Argonne NATIONAL LABORATORY

… for a brighter future

U.S. Department of Energy

UChicago ▶ Argonne LLC

A U.S. Department of Energy laboratory managed by UChicago Argonne, LLC

PHEV Battery Requirements – Uncertainty Based on Real World Drive Cycles

EDTA Conference

December 03, 2008

Aymeric Rousseau, Sylvain Pagerit, Mohamed Fellah

Argonne National Laboratory

Ed Nam

US. EPA

Sponsored by Lee Slezak (U.S. DOE)

FreedomCAR & Fuel Partnership

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

How does the Temperature Impacts Fuel Efficiency?

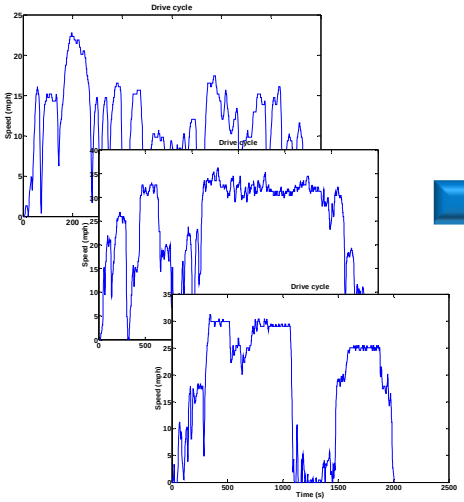
Characteristics at EOL (End of Life)		Short-Term Commercialization	Long-Term Commercialization
Commercialization Target	Year	**2012**	**2016**
Peak Pulse Discharge Power (10 sec)	kW	**45**	**38**
Peak Regen Pulse Power (10 sec)	kW	**30**	**25**
Available Energy for CD (Charge Depleting) Mode, 10 kW Rate	kWh	**3.4**	**11.6**
Available Energy for CS (Charge Sustaining) Mode	kWh	**0.5**	**0.3**
Minimum Round-trip Energy Efficiency (USABC HEV Cycle)	%	**90**	**90**
Cold cranking power at -30°C, 2 sec - 3 Pulses	kW	**7**	**7**
CD Life / Discharge Throughput	Cycles/MWh	**5,000 / 17**	**5,000 / 58**
CS HEV Cycle Life, 50 Wh Profile	Cycles	**300,000**	**300,000**
Calendar Life, 40°C	year	**15**	**15**
Maximum System Weight	kg	**60**	**120**
Maximum System Volume	Liter	**40**	**80**
Maximum Operating Voltage	Vdc	**400**	**400**
Minimum Operating Voltage	Vdc	**>0.55 x Vmax**	**>0.55 x Vmax**
Maximum Self-discharge	Wh/day	**50**	**50**
System Recharge Rate at 30°C	kW	**1.4 (120V/15A)**	**1.4 (120V/15A)**
Unassisted Operating & Charging Temperature Range	°C	**-30 to +52**	**-30 to +52**
Survival Temperature Range	°C	**-46 to +66**	**-46 to +66**
Maximum System Production Price @ 100k units/yr	$	**$1,700**	**$3,400**

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

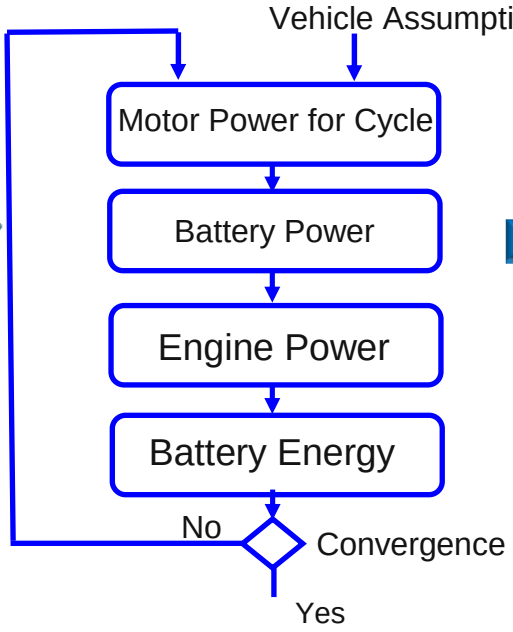
Real World Drive Cycles

Automated Sizing

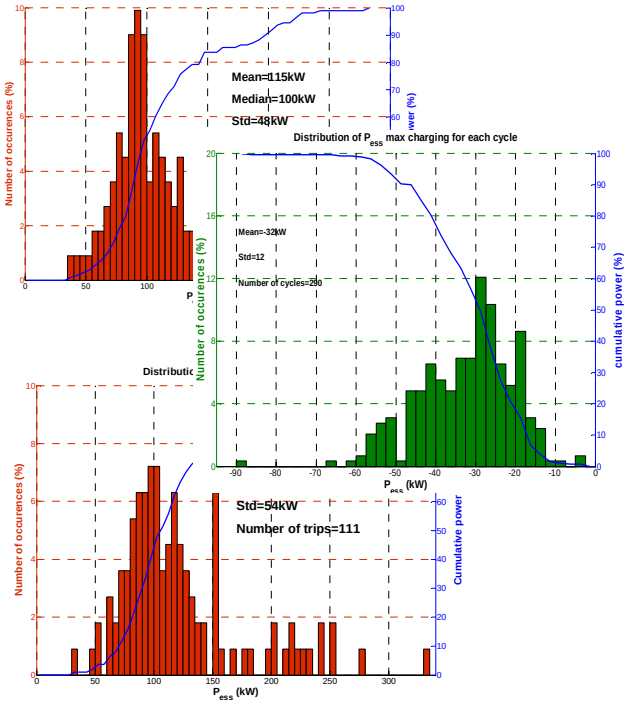
Analysis (Distribution)



>110 Trips
One day in
Kansas City



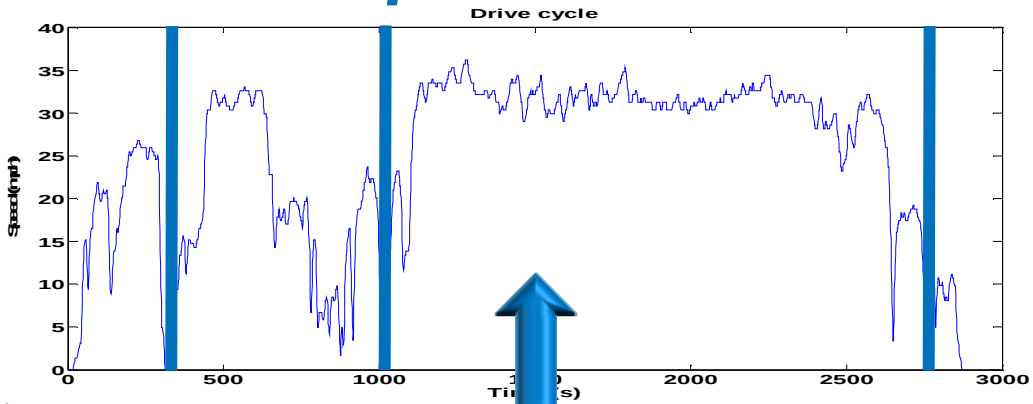
Power Split
Midsize Vehicle



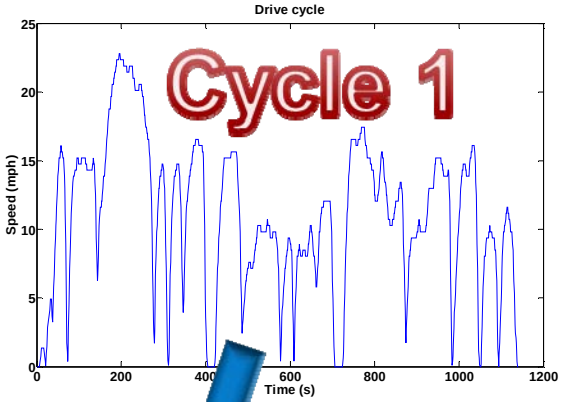
Only Hot Conditions Assumed!

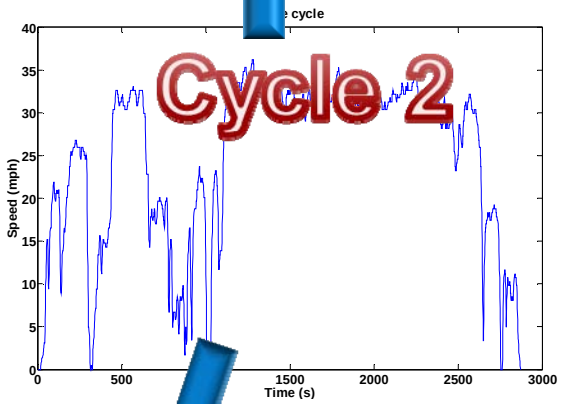
Analysis of Vehicle Speed Traces at Different Levels

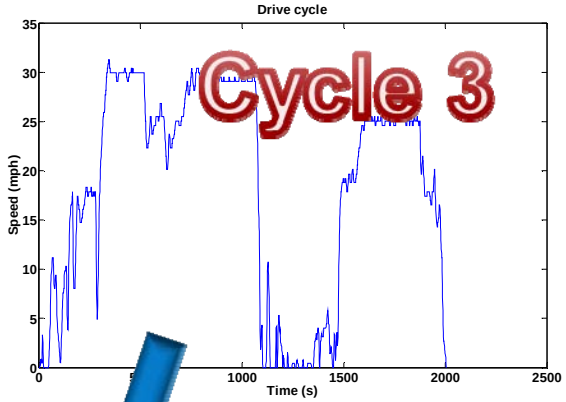
A hill is the portion of a cycle between two stops



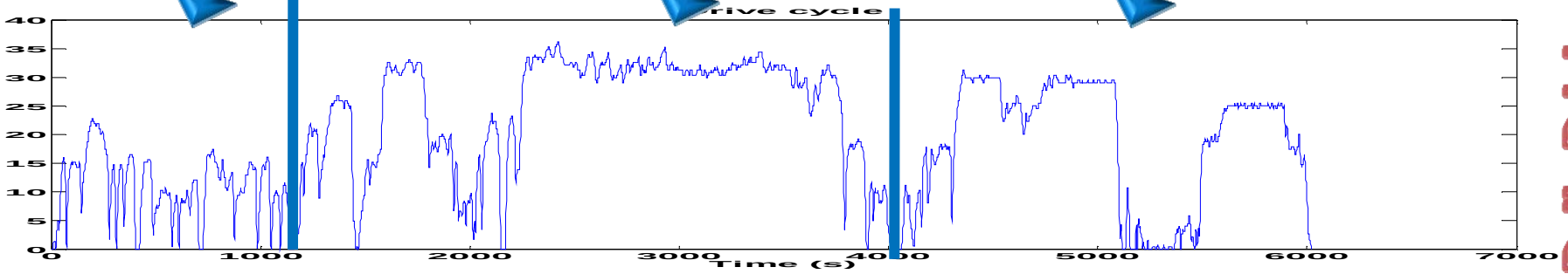
Hills







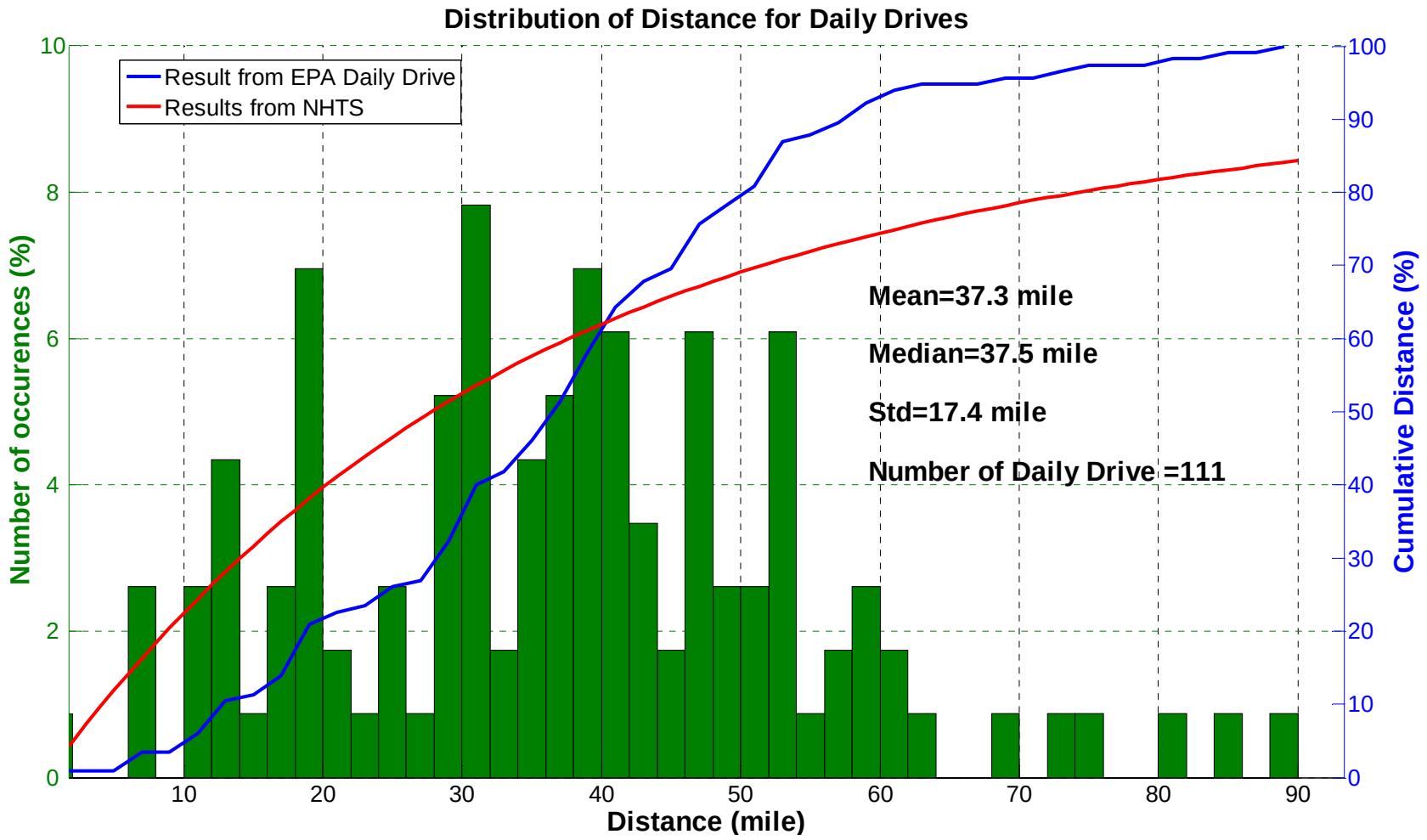
Trip



Daily Driving

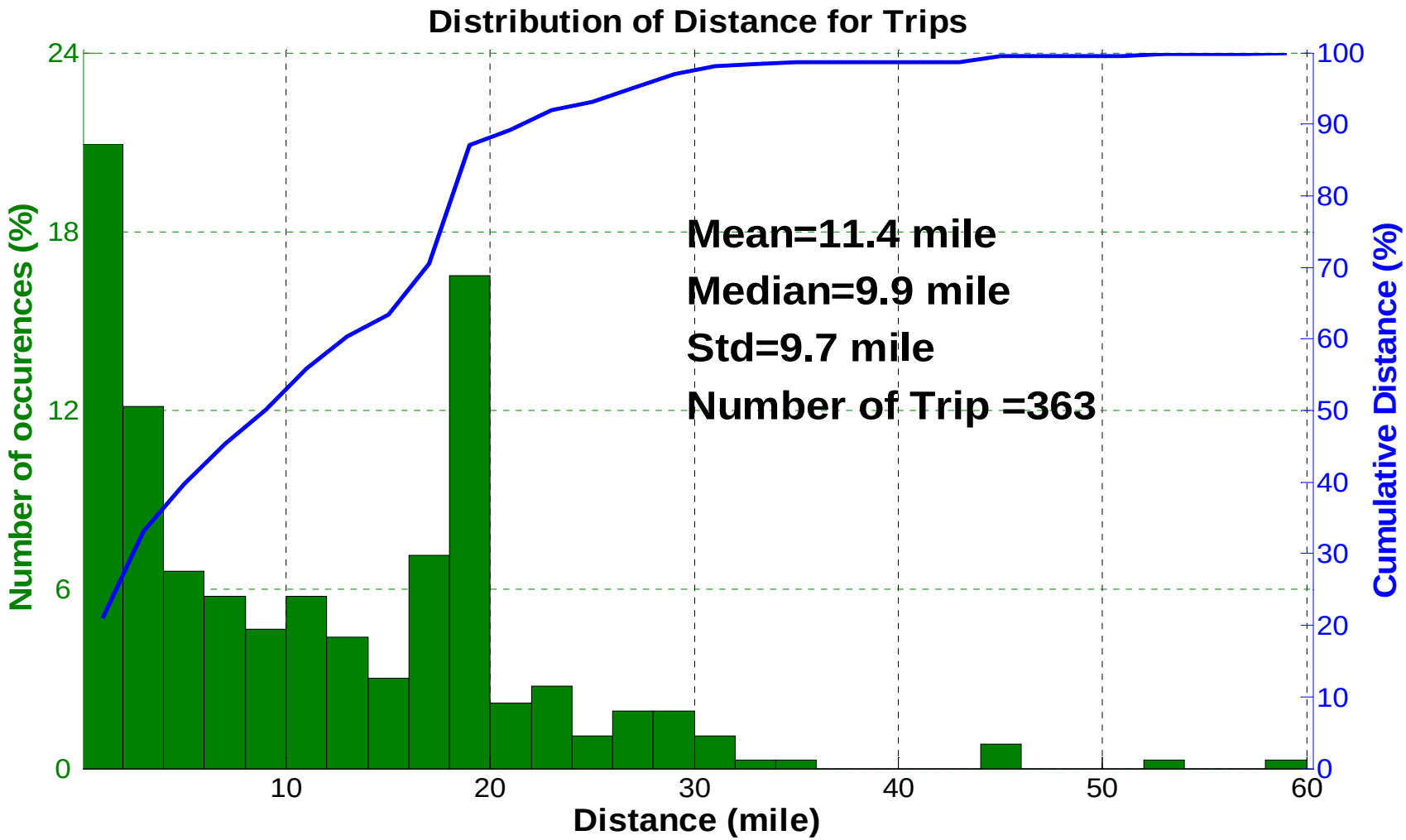
Daily Driving Characteristics

- 111 different drivers – All based on Conventional Vehicles

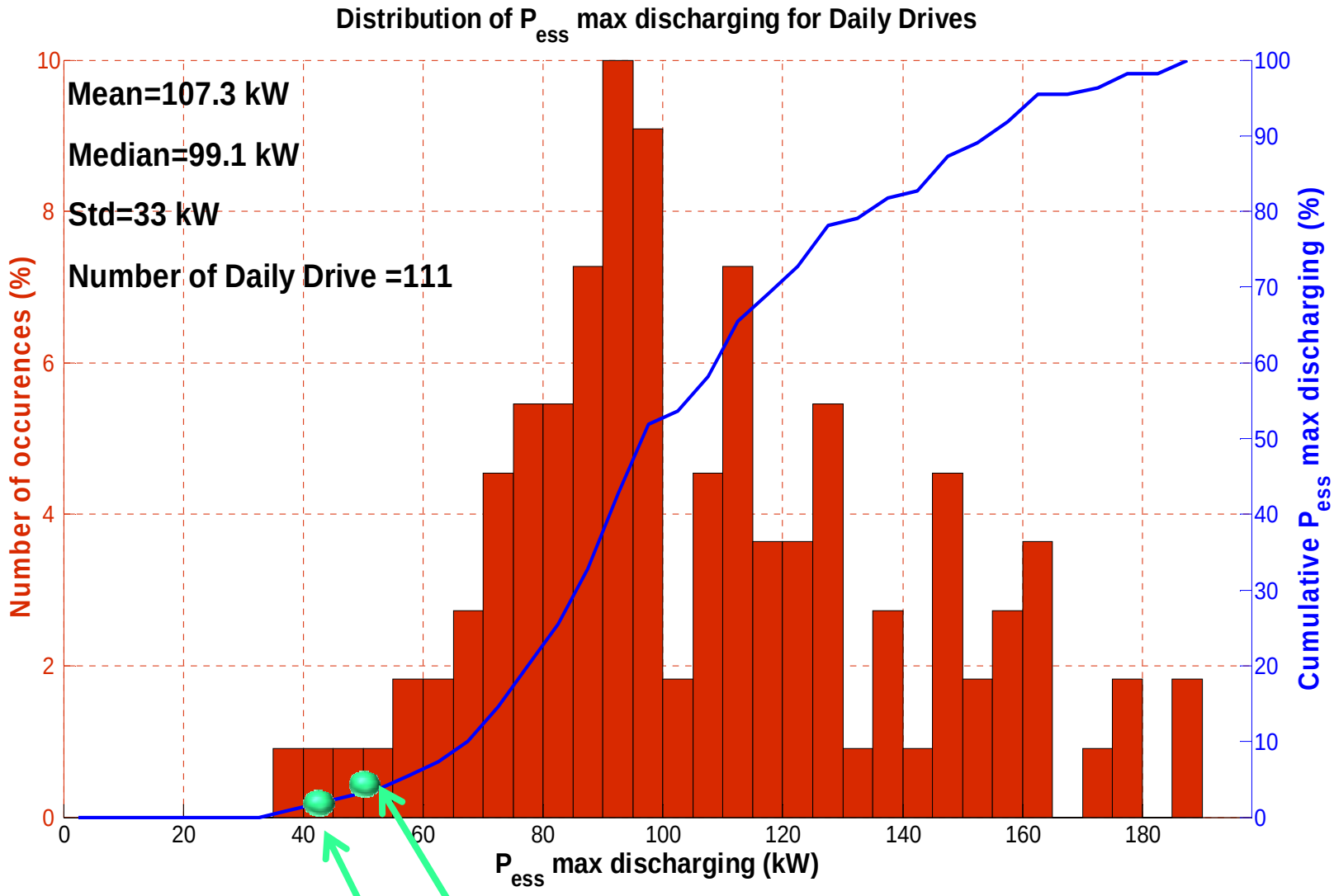


Trips Characteristics

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



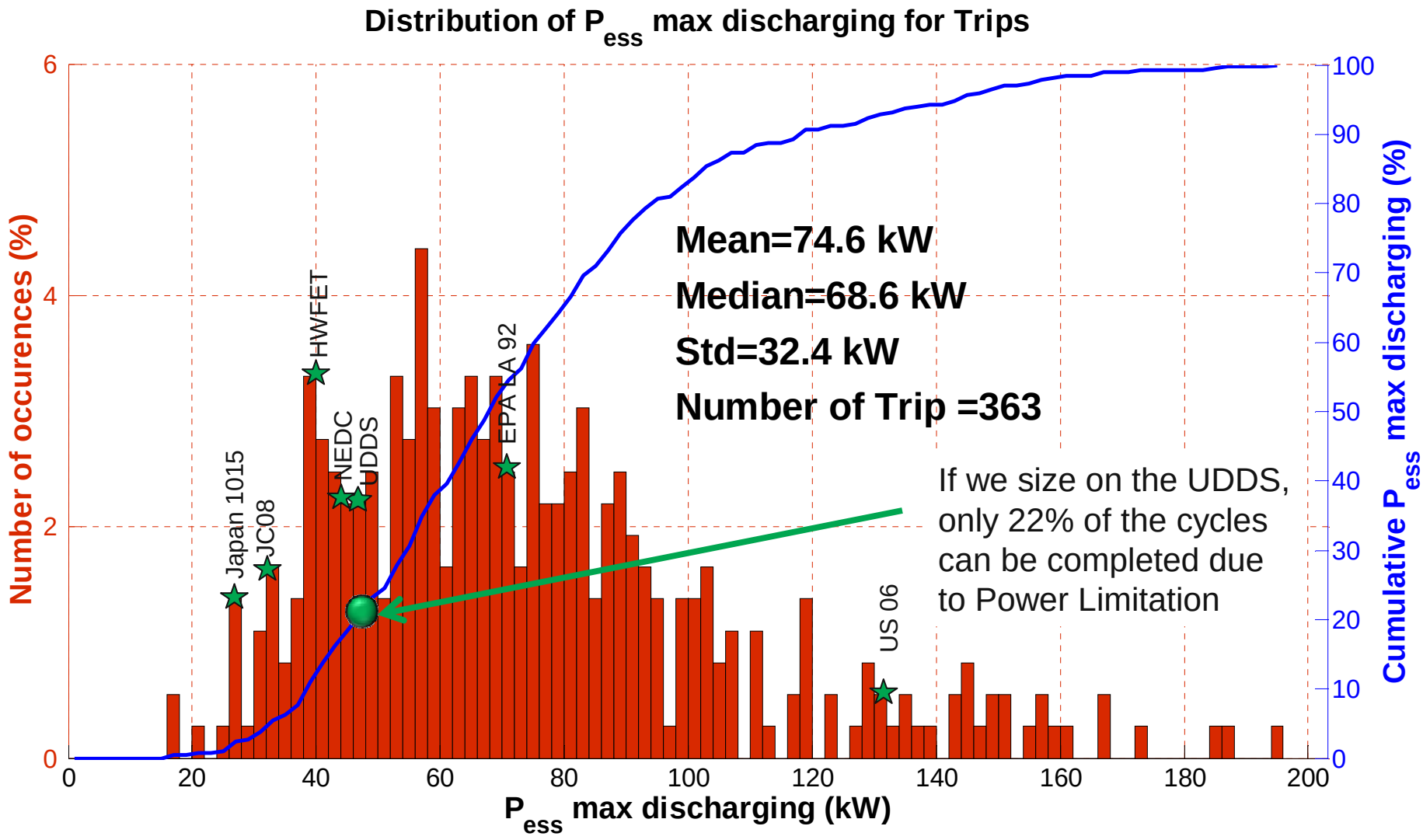
50% of the Daily Trips Require >100 kW



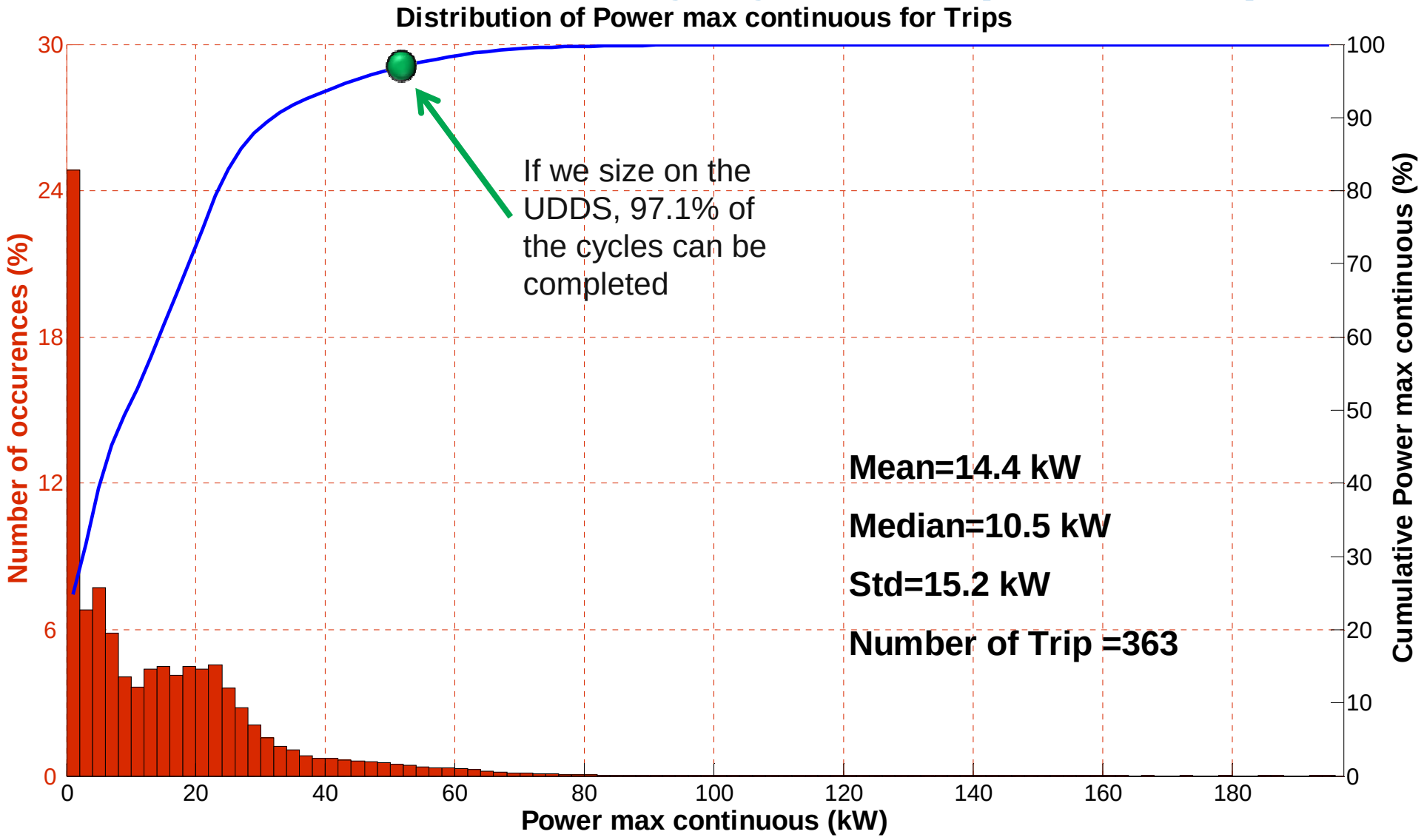
DOE Requirement (50 kW) => 3.5%

DOE Requirement (46 kW) => 2.9%

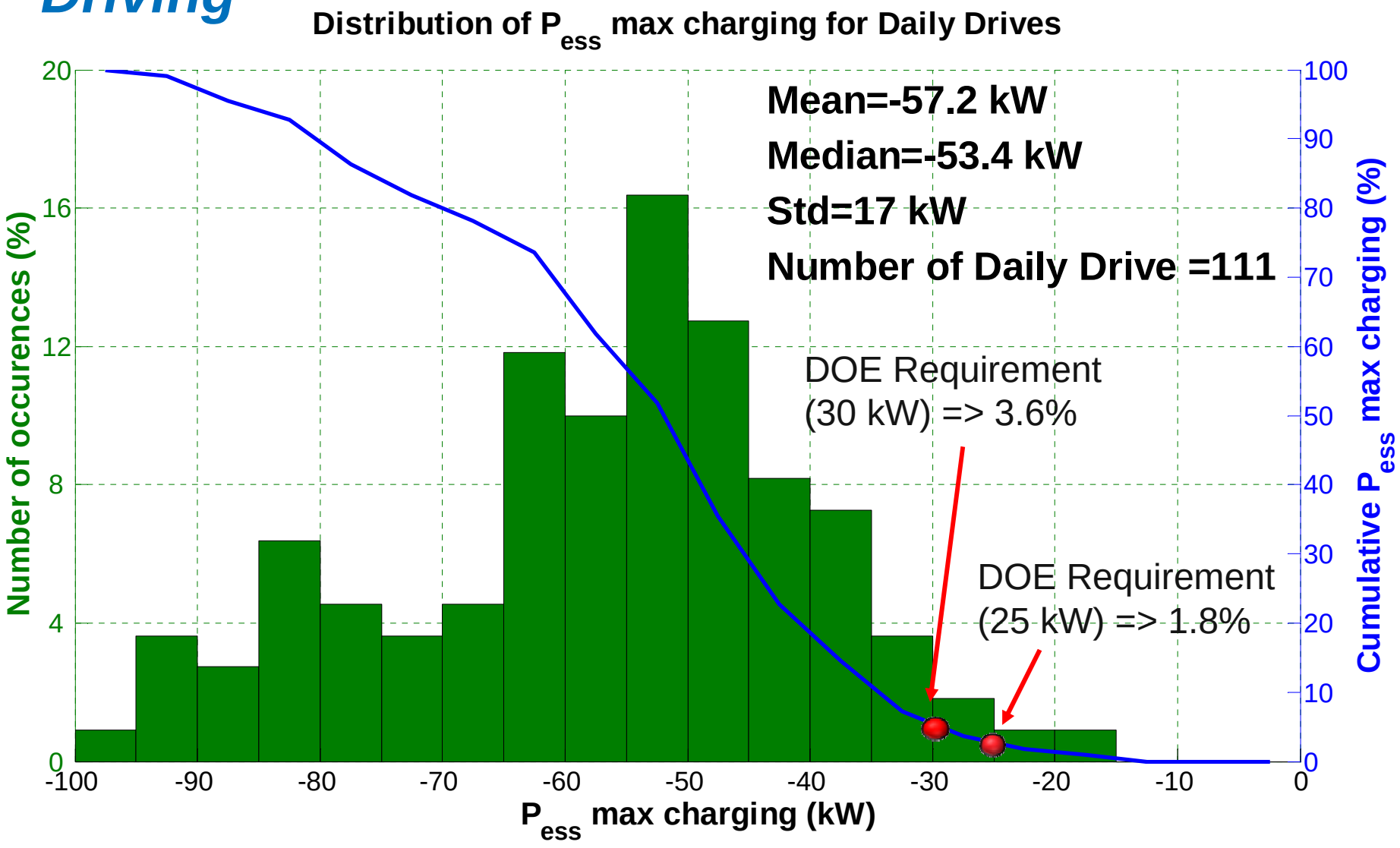
Distribution of Discharging Peak Power Per Trip



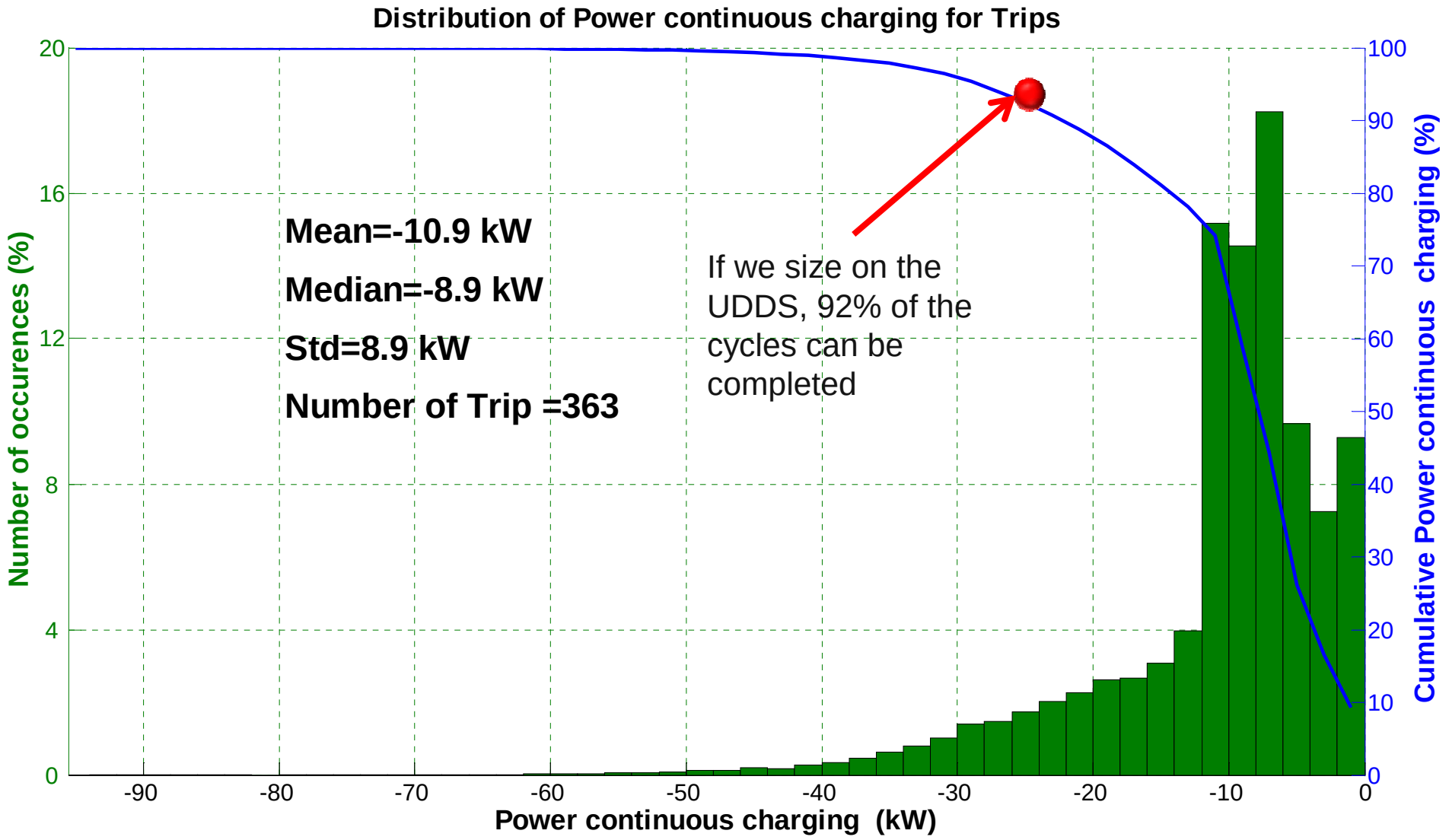
Distribution of Discharging Power (All Points)



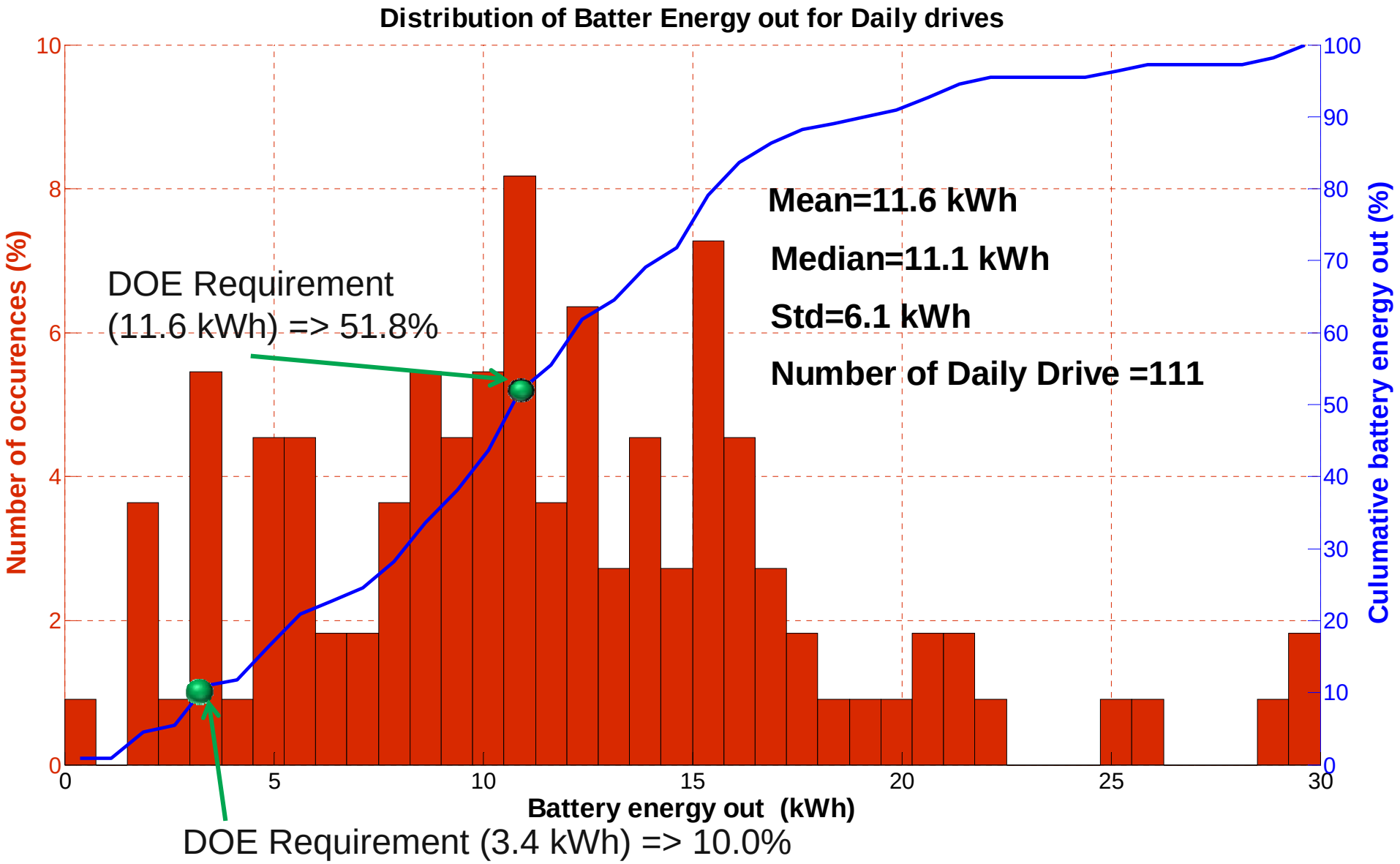
Distribution of Charging Peak Power Per Daily Driving



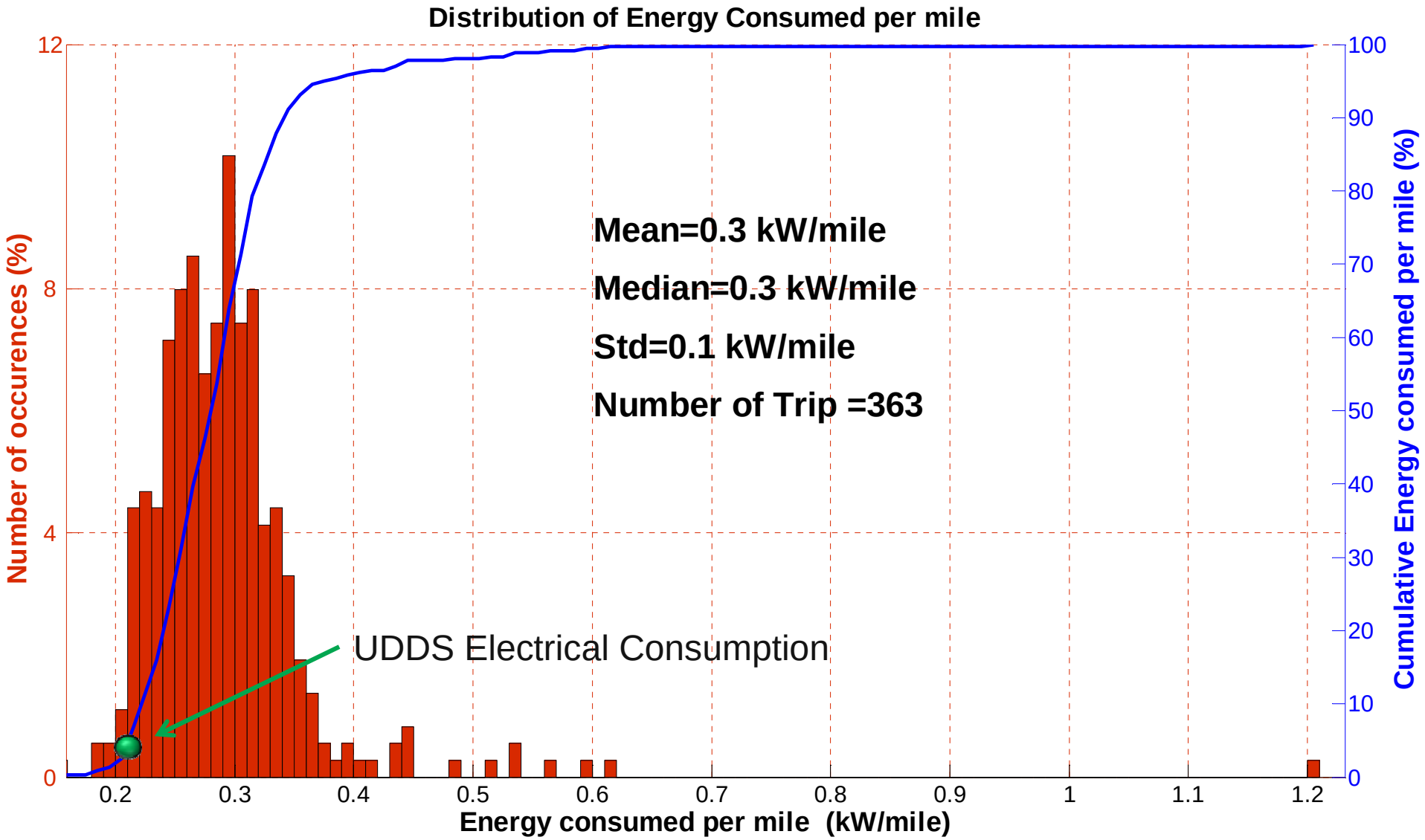
Distribution of Charging Power (All Points)



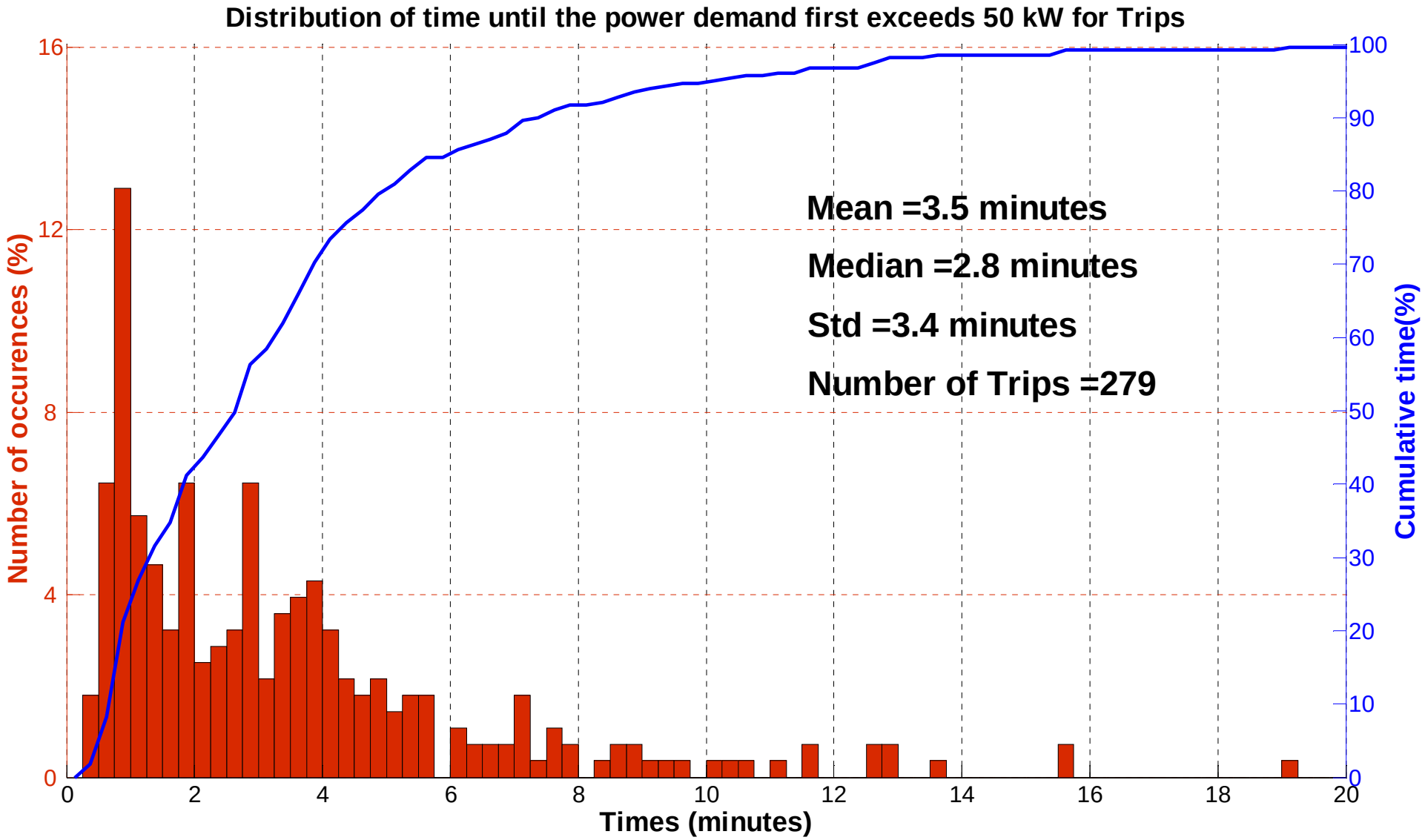
12 kWh Usable is Required to Complete 50% of the Daily Drives



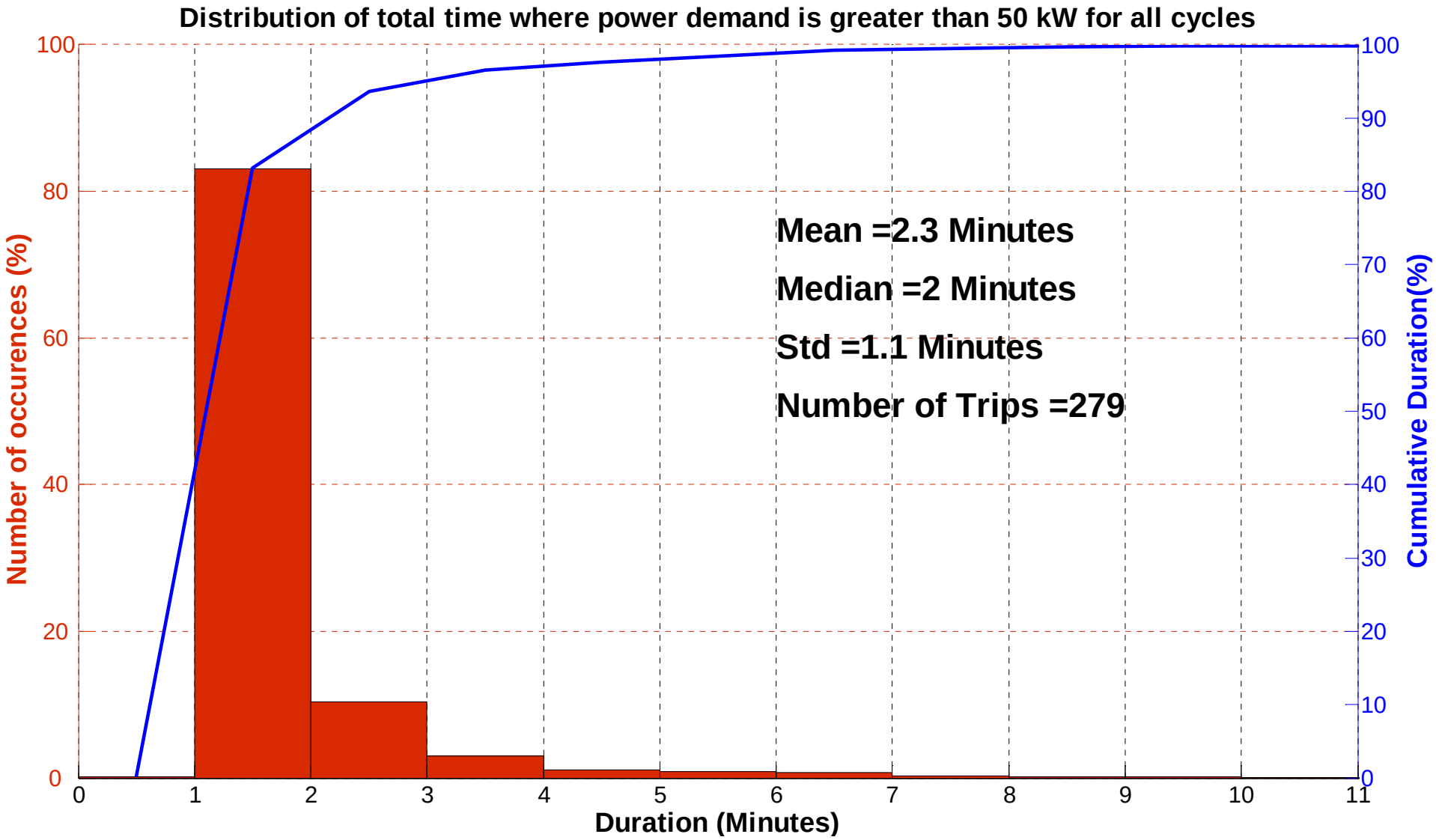
UDDS Represents only 10% of the Electrical Consumption



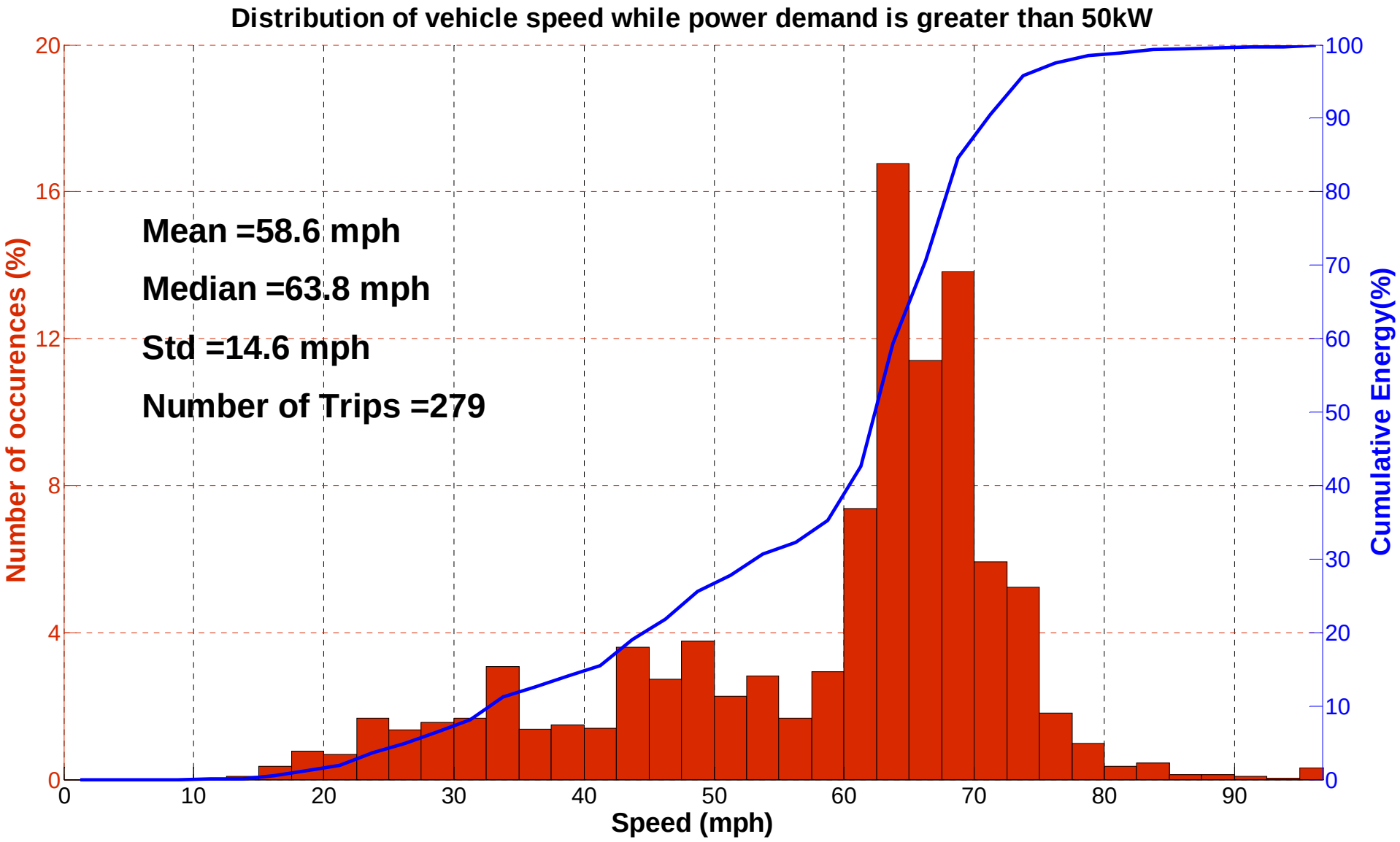
Maximum UDDS Power Reached Shortly After Departure



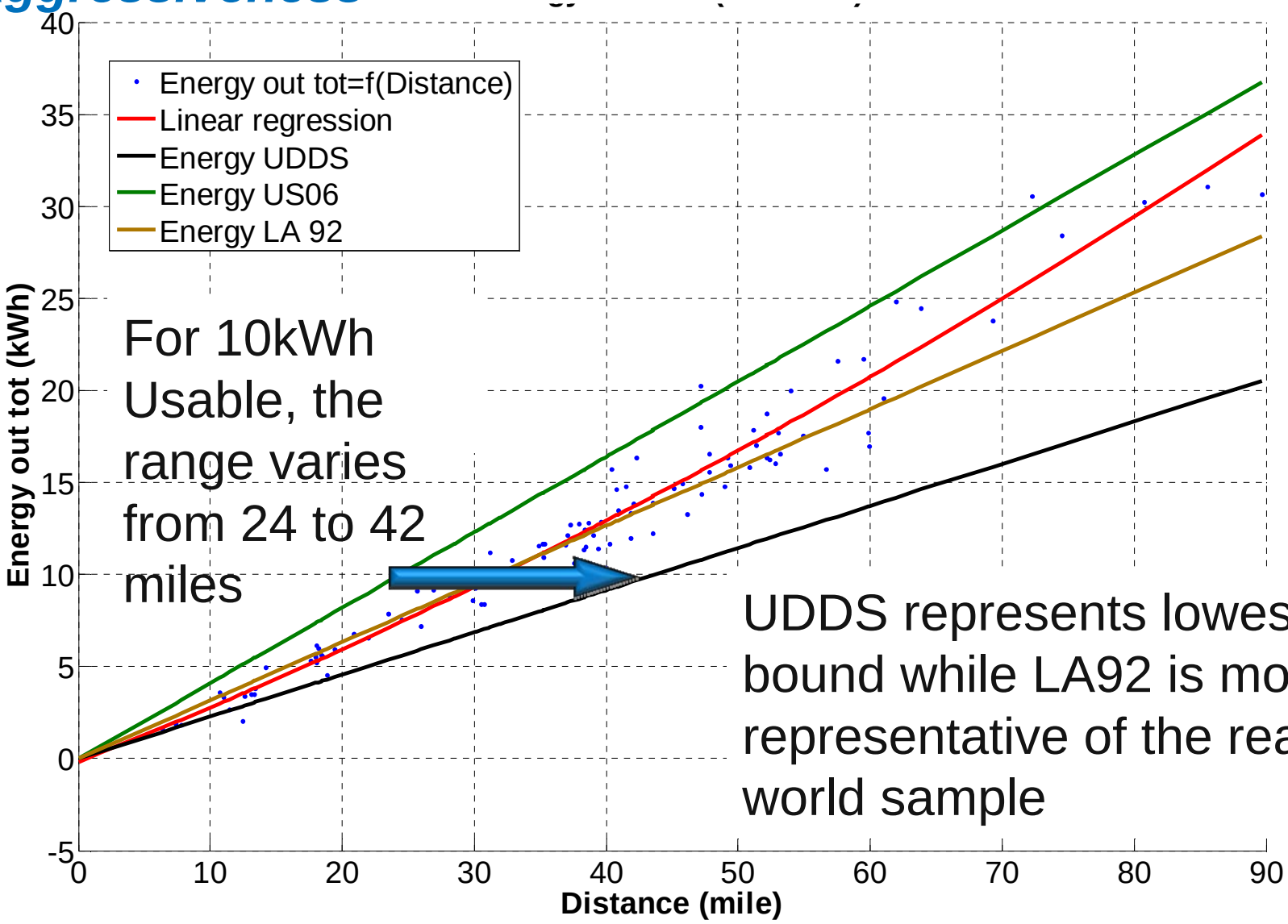
Power Demand >50 kW Occurs for Short Periods of Time



Maximum Power Demand Occurs at Highway Speeds



EV Distance Greatly Varies Depending Upon Cycles Aggressiveness



For 10kWh Usable, the range varies from 24 to 42 miles

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 to the US market.
- Aggressive driving will put limits on all EV range, which in turn favors a blended mode operational strategy.
- When the battery is sized for the UDDS,
  - 3% of the daily driving and 20% of the trips can be completed in EV due to power limitation. However, the power requirements are sufficient 97% of the time.
  - 1.5% (short term goal) and 50% (long term goal) of the daily driving can be completed in EV due to energy limitation
- The real world drive cycles are more aggressive than the UDDS, resulting in larger energy requirements to drive the same distance.
- LA92 better represents current drive cycle aggressiveness.