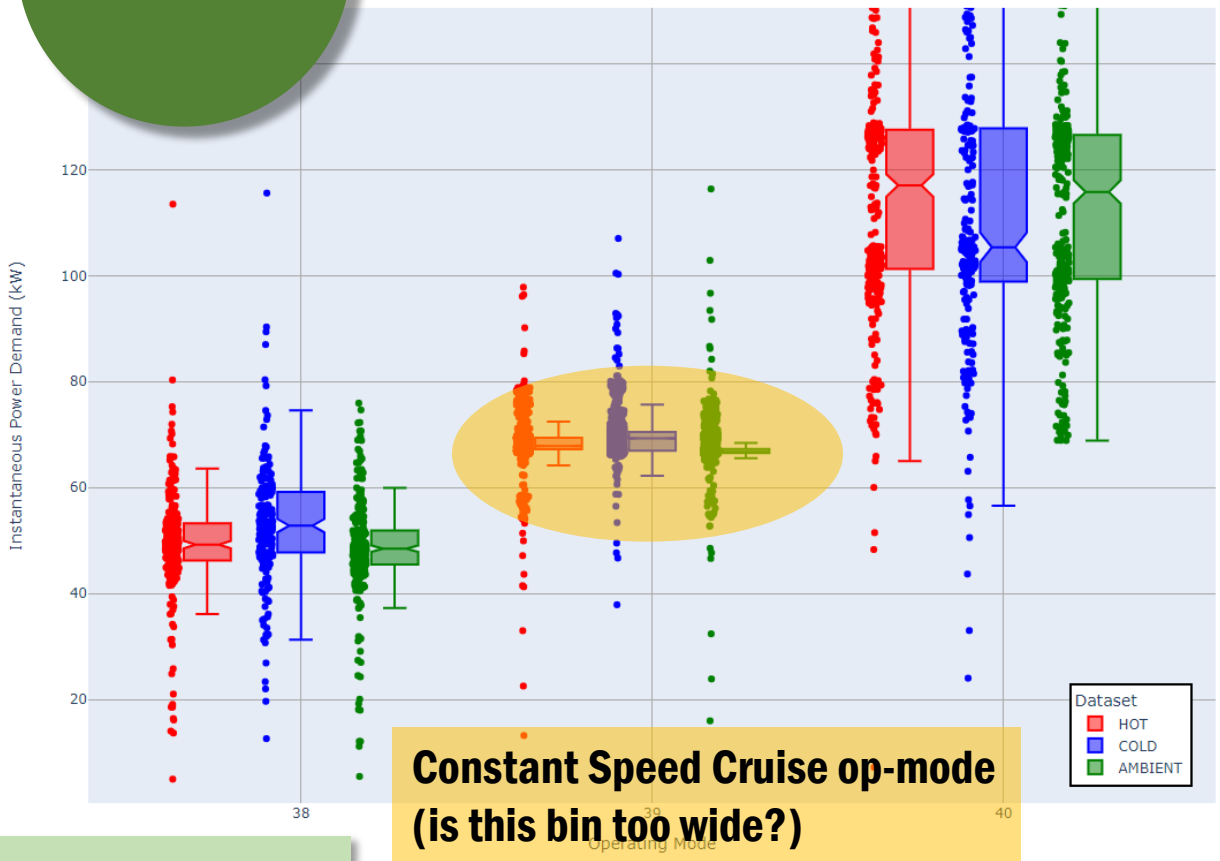


Medium Speed – High Power

Reg. Cycles



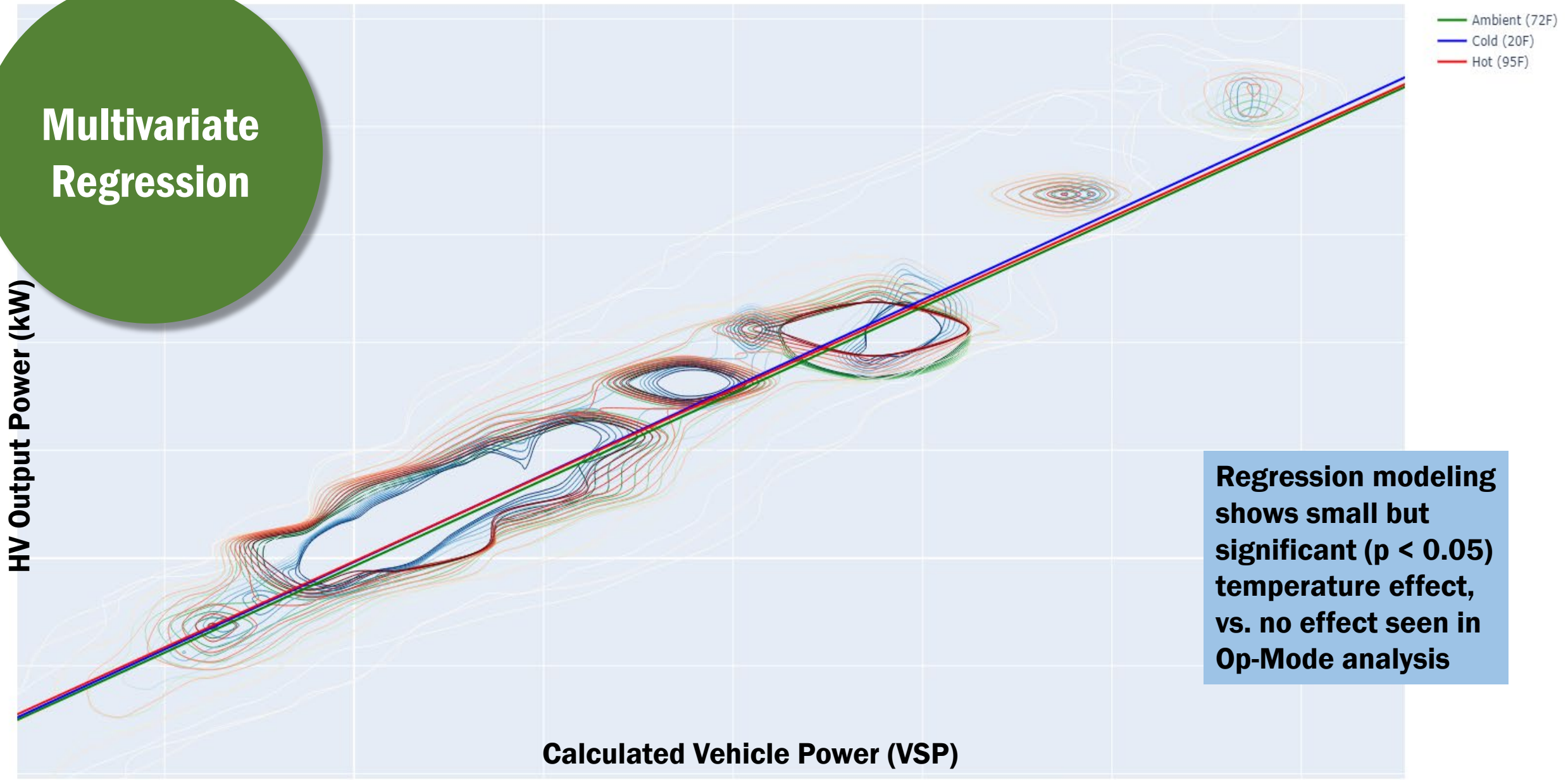
HIPO



Constant Speed Cruise op-mode (is this bin too wide?)

High Speed – High Power

Multivariate Regression



Regression modeling shows small but significant ($p < 0.05$) temperature effect, vs. no effect seen in Op-Mode analysis

Takeaways

Additional drive cycles may reveal modeling discrepancies

Current drive cycles and operating modes are based on data from vehicles that may no longer represent modern vehicles or driving behavior. Operating mode bins representing typical power in high power regime may be too wide for accurate modeling.

Multivariate linear regression may be a useful modeling technique for assessing / predicting EV efficiency in the future.

Even if some operating modes are considered ‘extreme’, collecting enough data in these bins can help better model and understand the full range of potential vehicle operation.

Simulation for grade and inertial weight, but what about ABCs?

The NVFEL dynamometers can accurately simulate high loads for trailer towing, hill climbs, etc… We can add additional load for increased aerodynamic drag, but do not have a solid understanding how these may change with off-cycle loads (e.g. towing).

There is already some evidence from other programs that cold weather adjustments for ABCs do not apply well to EVs.

DC Fast Charging

Mid 2023 TATD installed 3 DC Fast Charger Systems.

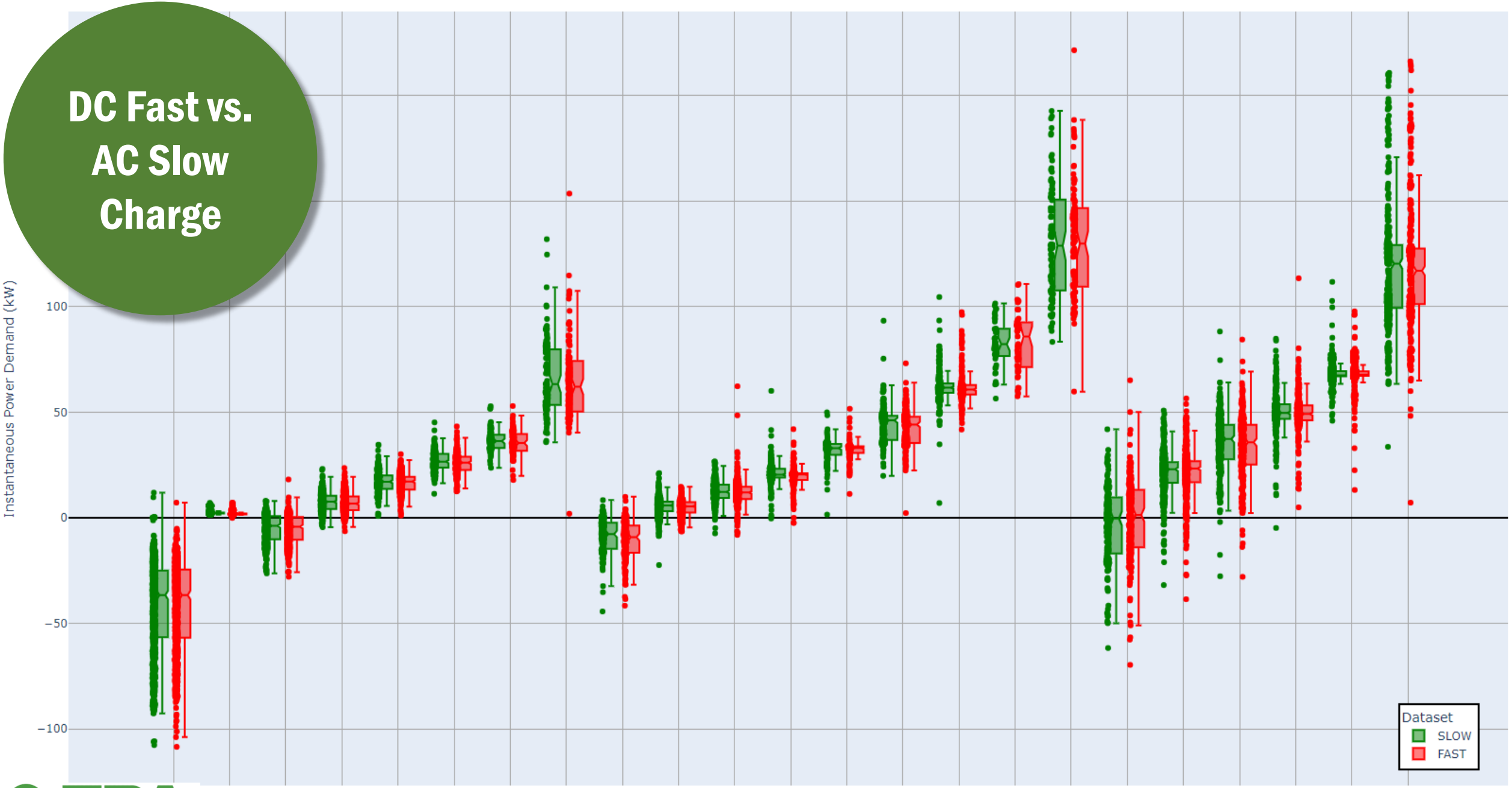
1 Chargepoint **65kW** CCS+CHAdeMO fixed installation in HD Chassis site.

1 Chargepoint **65kW** CCS+CHAdeMO mobile installation in HD prep area.

1 ABB **350kW** CCS+CHAdeMO fixed installation in Cold Test transfer area.

NACS retrofit is currently being explored.

DC Fast vs. AC Slow Charge



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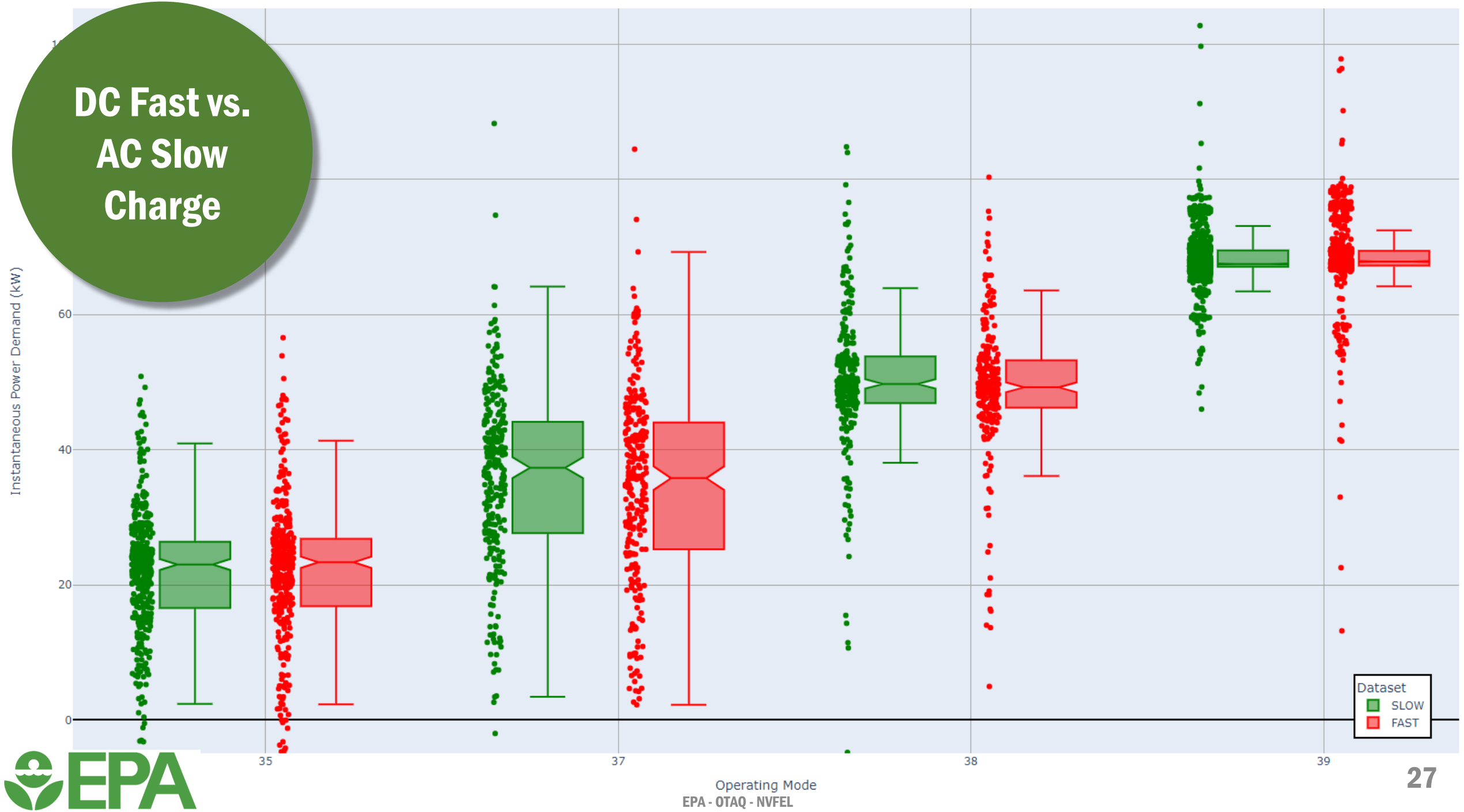
DC Fast vs. AC Slow Charge



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Questions?

Thank you!

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