

Proposal for MPR and metric of HD-EV

China, April 16, 2024

Background: HD-EV type and Battery type

□ HD-EV type and Battery type

- ✓ In China, **over 99% HD-EVs are PEVs and most of HD-PEV use LFP batteries.**
- ✓ For buses, 100 % of HD-PEVs use LFP batteries; 60 % of HD-OVC-HEVs use LFP batteries and 40 % of HD-OVC-HEVs use LMO batteries.
- ✓ For trucks, 99% of HD-PEVs use LFP batteries; 90 % of HD-OVC-HEVs use LFP batteries, 7 % of HD-OVC-HEVs use LMO batteries and 3 % of HD-OVC-HEVs use NCM batteries.

Different types of lithium battery installed data(MWh)					
Types		LFP	LMO	NCM	Total
Buses	HD-PEV	662.59	0	0	662.59
	HD-OVC-HEV	3.03	2.07	0	5.1
Trucks	HD-PEV	3264.71	0.58	24.04	3289.33
	HD-OVC-HEV	14.38	0.98	0.54	15.9
Total		3944.71	3.63	24.58	3972.92

HD-EV statistical data in December, 2023

lithium battery types:

LFP—LiFePO₄ batteries

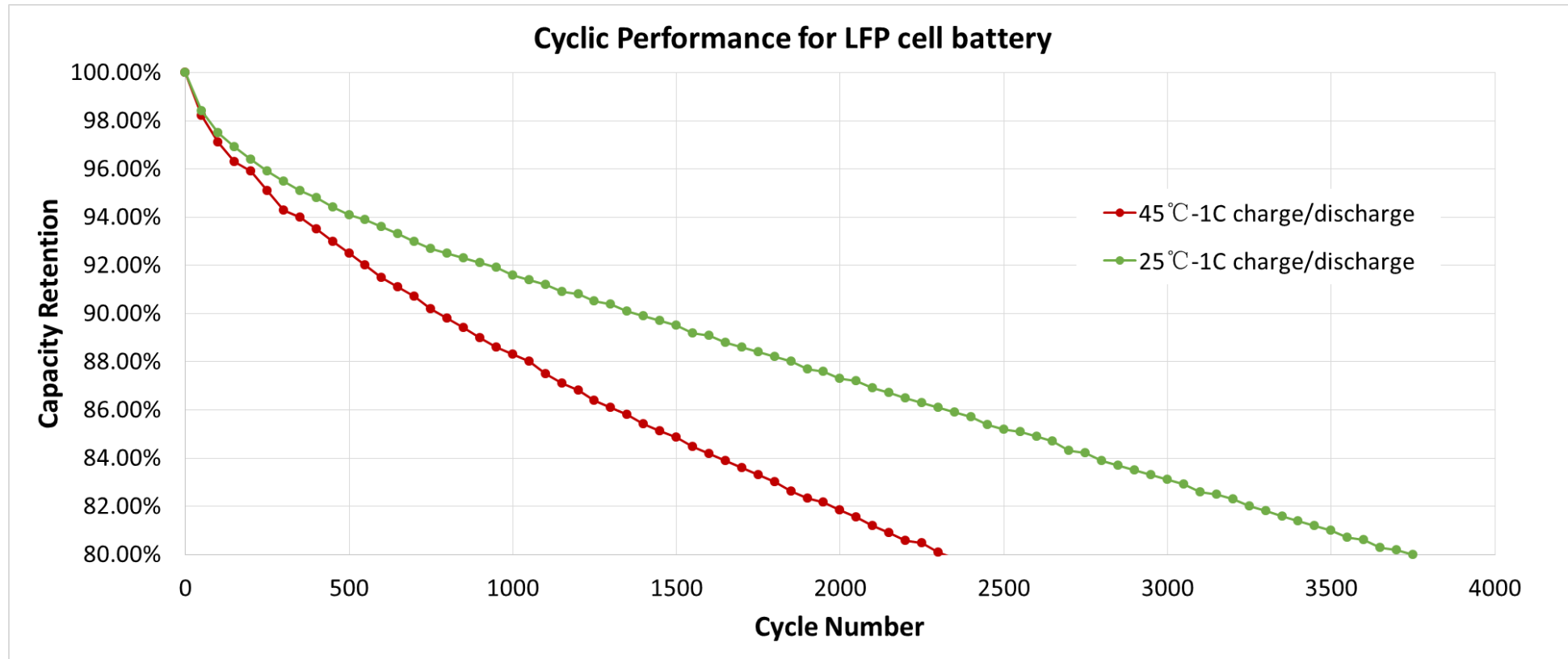
LMO—LiMn₂O₄ batteries

NCM—Li Ni_xCo_yMn_{1-x-y}O₂ batteries, such as LiNiCoMnO₂, LiNi_{0.5}Co_{0.2}Mn_{0.3}O₂, LiNi_{0.6}Co_{0.2}Mn_{0.2}O₂, LiNi_{0.8}Co_{0.1}Mn_{0.1}O₂

Background : Cyclic Performance

□ Cyclic Performance

- ✓ For LFP cell battery, the cycle life at 45°C is more than 2000 cycles and the cycle life at 25°C is more than 3500 cycles with about 80% capacity retention, which is obtained by continuously charging and discharging test with the same rate of 1C.
- ✓ The cyclic performance of HD-EV battery system was depend on application temperature and consistency of cell battery.



Background : Battery Attenuation Evaluation Model

□ Impact factor

- ✓ The Impact factors of battery cycle life are temperature, depth of discharge, rate, cycle number and using time.

□ Evaluation model

- ✓ Battery attenuation evaluation model is like : $Q_{loss} = Af(T, N, DOD, t)$

A means model parameter which can be calculated by cyclic and storage test,

T means average temperature which can be calculated by thermal simulation method,

N means average daily cycle number and DOD means depth of discharge, which derived from customer requirements.

t means **available time**, which can be calculated as a MPR metric.

- ✓ **Available mileage** = available time × average daily cycle number / energy consumption

MPR metric : Energy Throughput or Cycle Number?

❑ MPR metric : energy throughput or cycle number?

- ✓ With the same energy throughput, the higher installed energy value, the higher cycle number, resulting in the worse battery attenuation.
- ✓ **The cycle number maybe more proper to use as a MPR metric than energy throughput**, because the cycle number is directly related to the battery attenuation.
- ✓ The relationship between energy throughput and cycle number:

$$\text{Energy throughput} = \text{cycle number} \times \text{UBE}_{\text{certified}}$$

Energy Throughput	Installed Energy	Cycle Number	Battery Attenuation	
400MWh	100kWh	4000 cycles	60%	×
400MWh	200kWh	2000 cycles	80%	✓
400MWh	300kWh	1333 cycles	88%	✓✓

❑ Which types of HD-EVs have to use cycle number?

- ✓ For M2 and M3 vehicles, the operation scenario and energy consumption is relatively fixed, use year and mileage as MPR metric is OK.
- ✓ **For N2 and N3 vehicles**, the operation scenario is complicated and various, the energy consumption has a wide distribution. **It is necessary to add cycle number as MPR metric.**

MPR Evaluation: M2

❑ MPR suggestion

- ✓ The 160,000km of lifetime in draft is not enough for M2 type HD-EVs, which corresponding to 20,000km.
- ✓ The battery cyclic performance and energy consumption of M2 type HD-EVs can support 300,000km lifetime, which corresponding to 37,500km per year for 8 years lifetime.

M2	HD-PEV	HD-OVC-HEV
Main Lifetime [160,000] km or [8] years, whichever comes first		
Additional Lifetime After main lifetime and up to [200,000] km		

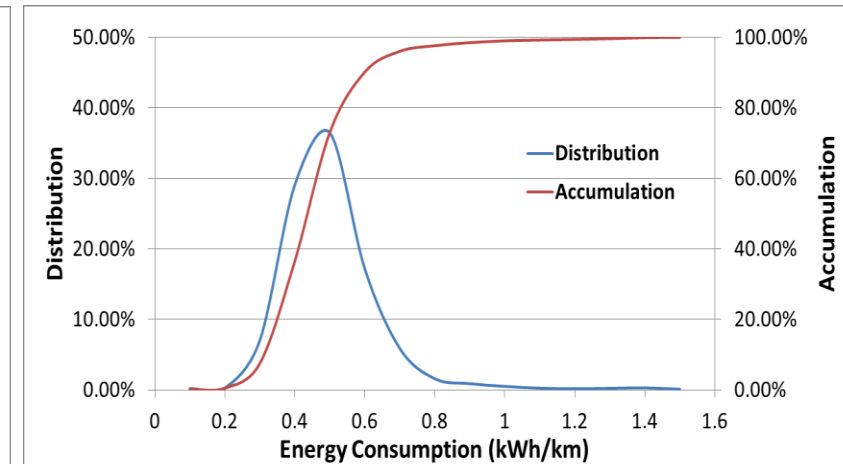
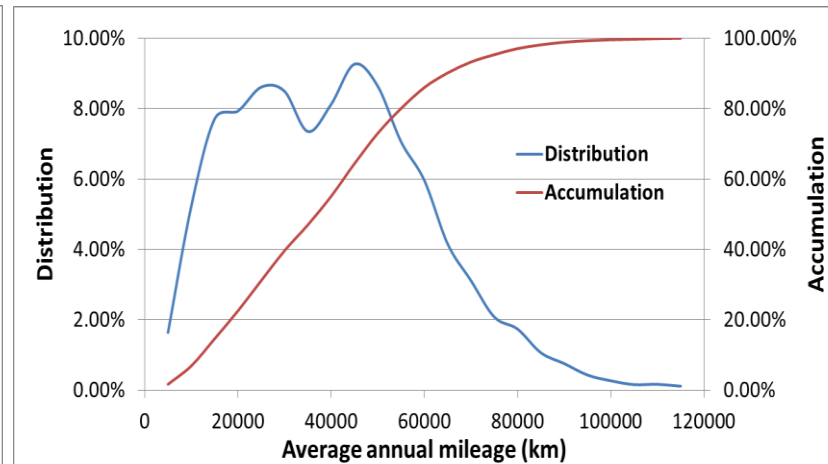
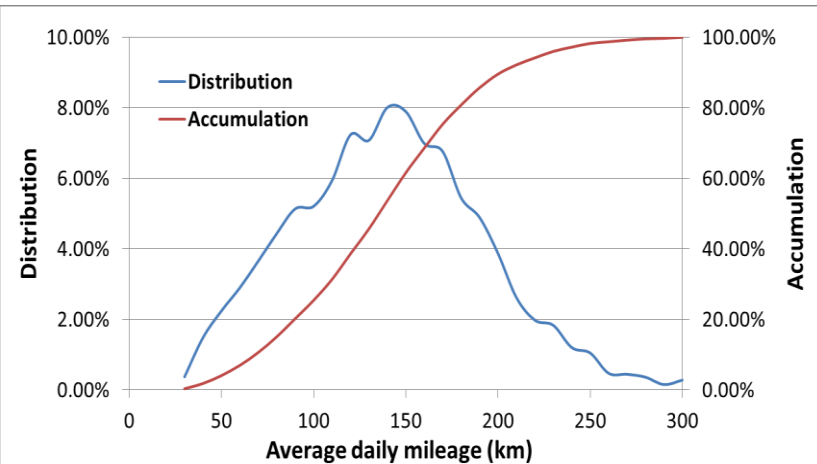


M2	HD-PEV	HD-OVC-HEV
Main Lifetime [300,000] km or [8] years, whichever comes first	70%	70%

MPR Evaluation: M3<7.5t

□ Mileage and Energy Consumption Range

- ✓ The average daily mileage of M3<7.5t type HD-EVs is concentrated in the 100-200km range, and about 90% vehicles within the 0-200km range.
- ✓ The year mileage of M3<7.5t type HD-EVs is concentrated in the 20000-60000km range, and about 90% vehicles within the 0-65000km range.
- ✓ The energy consumption of M3<7.5t type HD-EVs is concentrated in the 0.4-0.6kWh/km range, which is a narrow contribution, meas highly similar operation scenario for M3<7.5t type HD-EVs.



MPR Evaluation: M3<7.5t

❑ MPR suggestion

- ✓ The 300,000km of lifetime in draft is not enough for M3<7.5t type HD-EVs, which corresponding to 37,500km per year for 8 years lifetime, only meet 50% vehicles operation requirement.
- ✓ The battery cyclic performance and energy consumption of M3<7.5t type HD-EVs can support 500,000km lifetime, which corresponding to 62,500km per year for 8 years lifetime, meet 90% vehicles operation requirement.

M3<7.5t	HD-PEV	HD-OVC-HEV
Main Lifetime [300,000] km or [8] years, whichever comes first		
Additional Lifetime After main lifetime and up to [375,000] km		

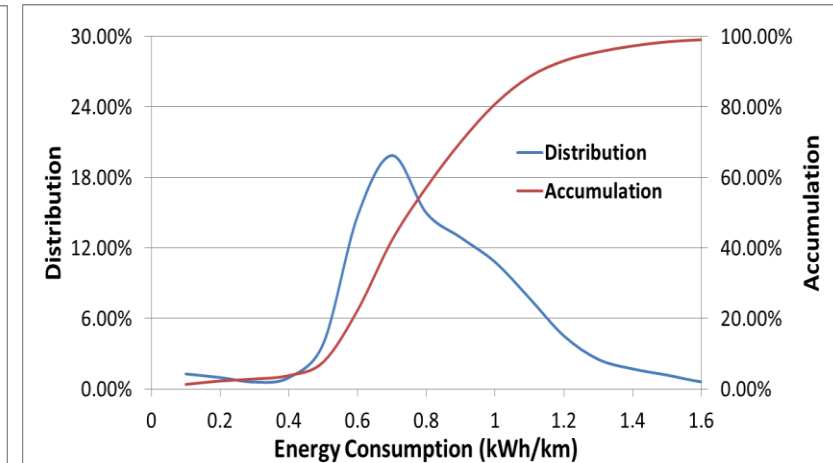
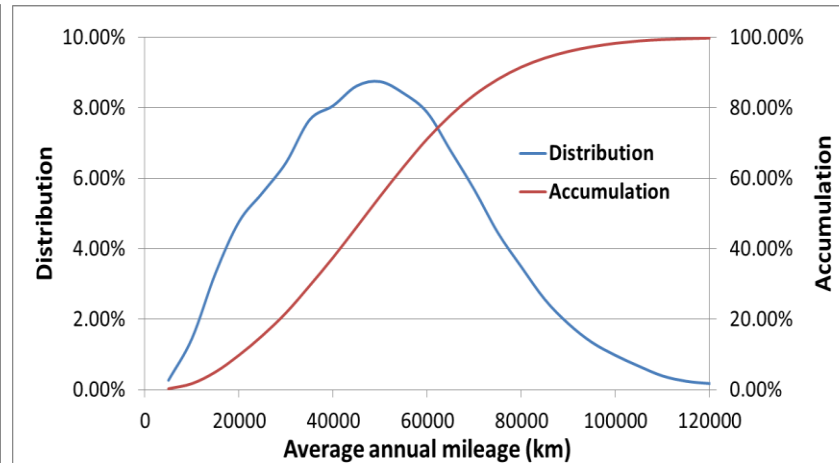
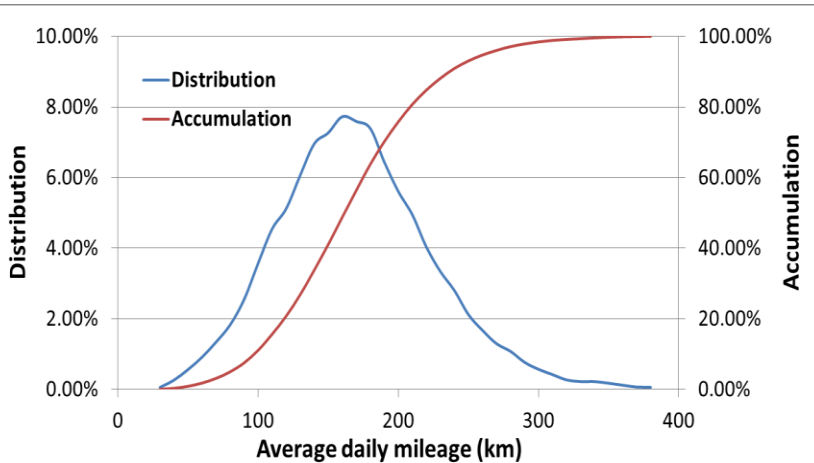


M3<7.5t	HD-PEV	HD-OVC-HEV
Main Lifetime [500,000] km or [8] years, whichever comes first	70%	70%

MPR Evaluation: M3>7.5t

□ Mileage and Energy Consumption Range

- ✓ The mileage and energy range of M3>7.5t type HD-EVs are quietly similar with M3<7.5t.
- ✓ The average daily mileage and year mileage distribution of M3>7.5t type HD-EVs are wider than M3<7.5t.
- ✓ About 90% vehicles within the 0-240km average daily mileage range and 0-75000km year mileage range.
- ✓ The energy consumption of M3>7.5t type HD-EVs is concentrated in the 0.6-1.0kWh/km range, which is a relatively narrow contribution.




MPR Evaluation: M3>7.5t

❑ MPR suggestion

- ✓ The battery cyclic performance and energy consumption of M3>7.5t type HD-EVs can only support 600,000km lifetime, which corresponding to 75,000km per year for 8 years lifetime, meet 90% vehicles operation requirement.

M3>7.5t	HD-PEV	HD-OVC-HEV
Main Lifetime [700,000] km or [15] years, whichever comes first		
Additional Lifetime After main lifetime and up to [875,000] km		

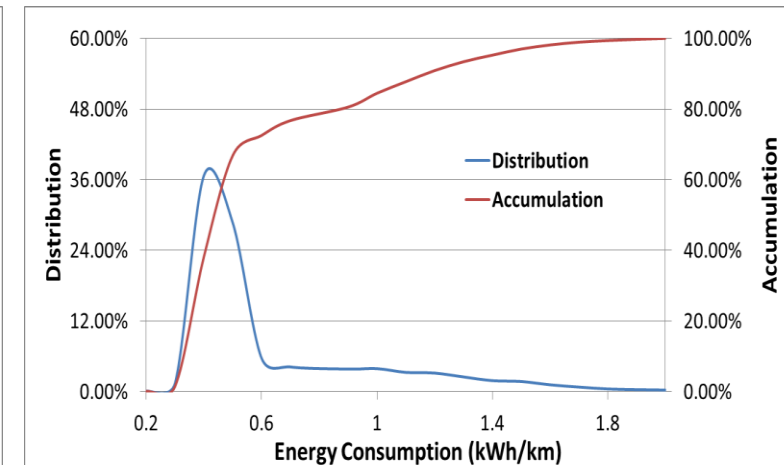
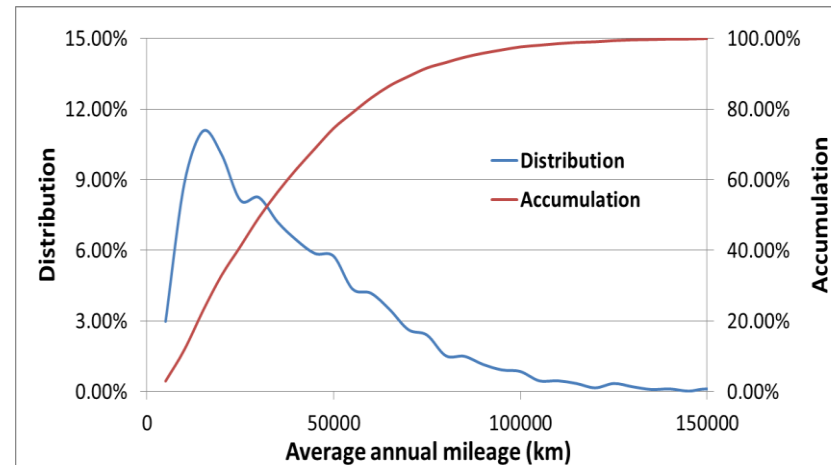
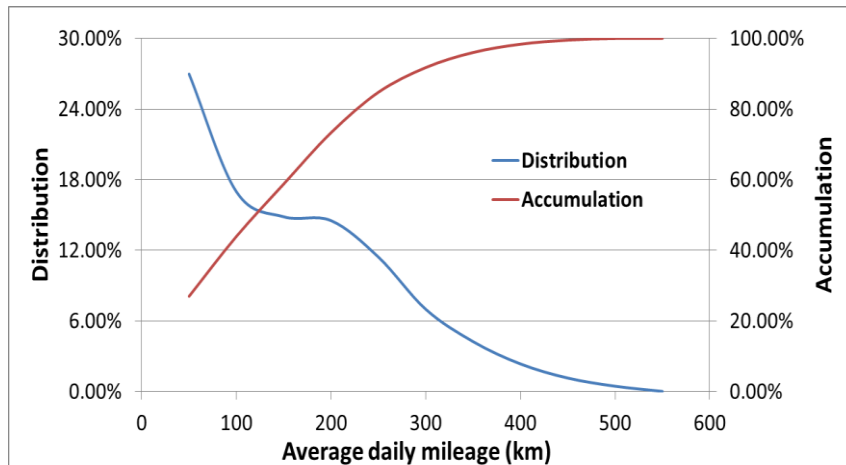


M3>7.5t	HD-PEV	HD-OVC-HEV
Main Lifetime [600,000] km or [8] years, whichever comes first	70%	70%

MPR Evaluation: N2,N3<16t

□ Mileage and Energy Consumption Range

- ✓ The average daily mileage of N2,N3<16t type HD-EVs is concentrated in the 100-300km range, and about 90% vehicles within the 0-320km range.
- ✓ The year mileage of N2,N3<16t type HD-EVs is concentrated in the 20000-60000km range, and about 90% vehicles within the 0-80000km range.
- ✓ The energy consumption of N2,N3<16t type HD-EVs is concentrated in the 0.4-0.5kWh/km range, but with a wide contribution at the 0.6-1.8kWh/km range, meas various operation scenario for N2,N3<16t type HD-EVs.



MPR Evaluation: N2,N3<16t

❑ MPR suggestion

- ✓ The 300,000km of lifetime in draft is not enough for N2,N3<16t type HD-EVs, which corresponding to 37,500km per year for 8 years lifetime, only meet 40% vehicles operation requirement.
- ✓ The battery cyclic performance and energy consumption of N2,N3<16t type HD-EVs can support 400,000km lifetime, which corresponding to 50,000km per year for 8 years lifetime, meet 75% vehicles operation requirement.
- ✓ Considering the various operation scenario (such as sanitation truck and transport truck) and energy consumption, the energy throughput shall added, which is $2800 * UBE_{certified}$ corresponding to battery cyclic performance.

N2,N3<16t	HD-PEV	HD-OVC-HEV
Main Lifetime [300,000] km or [8] years, whichever comes first		
Additional Lifetime After main lifetime and up to [375,000] km		

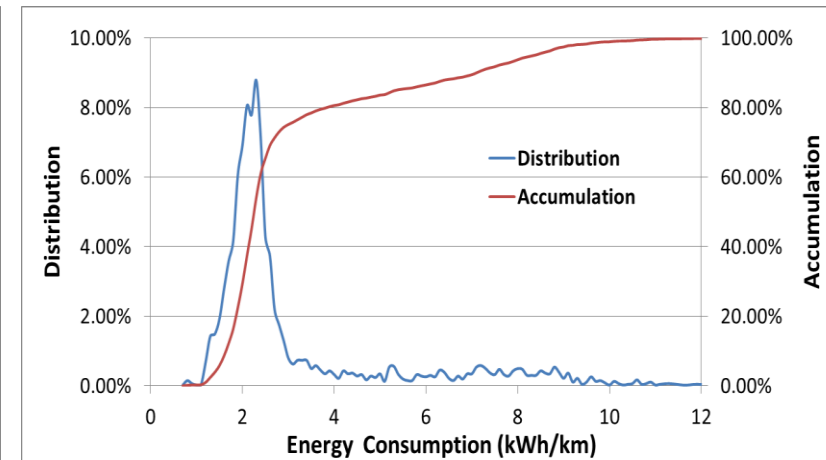
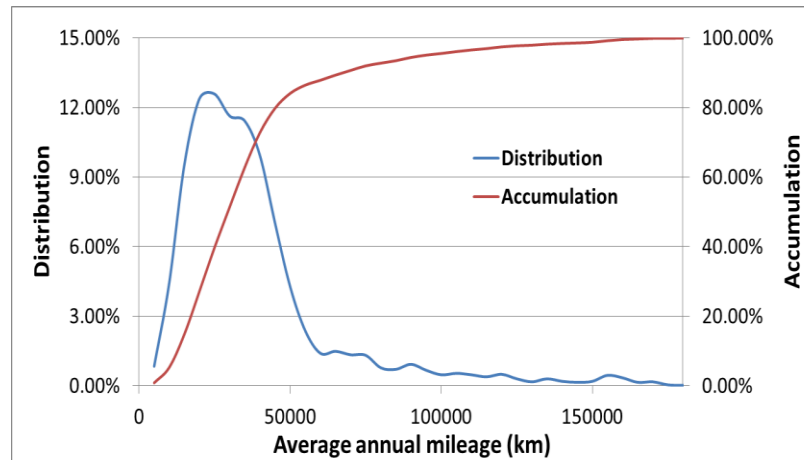
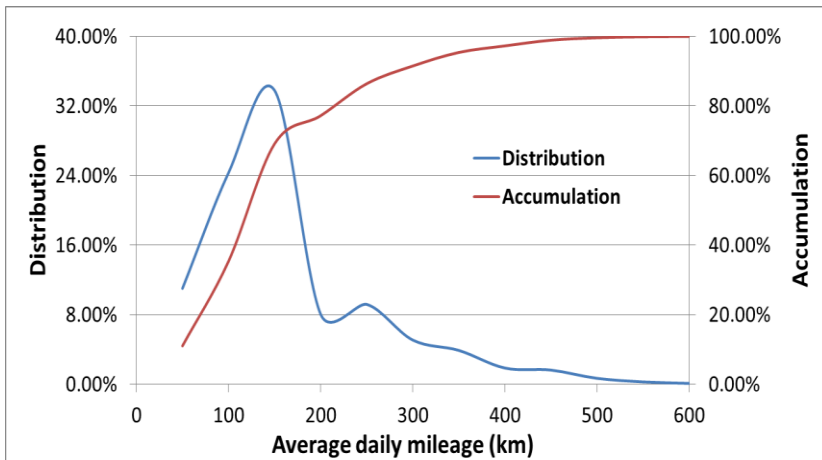


N2,N3<16t	HD-PEV	HD-OVC-HEV
Main Lifetime [400,000] km or [8] years or $2800 * UBE_{certified}$, whichever comes first	70%	70%

MPR Evaluation: N3>16t

□ Mileage and Energy Consumption Range

- ✓ The mileage and energy consumption distribution of N3>16t type HD-EVs are much wider than N2,N3<16t.
- ✓ The average daily mileage of N3>16t type HD-EVs has a narrow distribution at range of 0-200km and a wide distribution at range of 200-400km, and about 90% vehicles within the 0-300km range.
- ✓ The average daily mileage of N3>16t type HD-EVs has a narrow distribution at range of 20,000-40,000km and a wide distribution at range of 40,000-70,000km, and about 90% vehicles within the 0-70,000km range.
- ✓ The energy consumption of N3>16t type HD-EVs HD-EVs has a narrow distribution at range of 1.5-3.0kWh/km and a extremely wide contribution at range of 3.0-9.0kWh/km, meas complicated operation scenario for N3>16t type HD-EVs.



MPR Evaluation: N3>16t

❑ MPR suggestion

- ✓ The battery cyclic performance and power consumption of N3>16t type HD-EVs can only support 600,000km lifetime, which corresponding to 75,000km per year for 8 years lifetime, meet 92% vehicles operation requirement.
- ✓ Considering the extremely high energy consumption, the energy throughput shall added, which is $2800 * UBE_{certified}$ corresponding to battery cyclic performance.

N3>16t	HD-PEV	HD-OVC-HEV
Main Lifetime [700,000] km or [15] years, whichever comes first		
Additional Lifetime After main lifetime and up to [875,000] km		



N3>16t	HD-PEV	HD-OVC-HEV
Main Lifetime [600,000] km or [8] years or $2800 * UBE_{certified}$, whichever comes first	70%	70%