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Impact of Real World Drive Cycles on PHEV Battery Requirements

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How are The Current Power and Energy Requirements Impacted by Real World Drive Cycles?

- Battery Requirements of End of Life Energy Storage Systems for PHEVs
  - DOE & USABC goals
  - Sizing over UDDS (U.S. FTP-72)

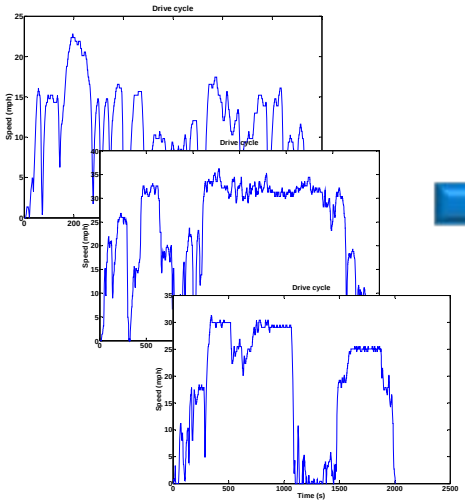
Characteristics at EOL (End of Life)	**units**	**High Power/Energy ratio Battery**	**High Energy/Power ratio Battery**
Peak Pulse Discharge Power (2s)	kW	50	46
Peak Pulse Discharge Power (10s)	kW	45	38
Peak Regen Pulse Power (10s)	kW	30	25
Available Energy: Charge Depleting Mode @ 10kW	kWh	3.4	11.6
Reference equivalent electric range		10 miles	40 miles

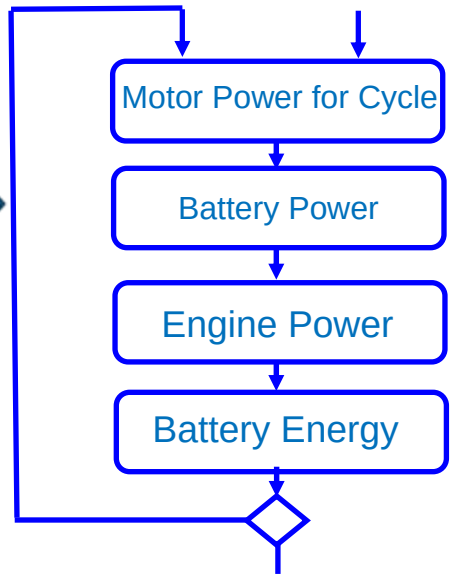
Objective: Impact of Real World Drive Cycles on Power and Energy Requirements

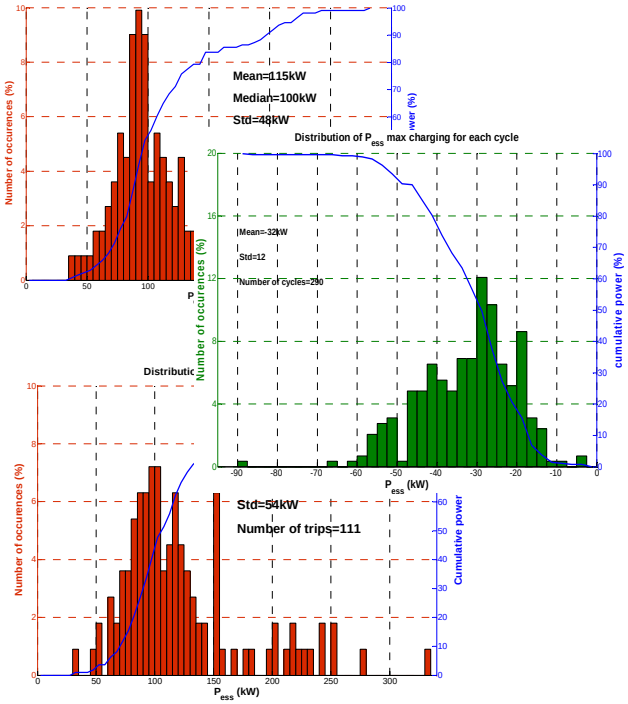
Real World Drive Cycles

Automated Sizing

Analysis (Distribution)







>100 Drivers
1 day in
Kansas City

Power Split
Midsize Vehicle

Only Hot conditions assumed

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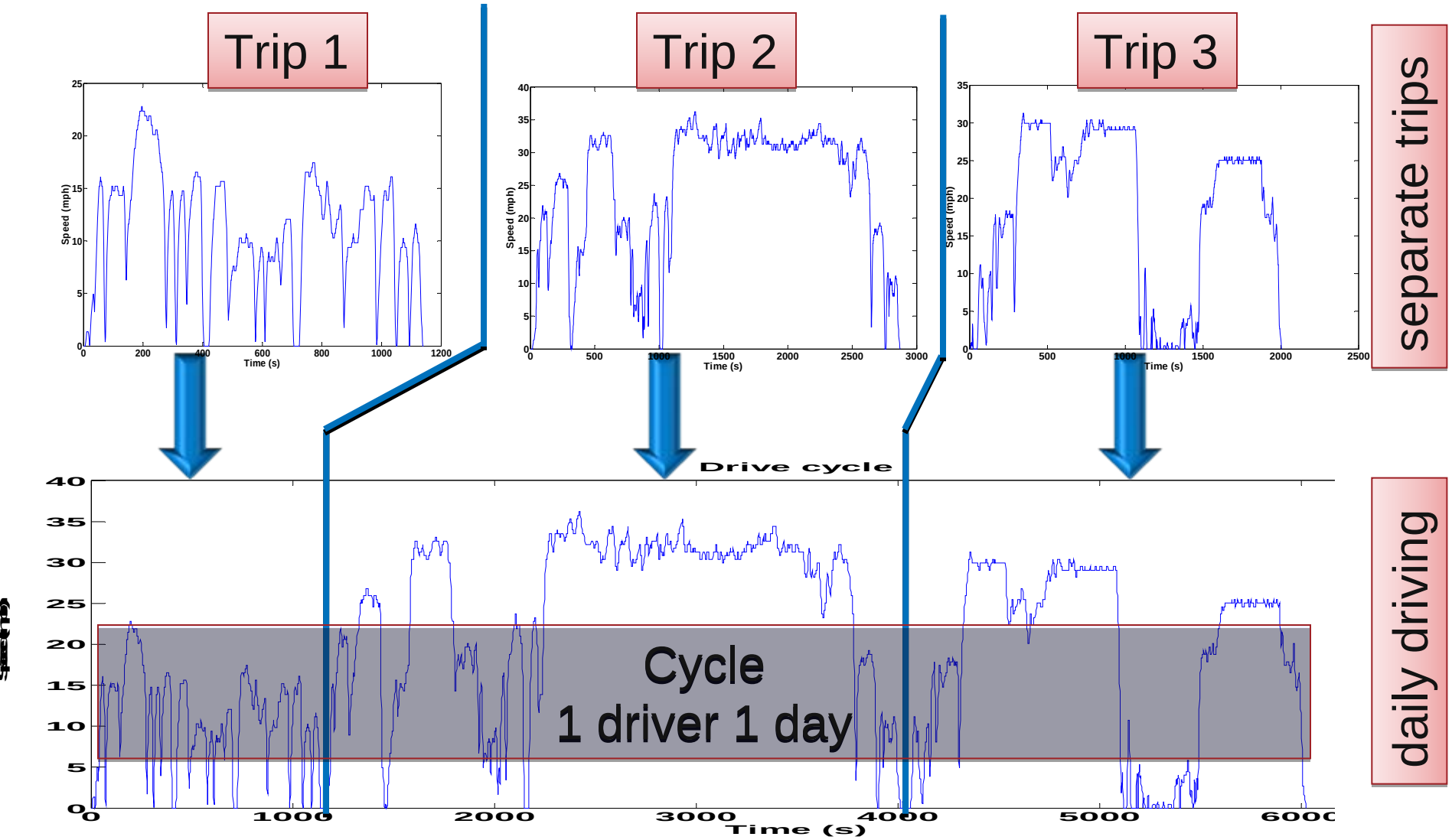
Analysis of Vehicle Speed Traces at Different Levels



May not be a representative sample

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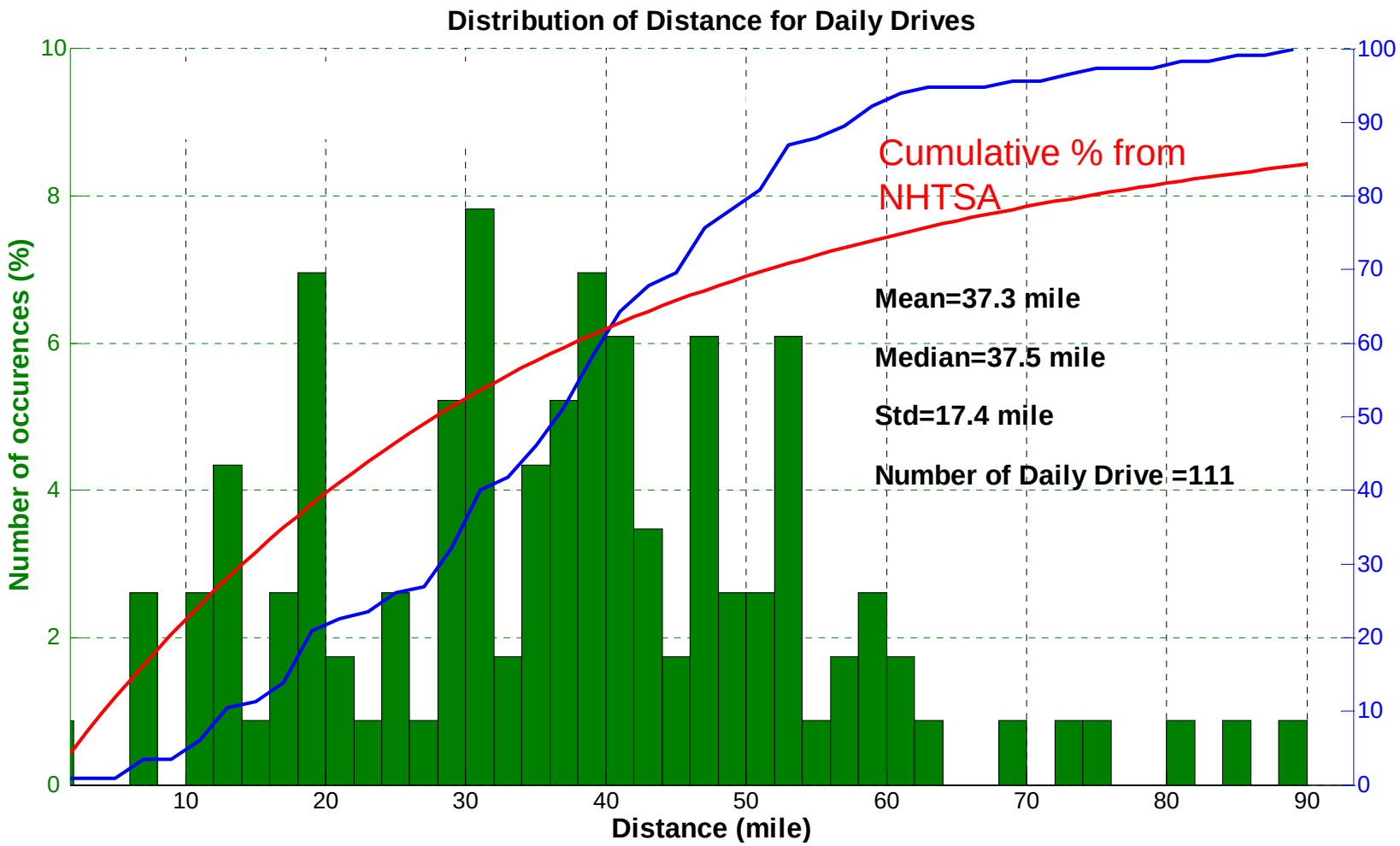
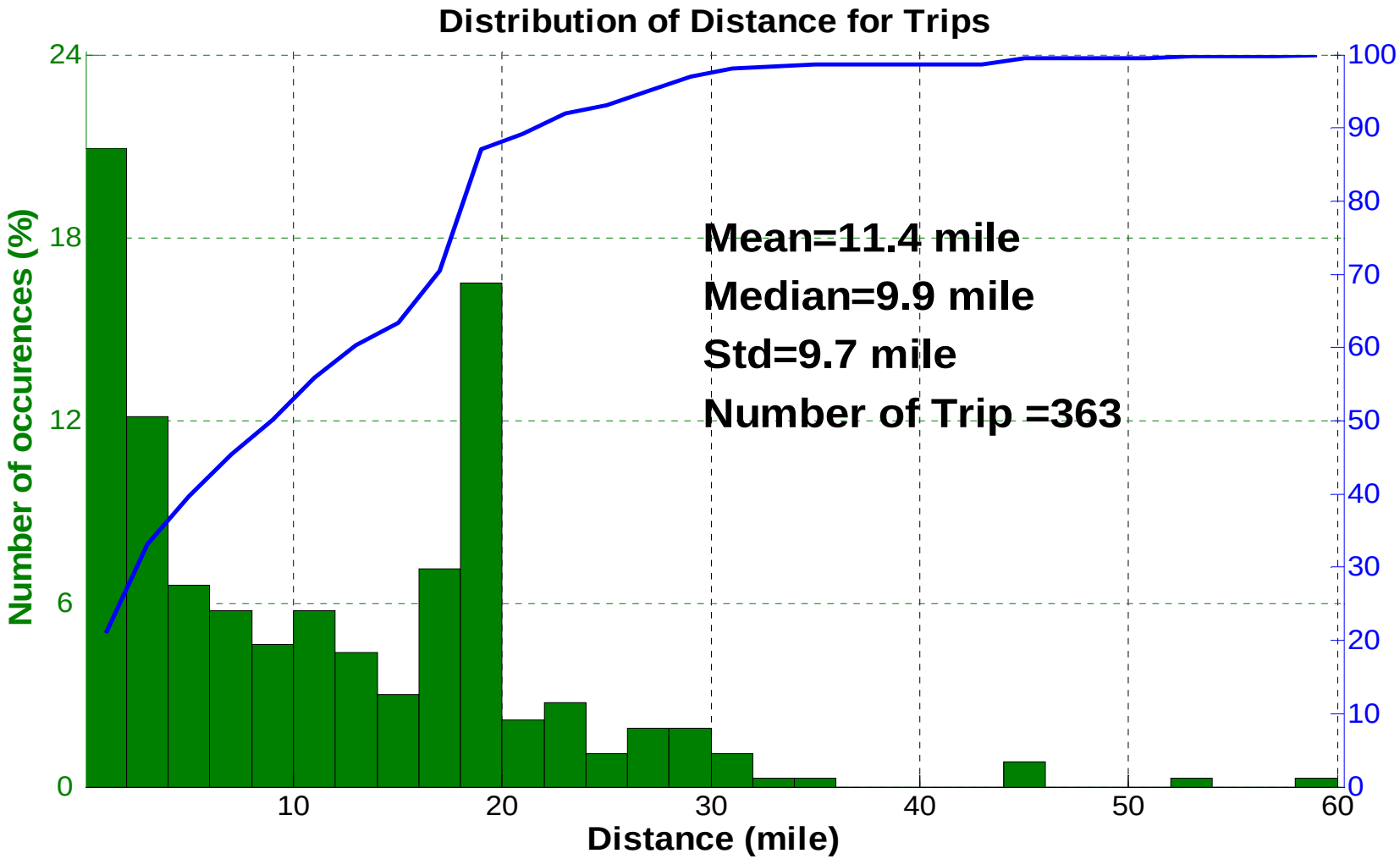
Daily Driving Characteristics

- 111 different drivers – All based on Conventional Vehicles

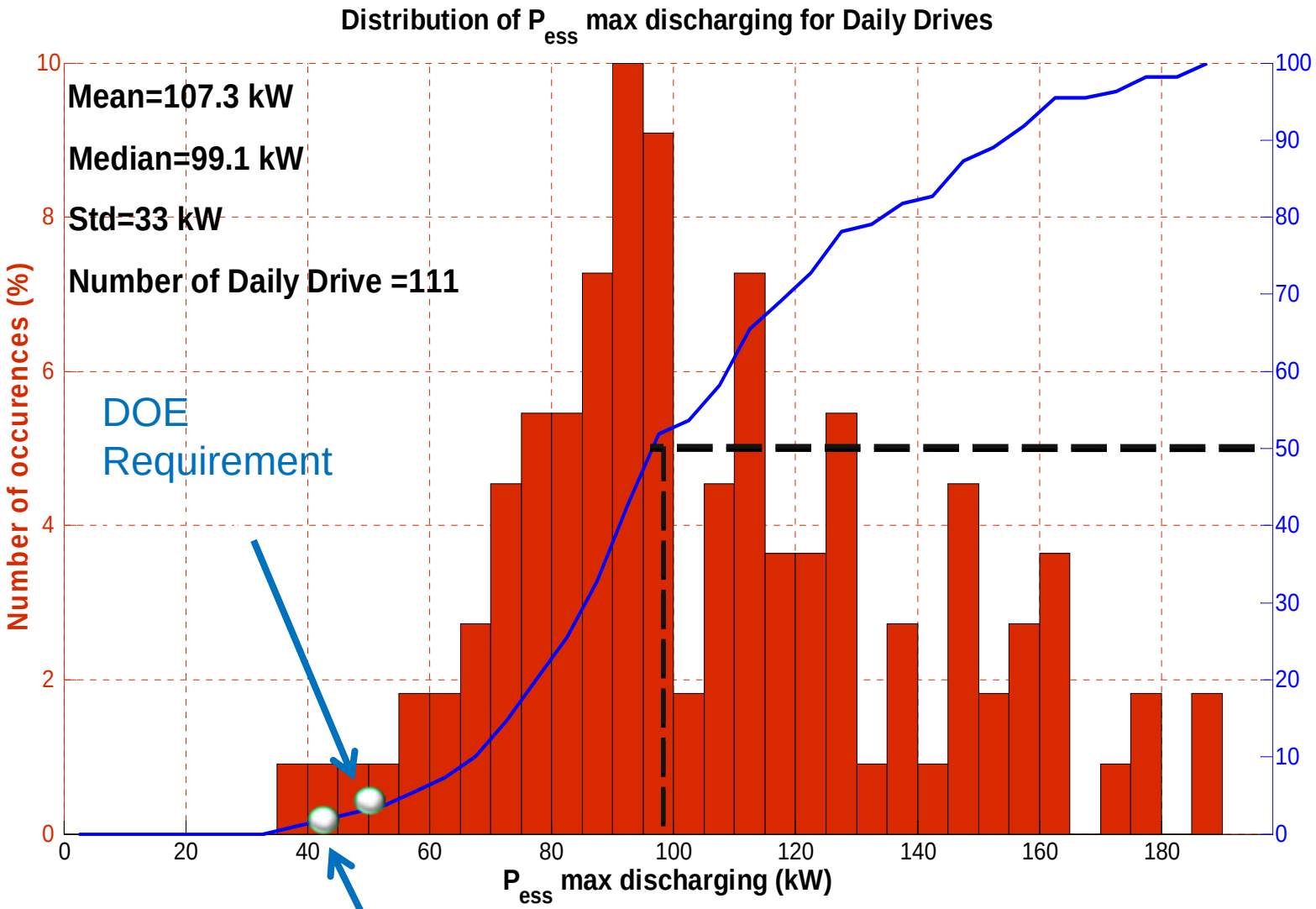


Trips Characteristics

- 363 trips (trip = get in and out of the car)



50% of the Daily Drives Require >100 kW



DOE Requirement (46 kW) => 2.9%

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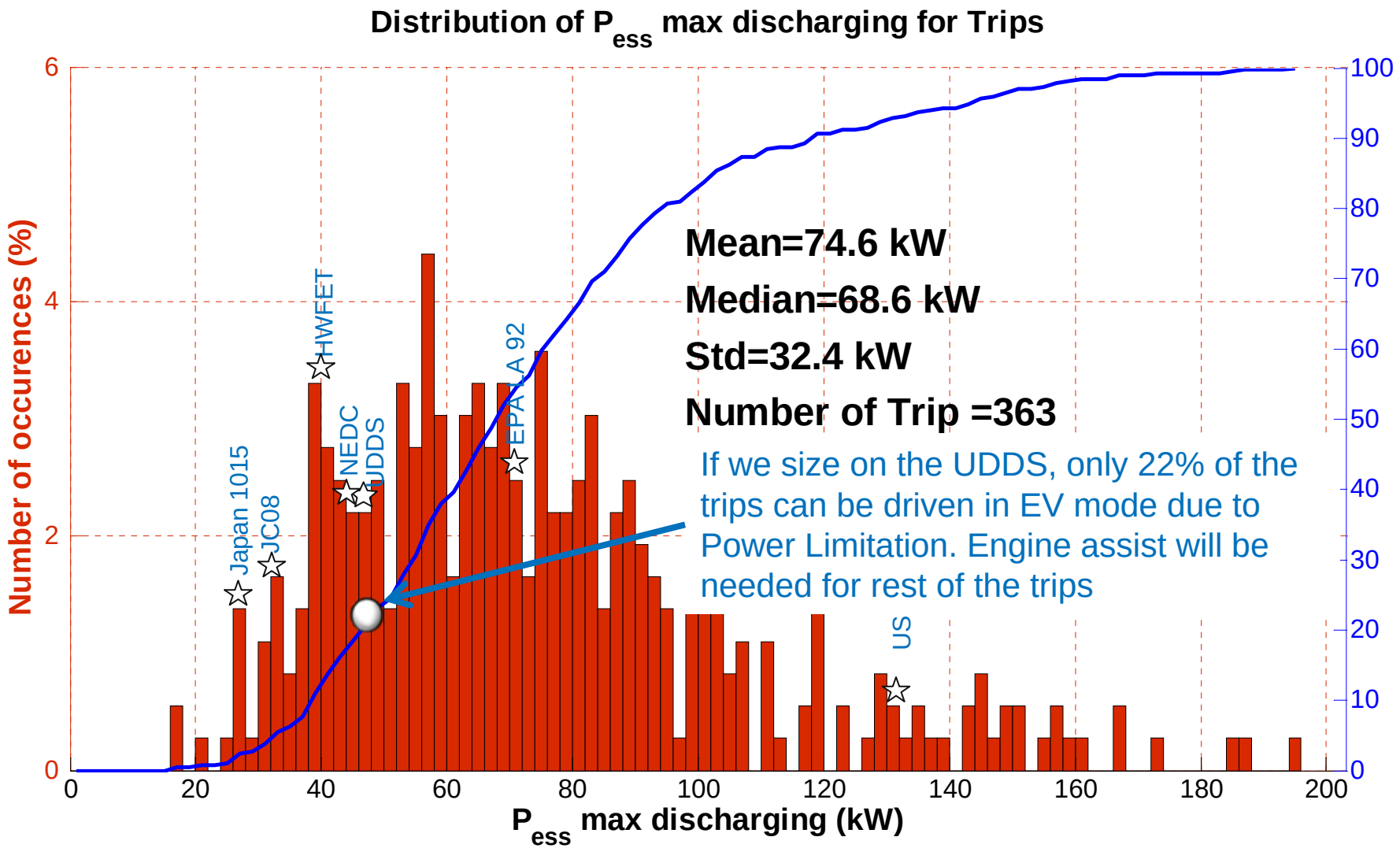
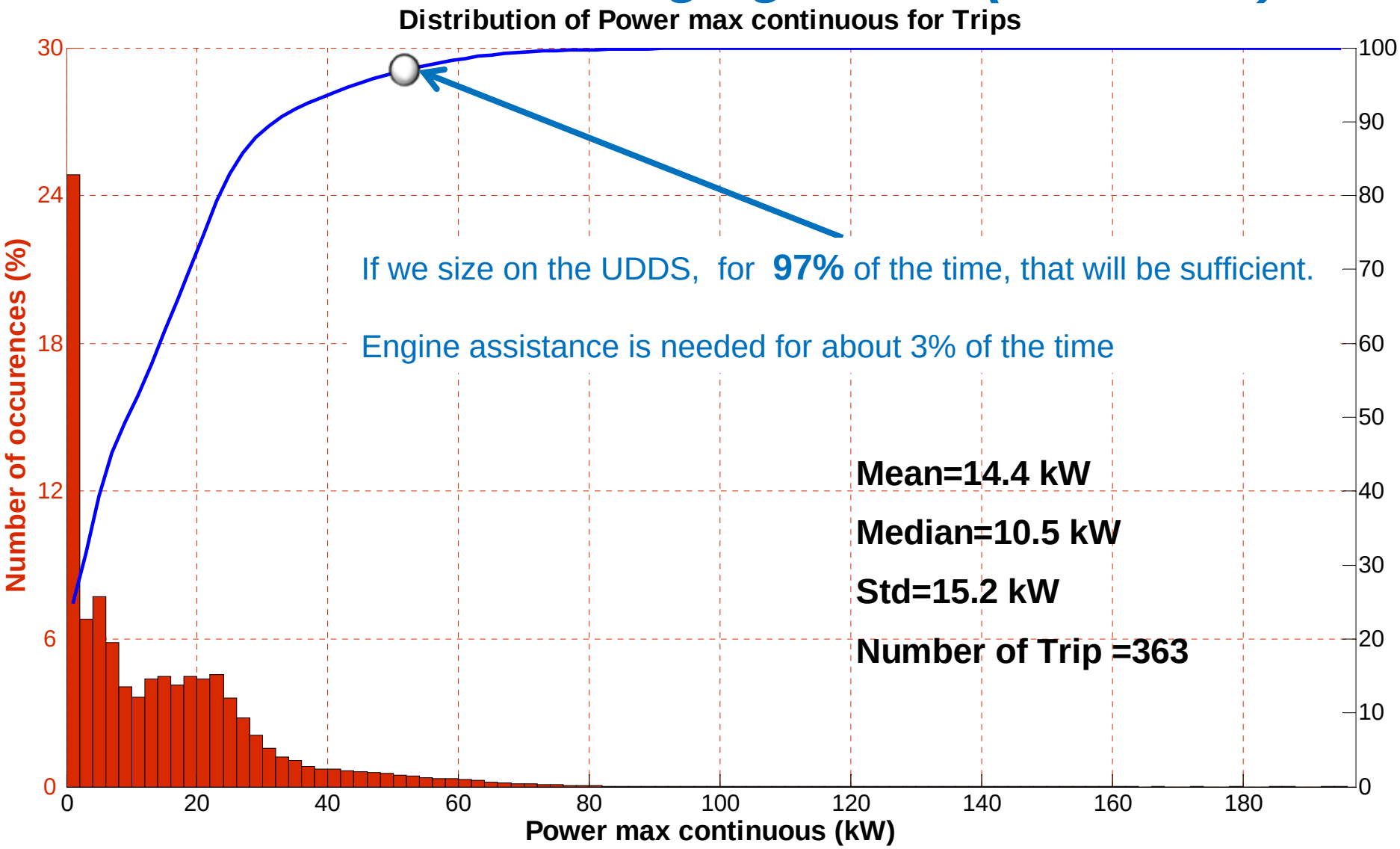
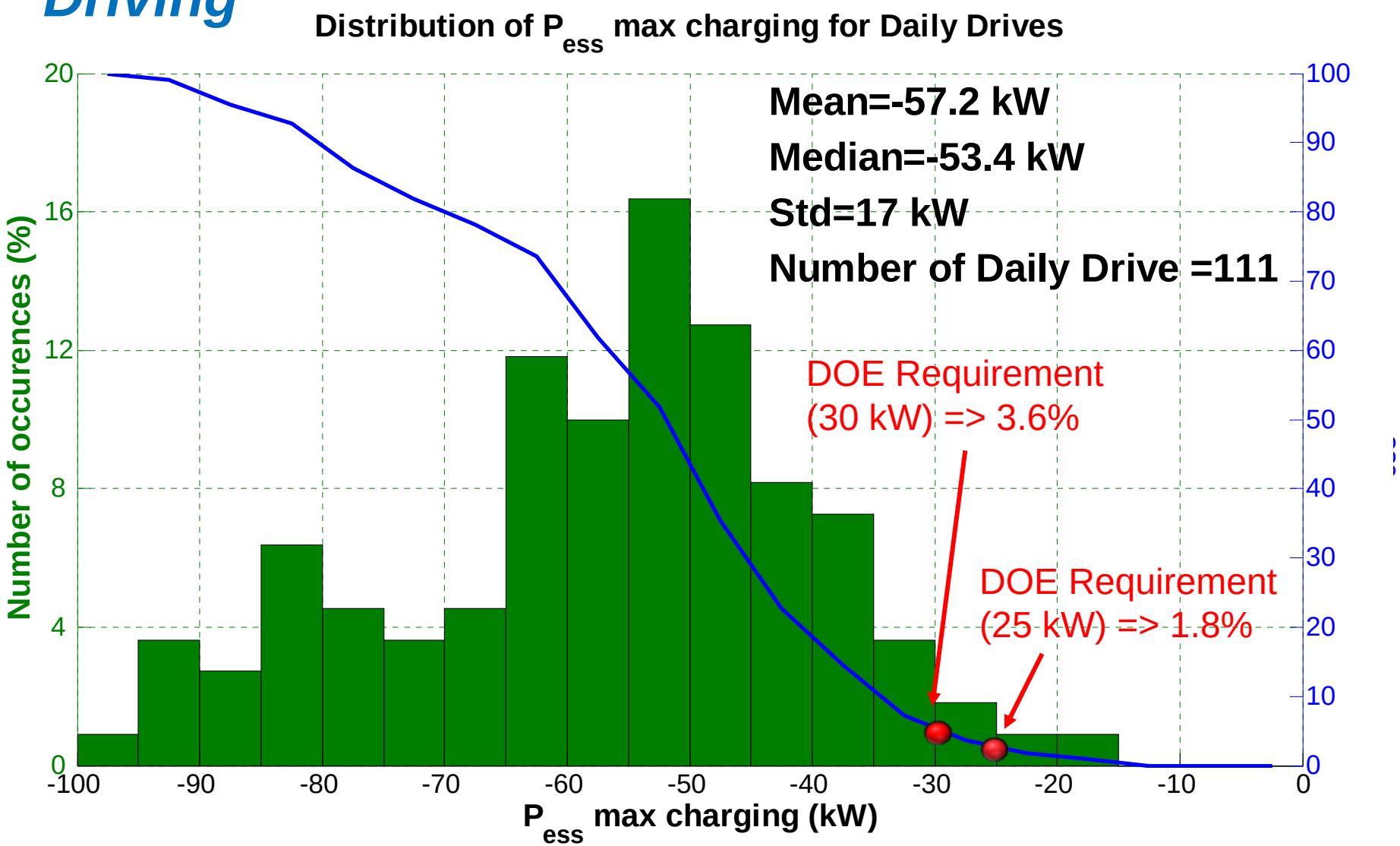
Distribution of Discharging Peak Power Per Trip



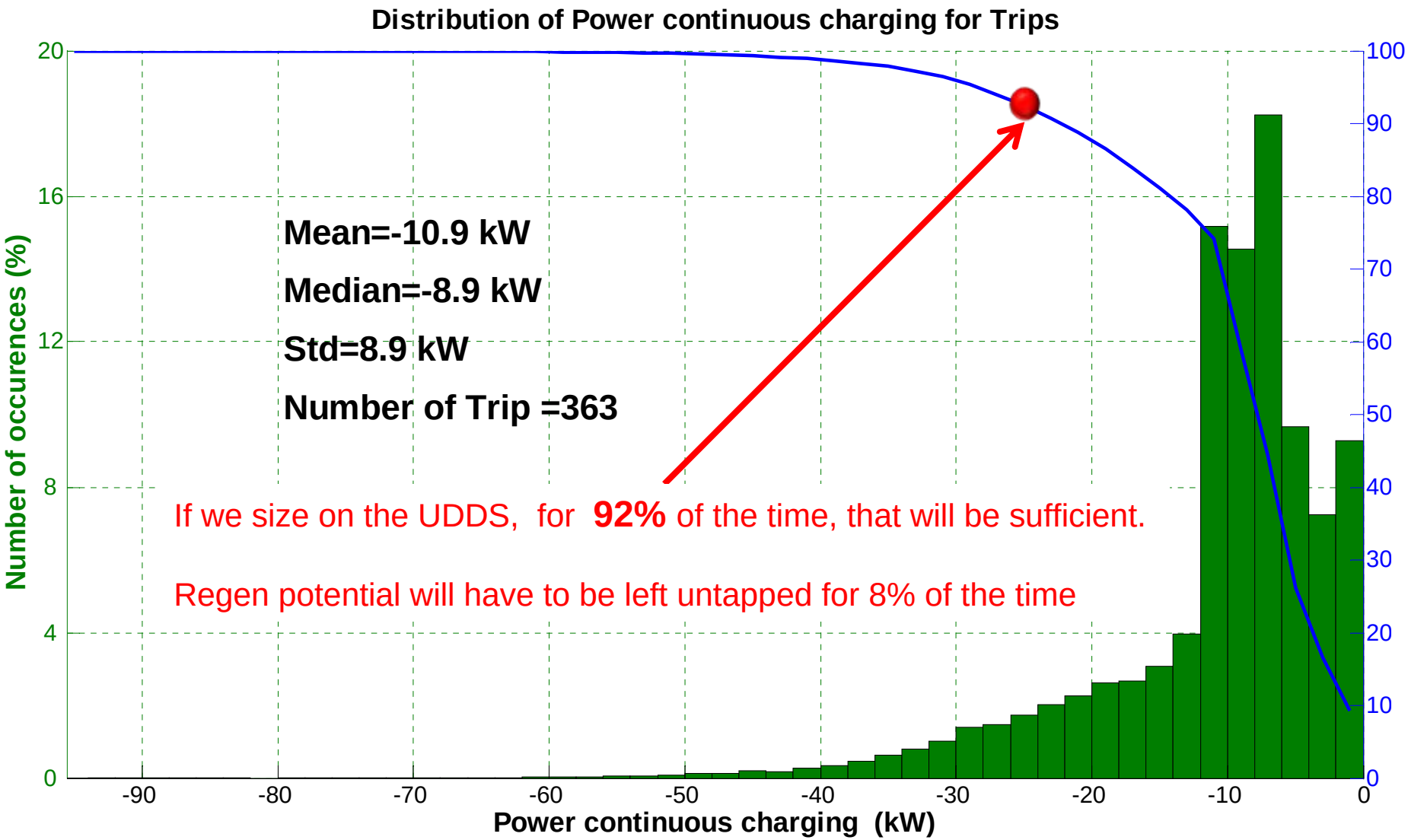
Distribution of Discharging Power (All Points)



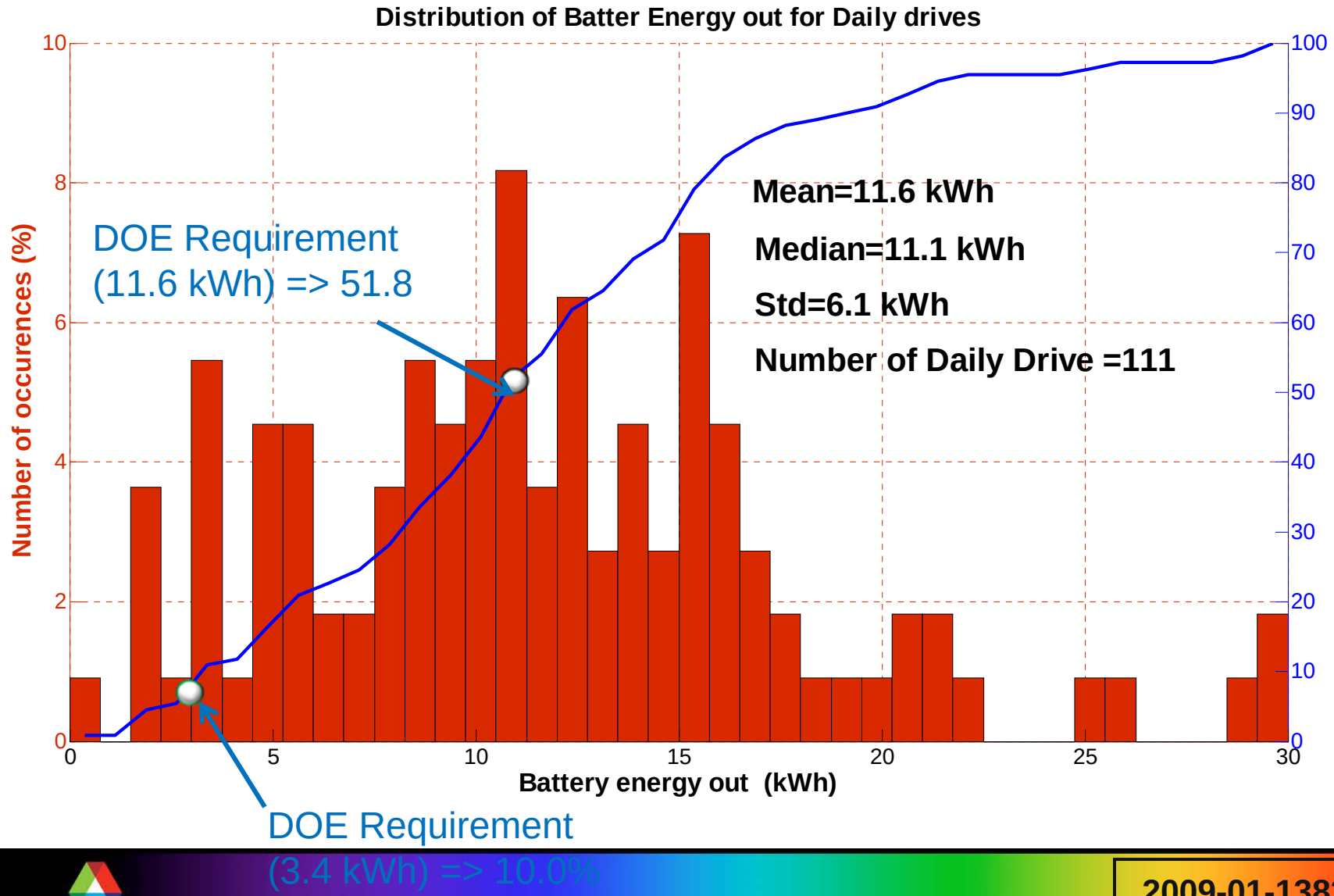
Distribution of Charging Peak Power Per Daily Driving



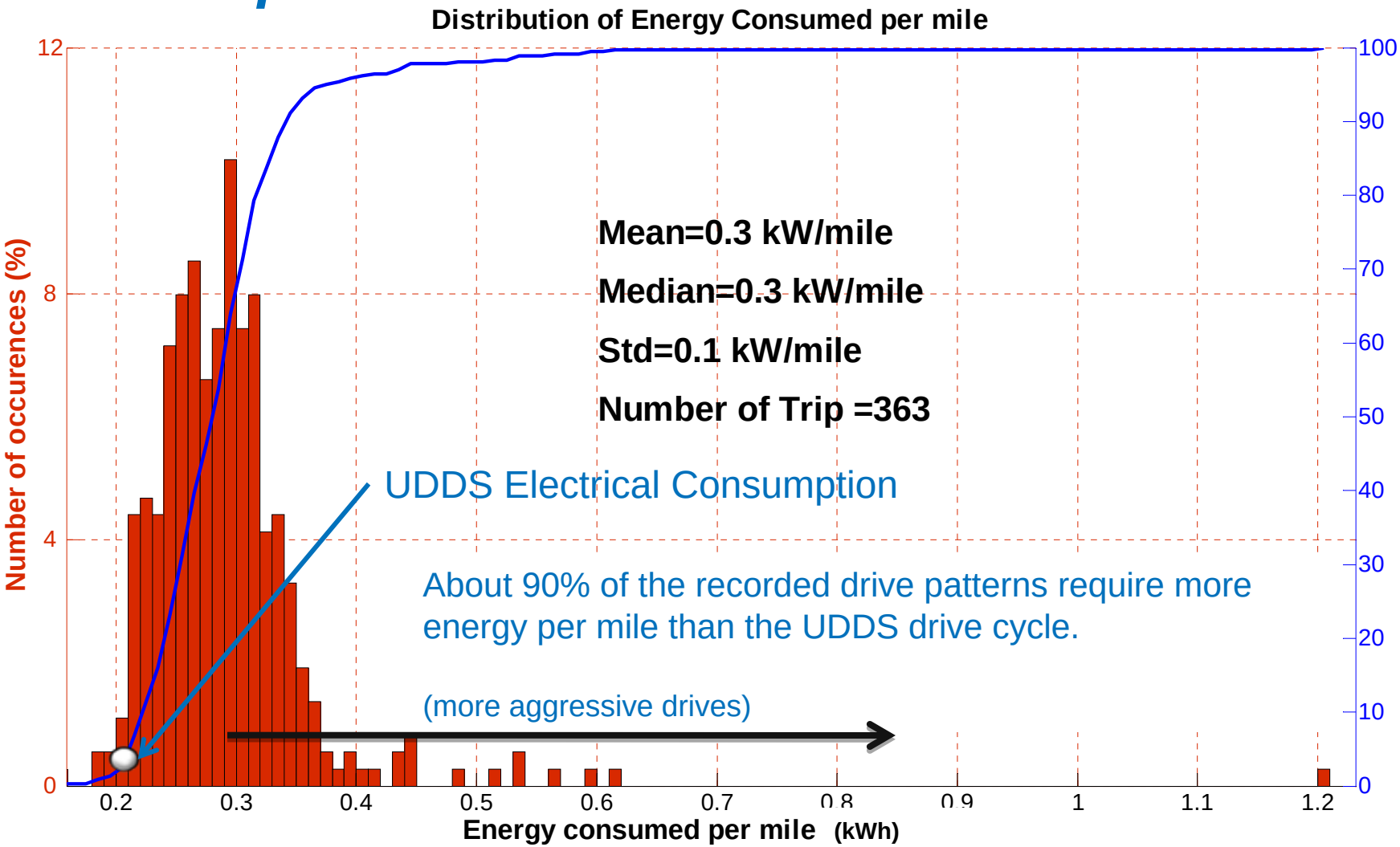
Distribution of Charging Power (All Points)



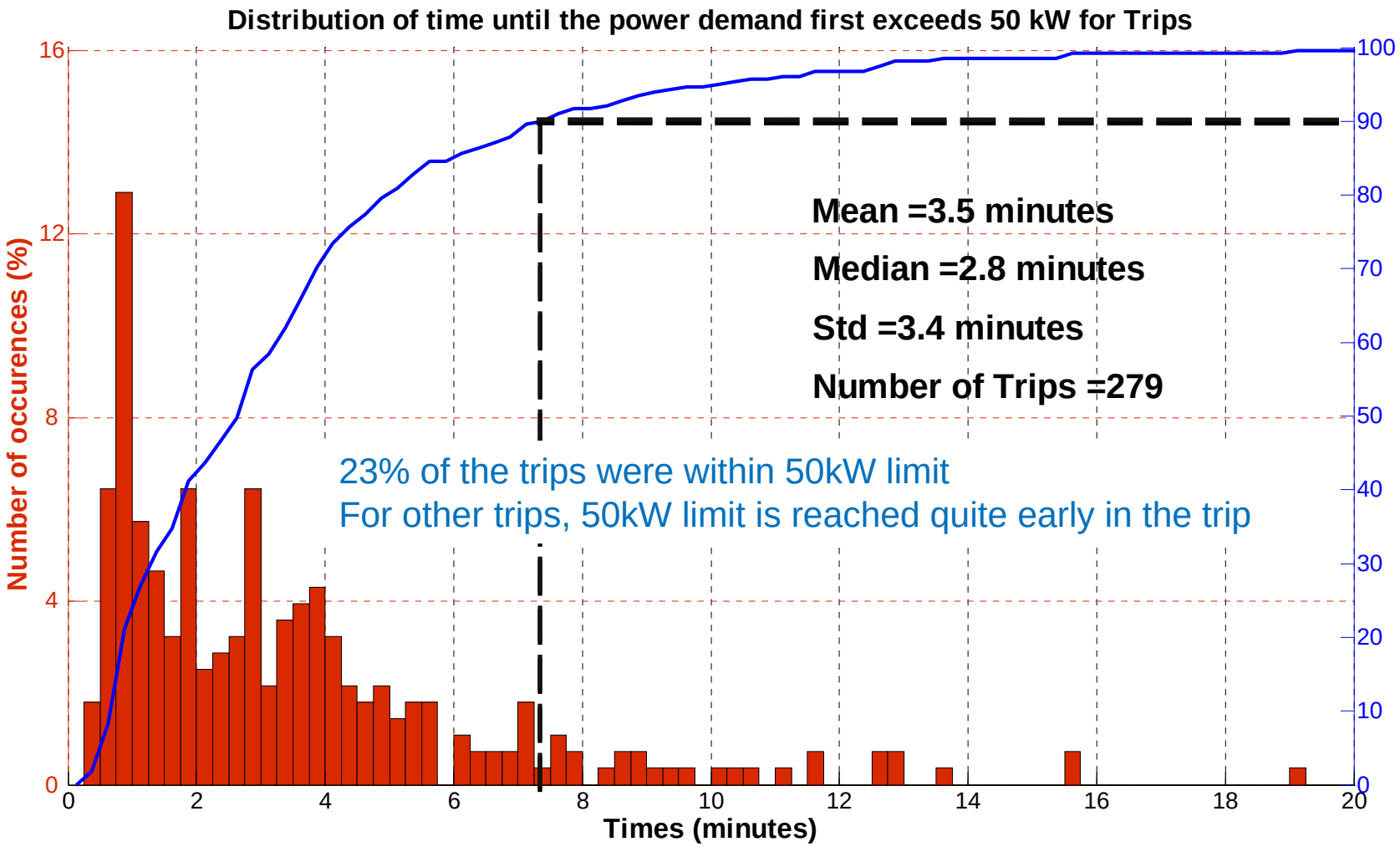
12 kWh Usable is Required to Complete 50% of the Daily Drives



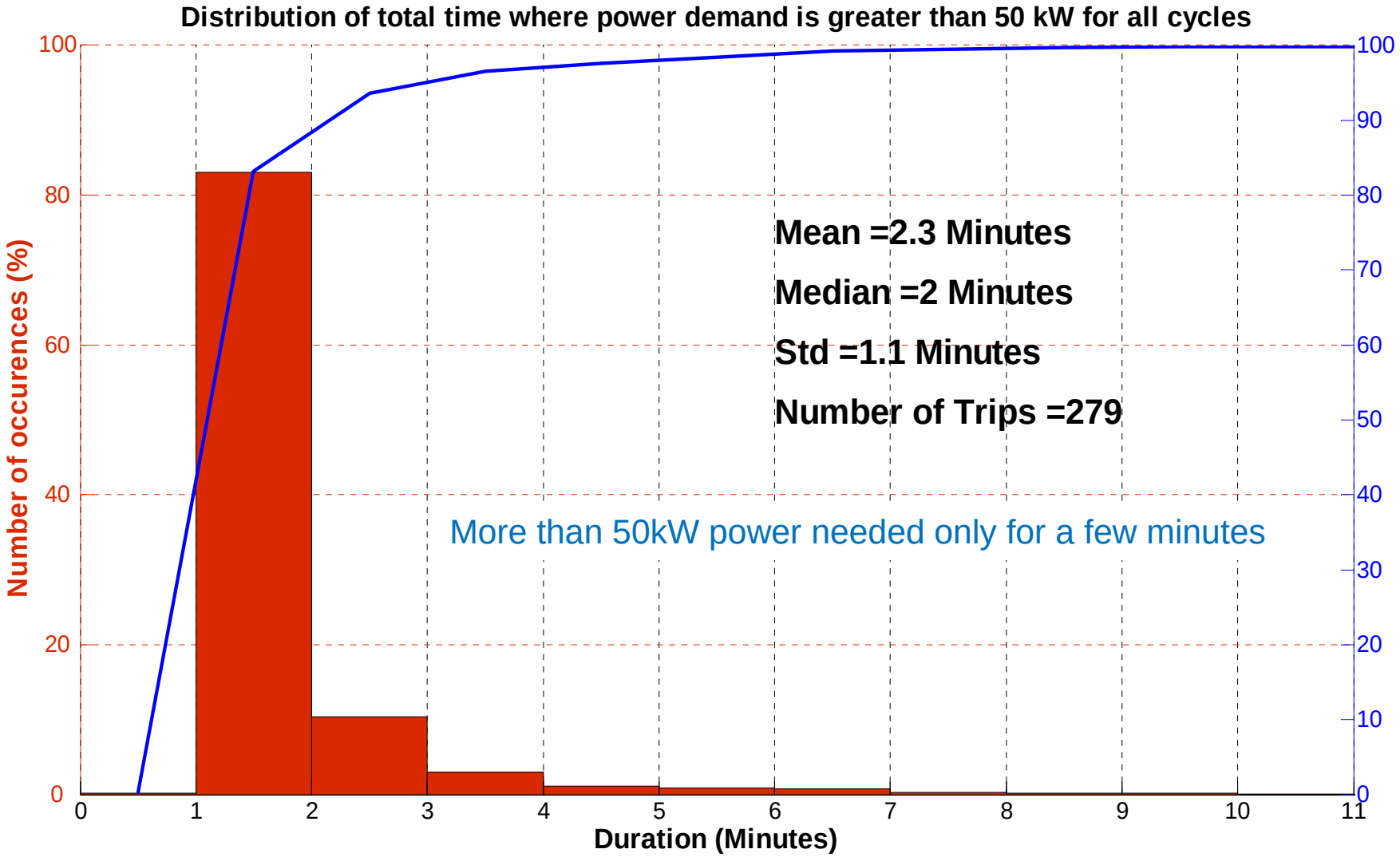
UDDS Represents only 10% of the Electrical Consumption



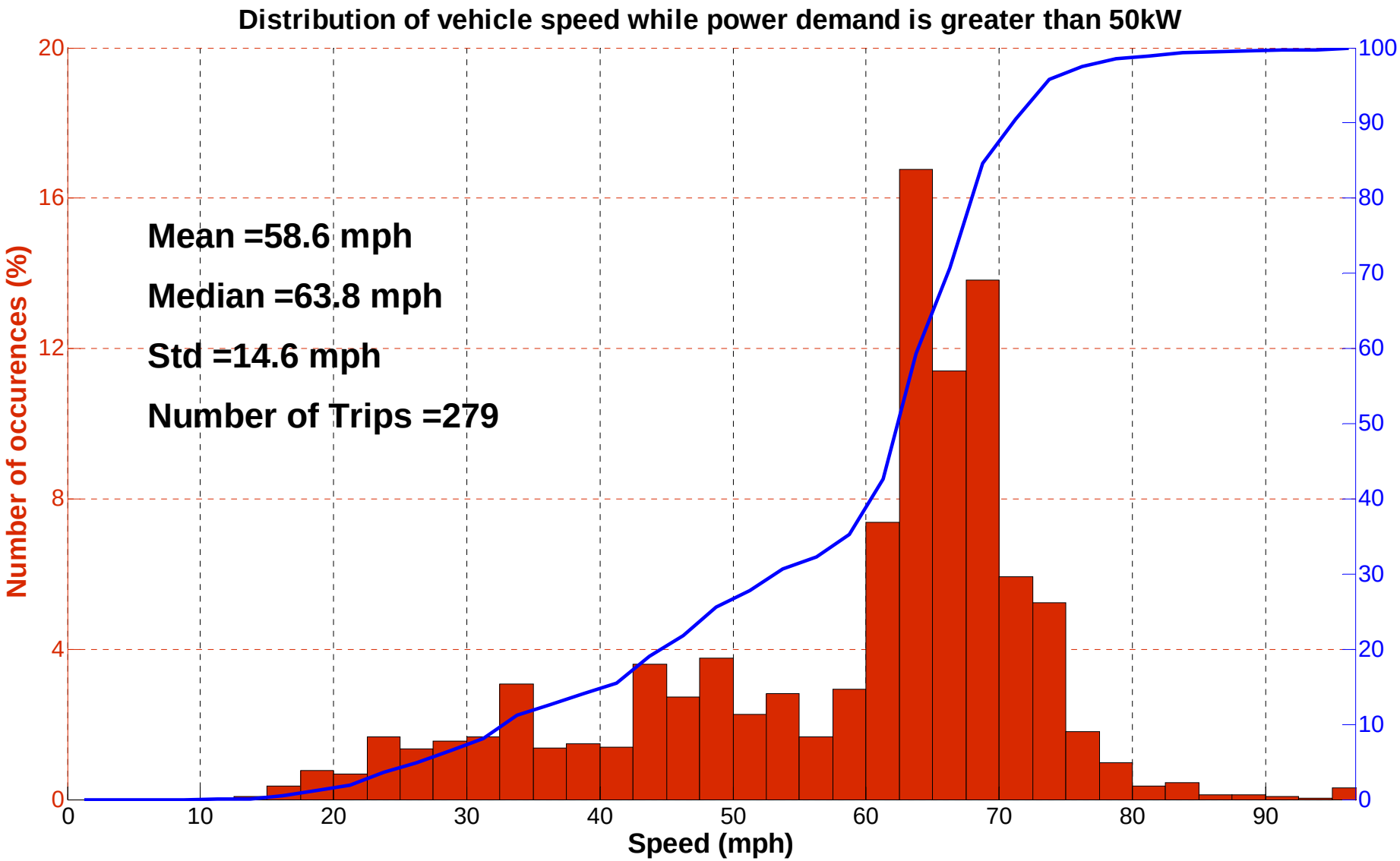
Maximum UDDS Power (50kW) Reached Shortly After Departure



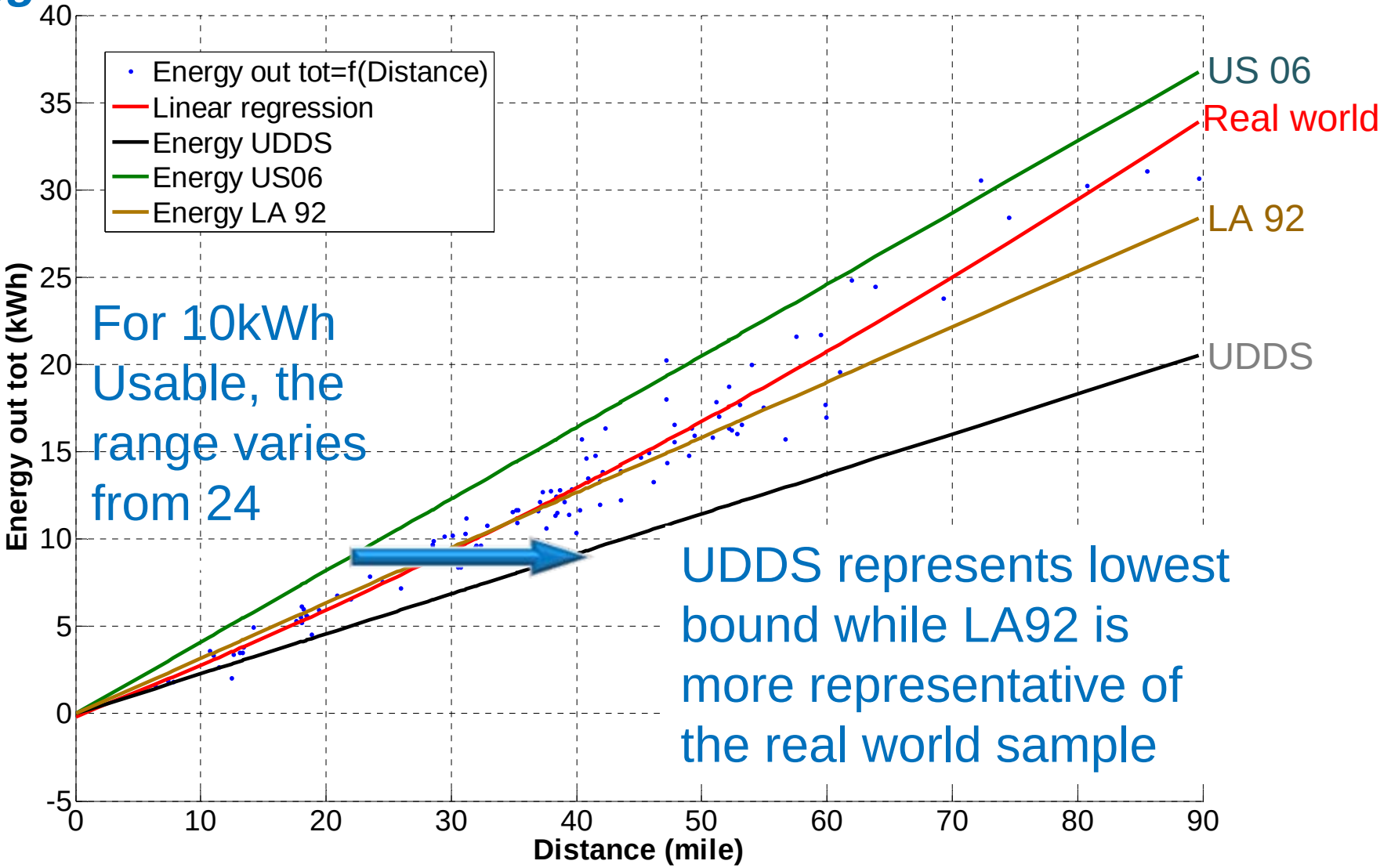
Power Demand >50 kW Occurs for Short Periods of Time



Maximum Power Demand Occurs at Highway Speeds



EV Distance Greatly Varies Depending Upon Cycles Aggressiveness



For 10kWh Usable, the range varies from 24

UDDS represents lowest bound while LA92 is more representative of the real world sample

Conclusion

- The PHEV requirements analysis is only valid for the set of drive cycles considered and should not be generalized.
- Effect of sizing Battery for UDDS
  - Only about 3.5% of the daily driving and 22% of the trips can be completed in all electric mode due to power limitation.
  - Battery power is sufficient for 97% of the time, if the engine can provide the additional power required.
  - High power/energy ratio battery (3.4kWh) can only complete 1.5% of the real world trips in all electric mode
  - High energy/power ratio battery (11.6kWh) can complete about 50% of the real world trips in all electric mode
- Drive cycle characteristics
  - The real world drive cycles are more aggressive than the UDDS, resulting in larger energy requirement to drive the same distance.
  - Aggressive driving can cause the EV range to vary significantly.
  - LA92 better represents current drive cycle aggressiveness.