



Industry Assessment & Roadmap for Zero-Emission Medium and Heavy-Duty Trucks in India

D3-Techno-commercial Feasibility



Enabling Smart & Clean Tech Markets



P' in our name stands for triple bottom line sustainability of people, profit and planet that we want to bring in all our internal functioning, projects we do, and industries we support. It also keeps us prompt, progressive and partnership valuing. **Manifold** represent abstraction of complex problem to smaller dimension, still preserving elements which matters and are available to influence/control and also measure the system dynamics. We are '**small data**' company and take pride in collecting and analysing most relevant data to help our clients with decisions and actions.

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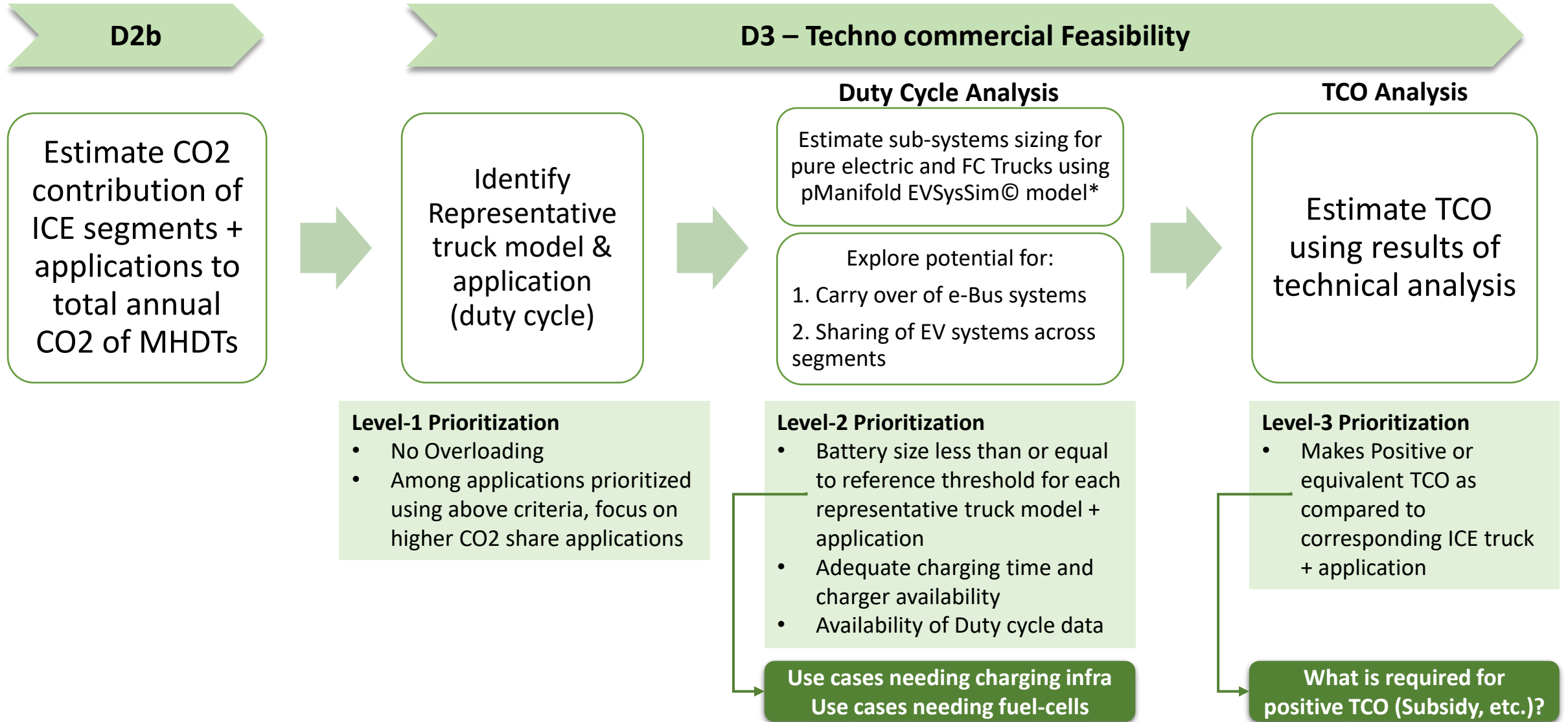
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Techno commercial Feasibility Study

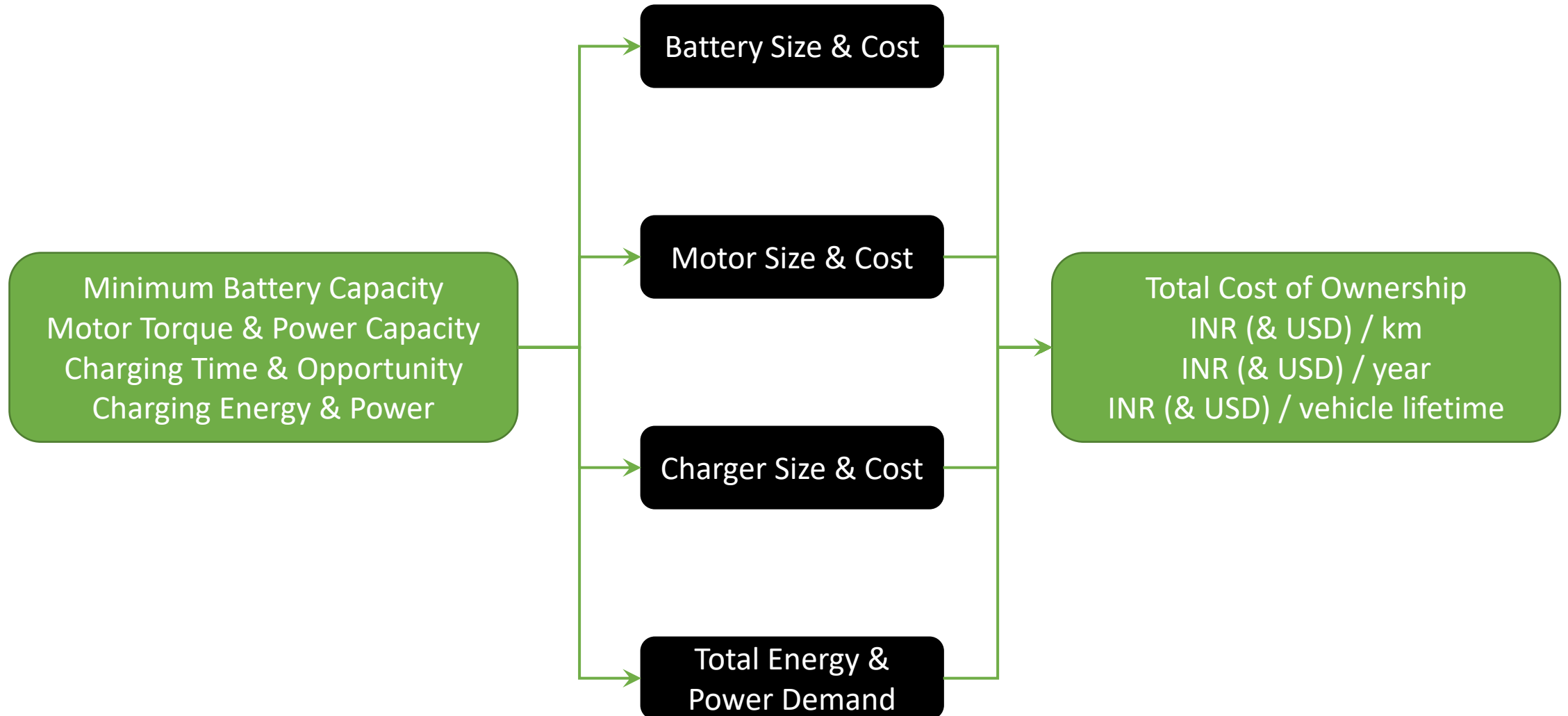


Techno commercial Feasibility Study – Methodology





Expected Outcomes of Duty Cycles Study for TCO





Specification Comparison – ICE vs. Electric Illustration

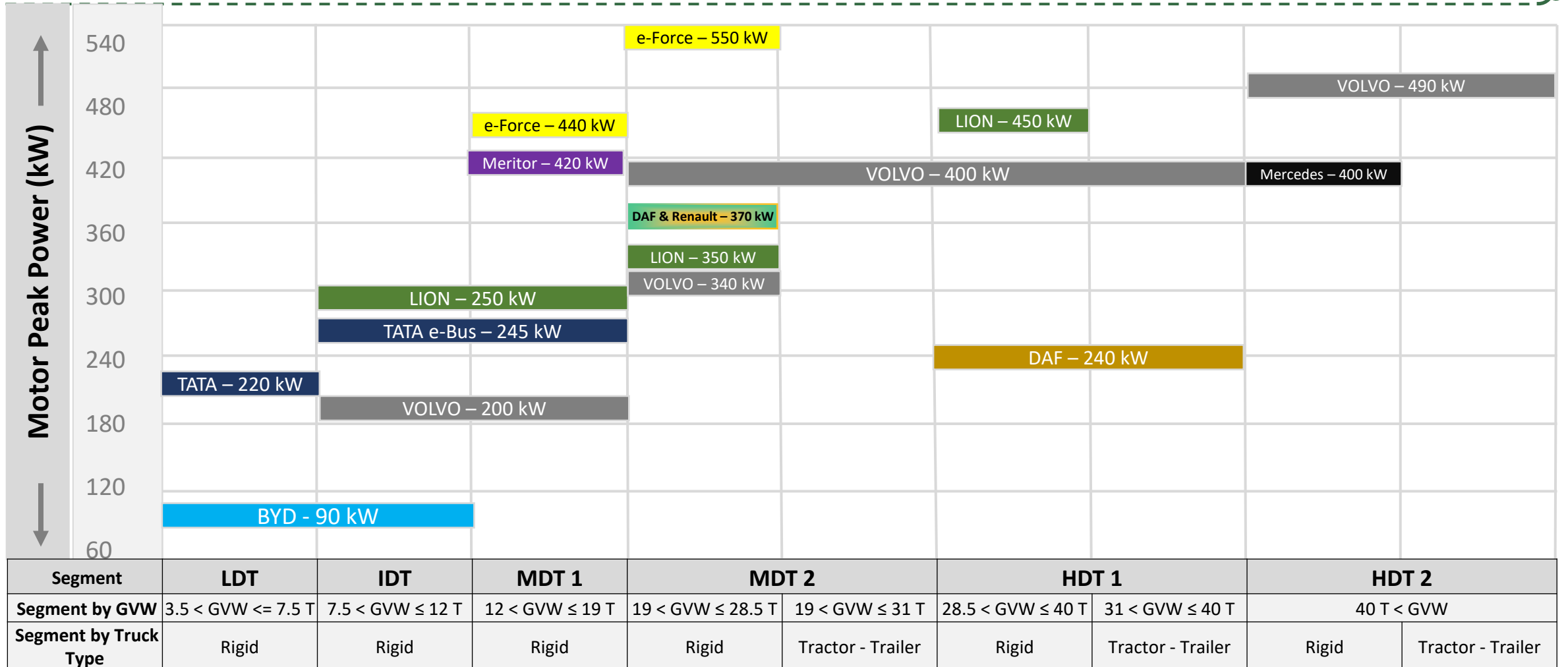


Parameter	Tata T7 ULTRA (62.5 kWh Battery)	Tata T7 ULTRA (160L Diesel Tank)	Tata T7 ULTRA (150L CNG Tank)
GVW [kg]	7,490 – 8,750	7,300	7,300
Fuel Tank / Battery Capacity [kWh or L]	62.5	160	150
Payload Capacity [kg]	3,692 – 4,935	3,680	3,530
Maximum Power [kW @ RPM]	220	73.5 @ 2800	63.4 @ 2500
Maximum Torque [Nm @ RPM]	2800	300 @ 1200 – 2200	285 @ 1200 – 1600
Maximum Gradeability [%]	26%	33.5%	25%
Maximum Speed [kph]	80	80	NA
Mileage [kWh/km or km/L]	0.5 – 0.7	4 – 6	3 – 4
Estimated Range [km]	100 – 130	650 – 800	450 – 600

- Central motors tend to have similar max. torque & higher max. power ratings due to wider speed range
- Axle motors typically have 5-8 times max torque and 3-5 times max. power ratings with narrow speed range
- Hub motors are expected to have 2-3 times max torque and 3-5 time max. power ratings with narrow speed range



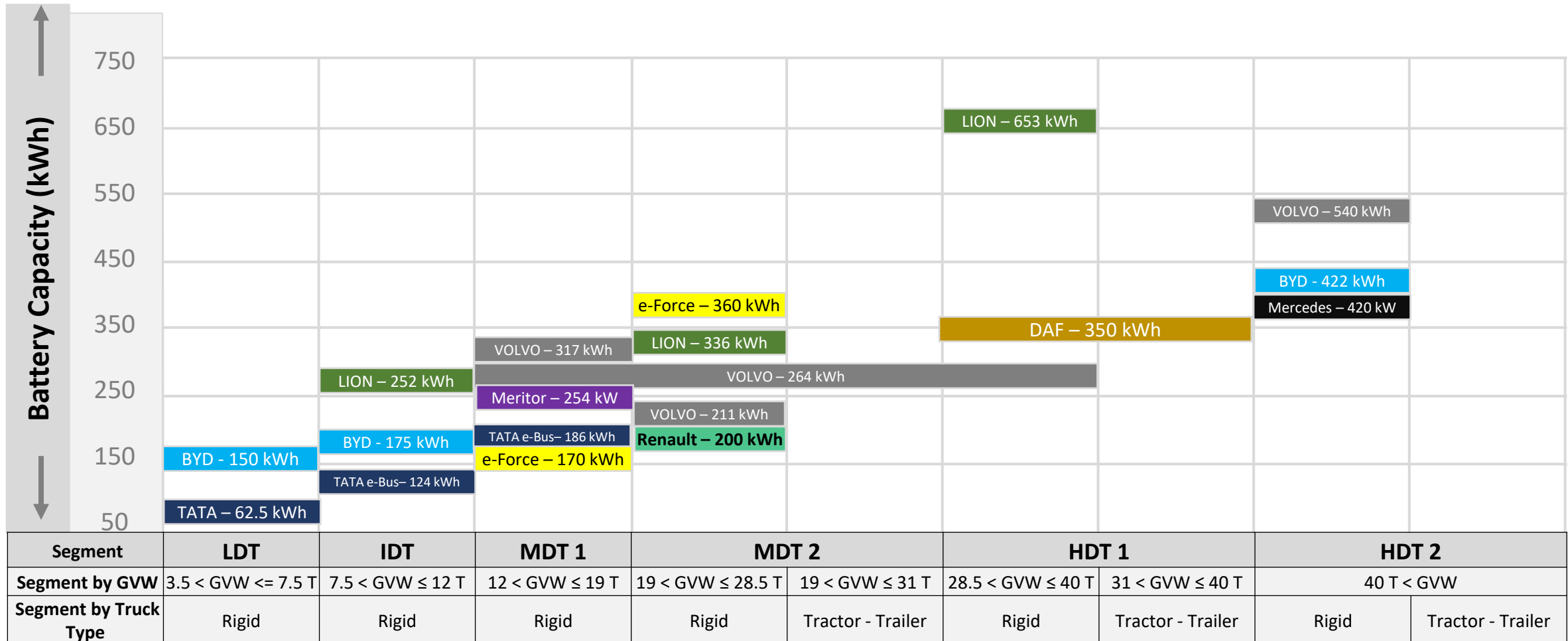
Motor Peak Power



Just like in to IC engine trucks, same motors are often used across segments of e-Trucks
 Stackable motors and e-axes for MAVs are also being considered by e-powertrain suppliers like Dana & ZF



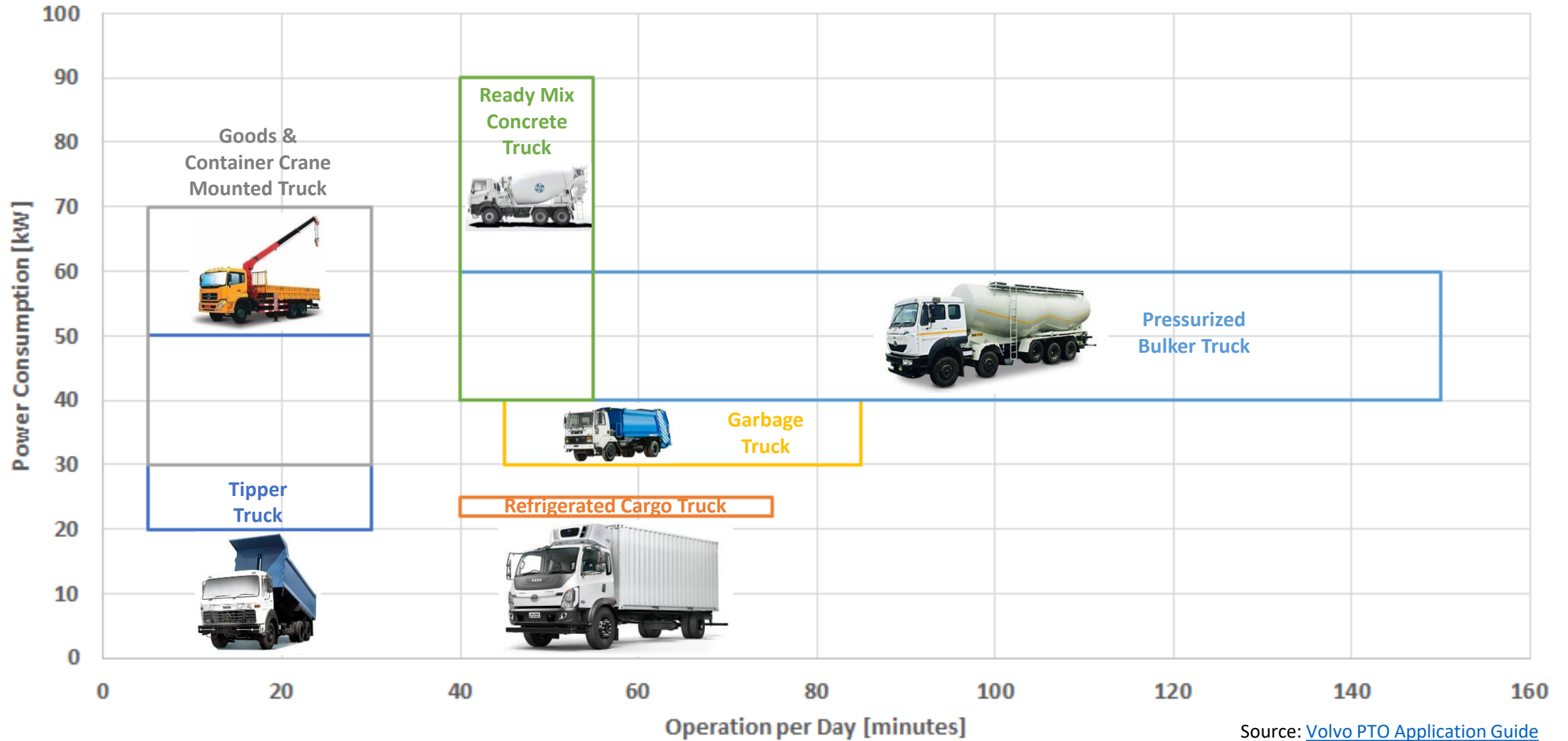
Battery Capacity



Battery capacity seems to vary a lot from one model / make to other – mostly catering to different applications (just like fuel tank sizes in ICE Trucks)
 Modular battery packs with scalable architecture are often used in e-Buses and are carried over into e-Trucks



Power Take-Off (PTO) Characteristics



Source: [Volvo PTO Application Guide](#)

In absence of e-PTO this is additional energy demand on traction battery

Duty Cycle Analysis

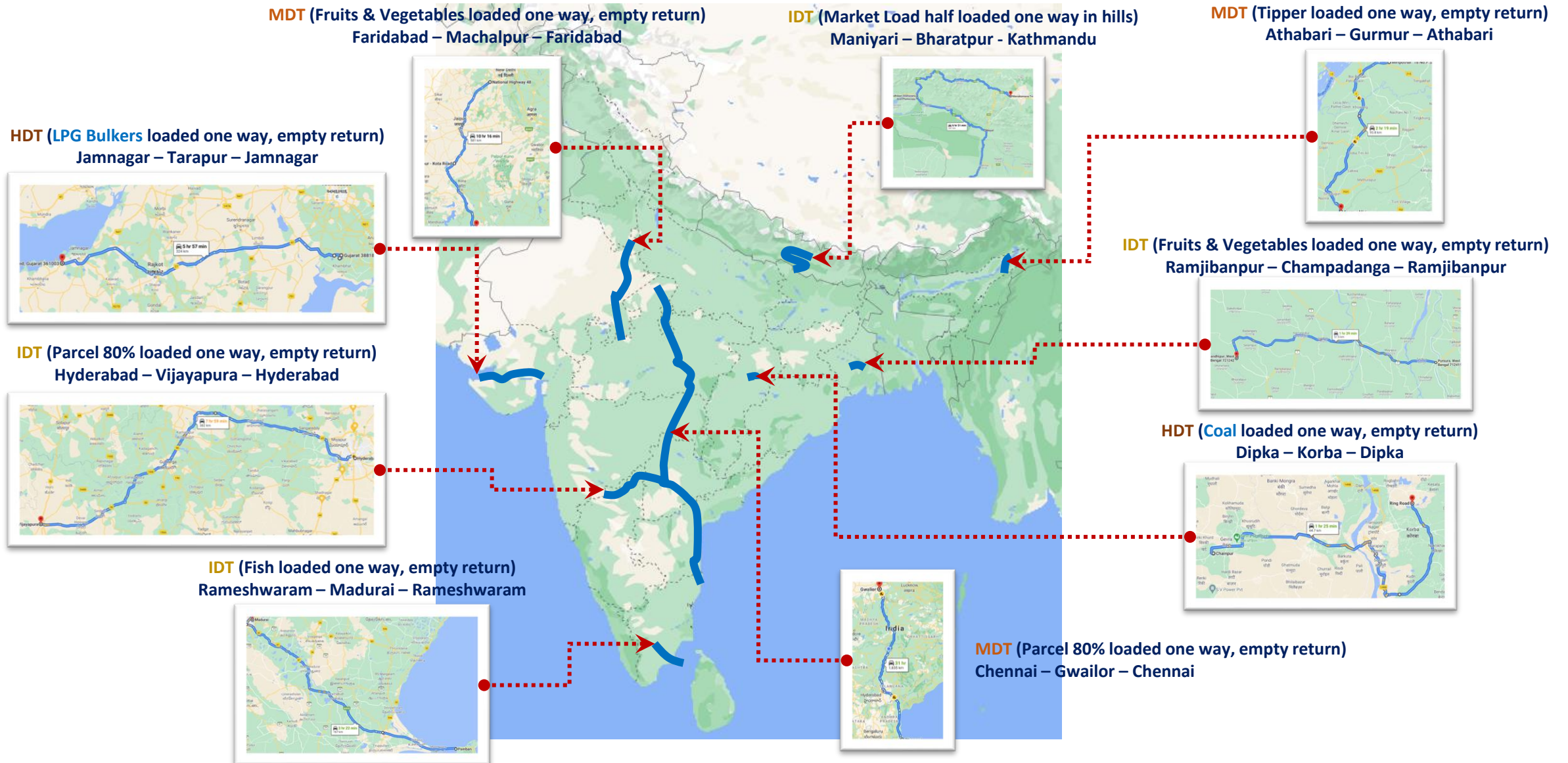


Representative Models for Duty-Cycle Simulations

Parameter	LDT 3.5 < GVW ≤ 7.5 T Rigid	IDT 7.5 < GVW ≤ 12 T Rigid	MDT 1 12 < GVW ≤ 19 T Rigid	MDT 2 19 < GVW ≤ 28.5 T Rigid	MDT 2 19 < GVW ≤ 31 T Tractor - Trailer	HDT 1 28.5 < GVW ≤ 40 T Rigid	HDT 1 31 < GTW ≤ 40 T Tractor - Trailer	HDT 2 >40 T GVW Rigid	HDT 2 >40 T GVW Tractor - Trailer
GVW Rating	7.5 T	11 T	19 T	29 T		40 T		52 T	
GVW [kg]	8,750	11,000	19,000	29,000		40,000		51,900	
Reference Vehicle	Tata Ultra T.7 Electric Truck	Tata Ultra 9/9m Electric Bus	Tata Urban 9/12m Electric Bus	Volvo FE Electric Rigid Truck			Volvo VNR 6x2 Electric Tractor-Trailer Truck	IPLT Rhino Electric Tractor Trailer Truck	
Kerb Weight including cabin & load-body [kg]	3,815	5,100	10,000	13,000			10,000	11,180	
Payload Capacity [kg]	4,935	5,900	9,000	16,000			30,000	40,720	
Battery Capacity [kWh]	62.5	124	186	248			225	256	
Motor Max. Power [kW]	220	245	245	330			360	360	
Motor Max. Speed [rpm]	2,500	2,000	2,000	2,000			2,000	2,000	
Motor Max. Torque [Nm]	2,800	3,000	3,000	4,000			5,000	5,000	

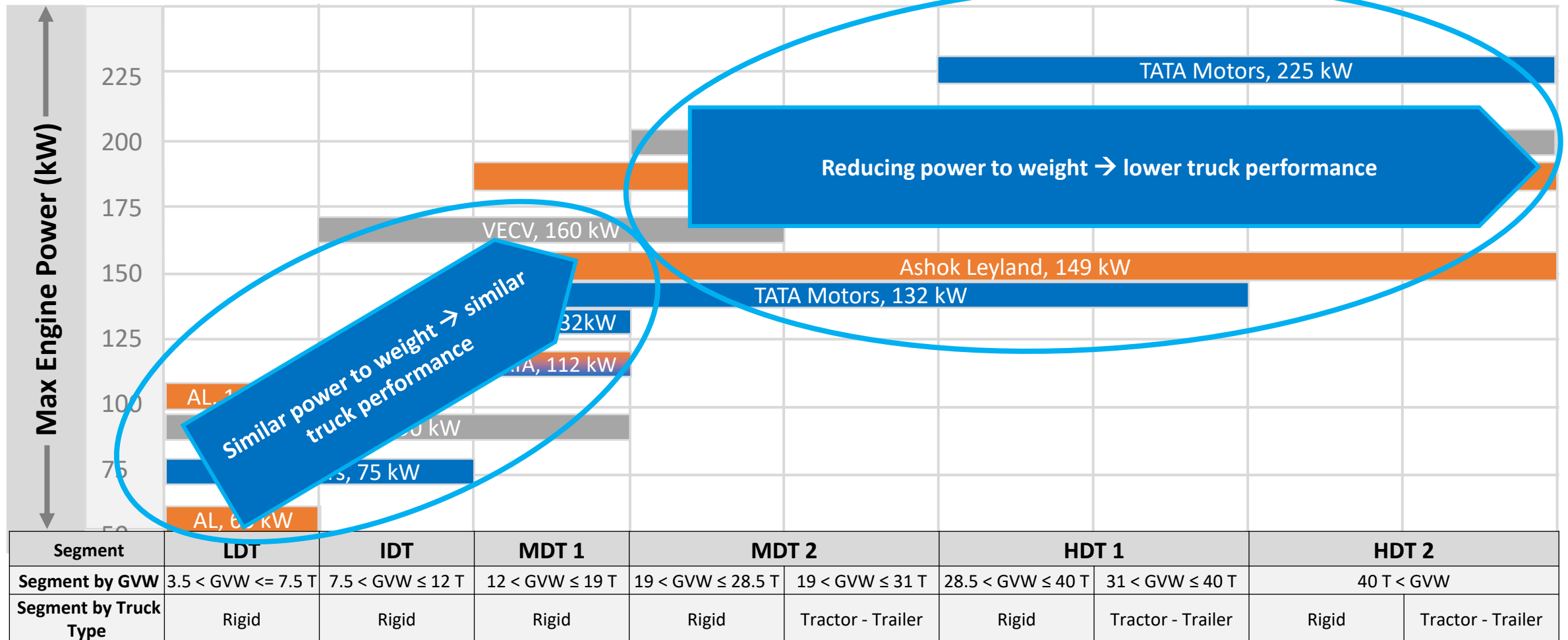


Duty Cycles Used in the Study - Illustrations





Engine Power-to-Weight



Source: pManifold Analysis

- It is feasible to use same duty cycles based on measurements for a 11 T or 16 T truck for a 7.5 T or 19 T truck
- To use a duty cycle based on measurements for a 29 T truck for a 40 T or 55 T truck, max. accelerations would have to be reduced



Duty Cycles Used in the Study – Complete List

Duty Cycle	Reference Truck	Simulated for...	Terrain	Loading Profile	Distance / Day	Distance / Leg
Coal (Mine to Power Plant) – Round Trip <i>(lower max. accelerations for heavier GVW)</i>	HDT 30 T	30 T & 55 T	Moderate Hilly	100% - 0%	100 km ≤ D ≤ 400 km	≤ 100 km
Market Load – One way	IDT 7.5 T	7.5 T & 11 T	Very Hilly	50% - 50%	100 km ≤ D ≤ 400 km	100 km ≤ D ≤ 400 km
Market Load – Round Trip	MDT 19 T	11 T & 19 T	Mild Hilly	100% - 100%	100 km ≤ D ≤ 400 km	100 km ≤ D ≤ 400 km
Parcel Load – Round Trip	IDT 12 T	7.5 T, 11 T & 19 T	Flat	80% - 0%	100 km ≤ D ≤ 400 km	100 km ≤ D ≤ 400 km
Parcel Load – Round Trip	MDT 28 T	29 T	Mild Hilly	80% - 80%	D > 400 km	D > 400 km
LPG / CNG Cylinder – Round Trip	IDT 16 T	11 T & 19 T	Flat	100% - 55%	D ≤ 100 km	≤ 100 km
On-Road Tipper – Round Trip	IDT 12 T	11 T & 19 T	Mild Hilly	100% - 0%	D ≤ 100 km	≤ 100 km
On-Road Tipper – Round Trip	MDT 19 T	19 T & 29 T	Moderate Hilly	100% - 0%	D ≤ 100 km	≤ 100 km
LPG Bulker – Round Trip <i>(lower max. accelerations for heavier GVW)</i>	HDT 40 T	29 T, 40 T & 55 T	Flat	100% - 0%	100 km ≤ D ≤ 400 km	100 km ≤ D ≤ 400 km
Petroleum Tanker – Round Trip <i>(lower max. accelerations for heavier GVW)</i>	MDT 28 T	19 T, 29 T & 40 T	Flat	100% - 0%	100 km ≤ D ≤ 400 km	100 km ≤ D ≤ 400 km
Water Tanker – Round Trip	MDT 19 T	11 T & 19 T	Flat	100% - 0%	100 km ≤ D ≤ 400 km	≤ 100 km
Vegetable & Fruits – Round trip	IDT 12 T	7.5 T & 11 T	Flat	100% - 0%	D ≤ 100 km	≤ 100 km
Vegetable & Fruits – Round trip	MDT 19 T	19 T & 29 T	Moderate Hilly	100% - 0%	D > 400 km	D > 400 km
Fish – Round trip	IDT 12 T	11 T & 19 T	Mild Hilly	100% - 0%	100 km ≤ D ≤ 400 km	100 km ≤ D ≤ 400 km

Overall 60+ iterations were simulated with different duty-cycles, truck segments & loading conditions

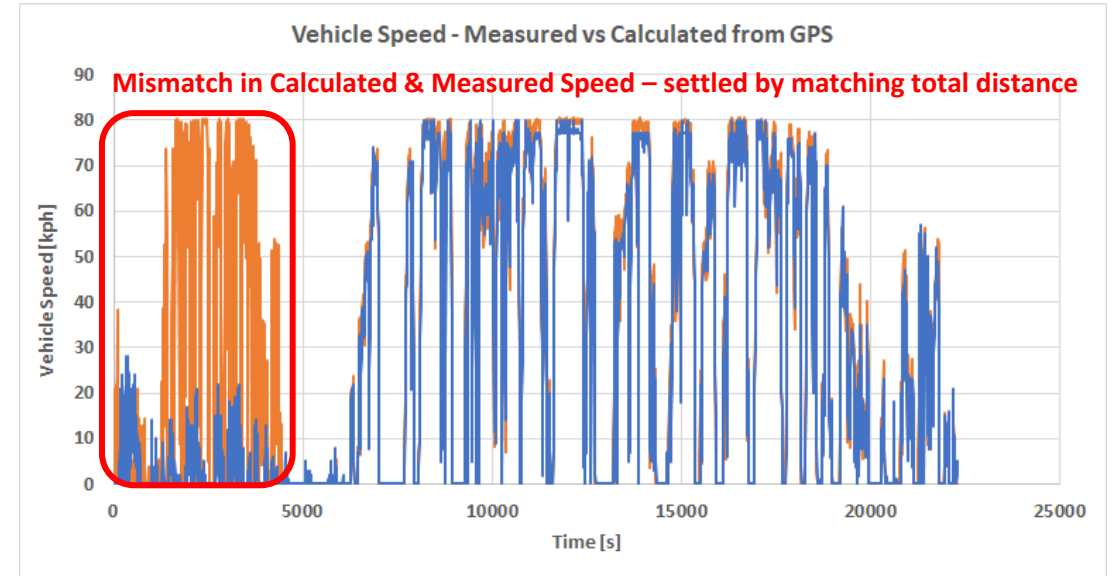


Duty Cycles Construction from Raw Data - Illustration

Time (Sec)	latitude	longitude	Altitude (m)	Vehicle speed (Kmph)	Vehicle speed (m/s)	Distance (m)	Cumulative Distance (km)
0	9.922308	78.11176	136.139	0	0.00	0	0
6	9.9221	78.11175	164.339	0	0.00	0.00	0.000
12	9.922083	78.11175	141.11	0	0.00	0.00	0.000
18	9.922102	78.11175	134.11	0	0.00	0.00	0.000
24	9.922056	78.11173	133.369	2.78	0.77	2.32	0.002
30	9.921878	78.11169	133.779	17.37	4.83	16.79	0.019
36	9.921623	78.11156	134.339	21.38	5.94	32.29	0.051
42	9.921364	78.11148	135.199	17.97	4.99	32.79	0.084

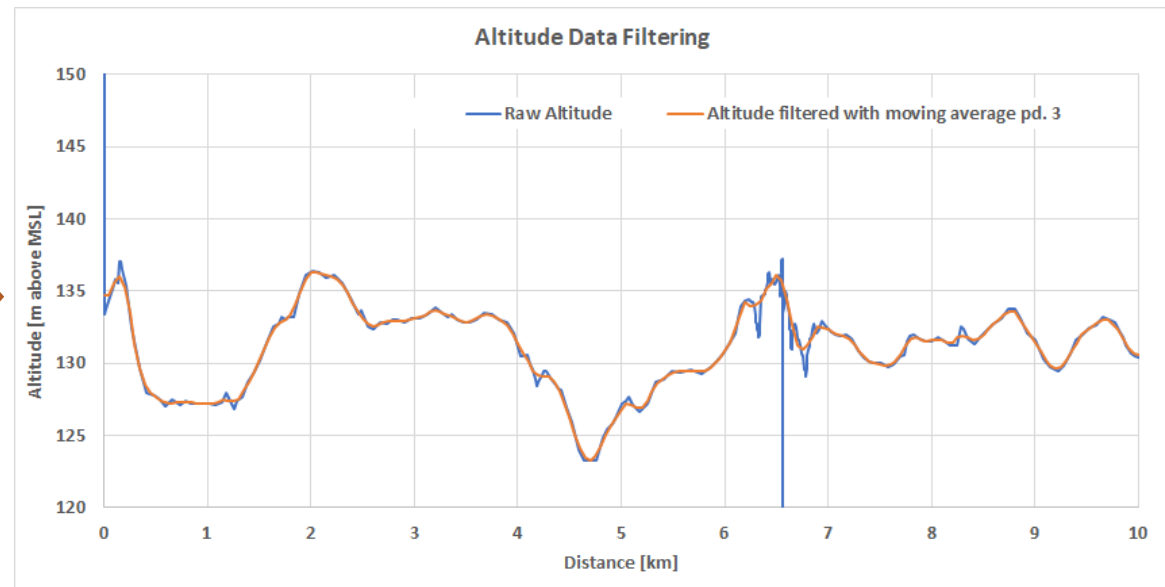
Raw Data

Processed Time-based Data



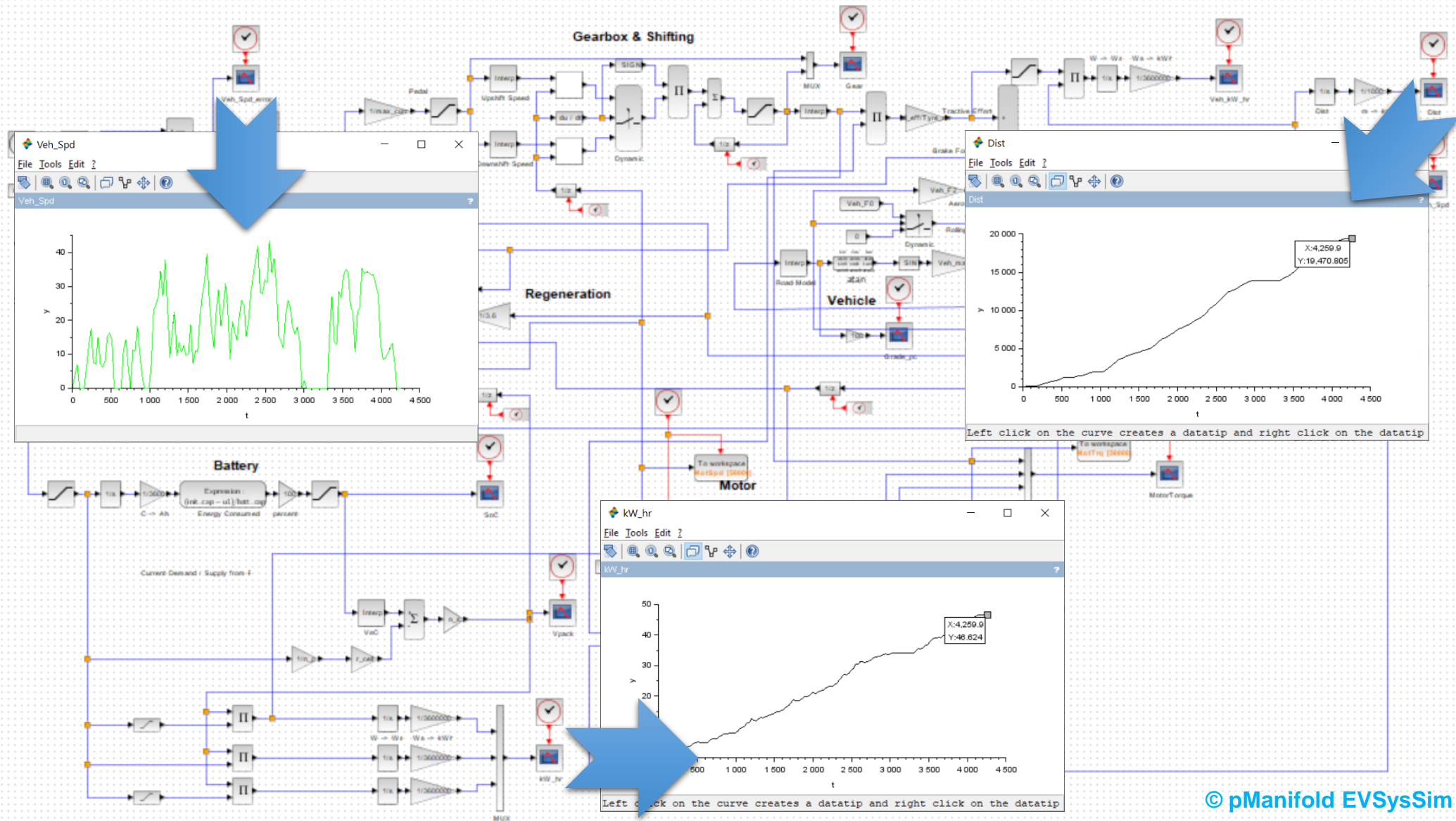
Cumulative Distance [km]	Intrapolated Altitude (m)	Grade (%)	Moving Average 3 (m)
0	134.11	0.4%	134.7
0.050	134.3147213	0.4%	134.7
0.1	135.5618078	2.5%	135.5
0.150	136.6806455	2.2%	136.0
0.2	135.7681175	-1.8%	135.3
0.250	133.4191713	-4.7%	133.5
0.3	131.2194472	-4.4%	131.3
0.350	129.408545	-3.6%	129.6

Processed Distance-based Data





Simulation Model in Scilab / Xcos



© pManifold EVSysSim



Simulation Model – Correlation Example for HDT



Vehicle model correlation using ICE fleet operator consultations	Unloaded	Loaded*	Average
Truck model vehicle energy requirement for Mine 1 [kWh/km]	0.7	3.4	1.6
Typical diesel ICE and driveline efficiency for heavy trucks	$30\% (\eta_{\text{engine}}) \times 85\% (\eta_{\text{driveline}}) = 25\%$		
Energy of diesel required by ICE [kWh/km]	2.82	13.85	6.4
Energy density of diesel [kWh/L]		9.7	
Fuel efficiency expected from diesel truck [km/L]	3.4	0.7	2.0

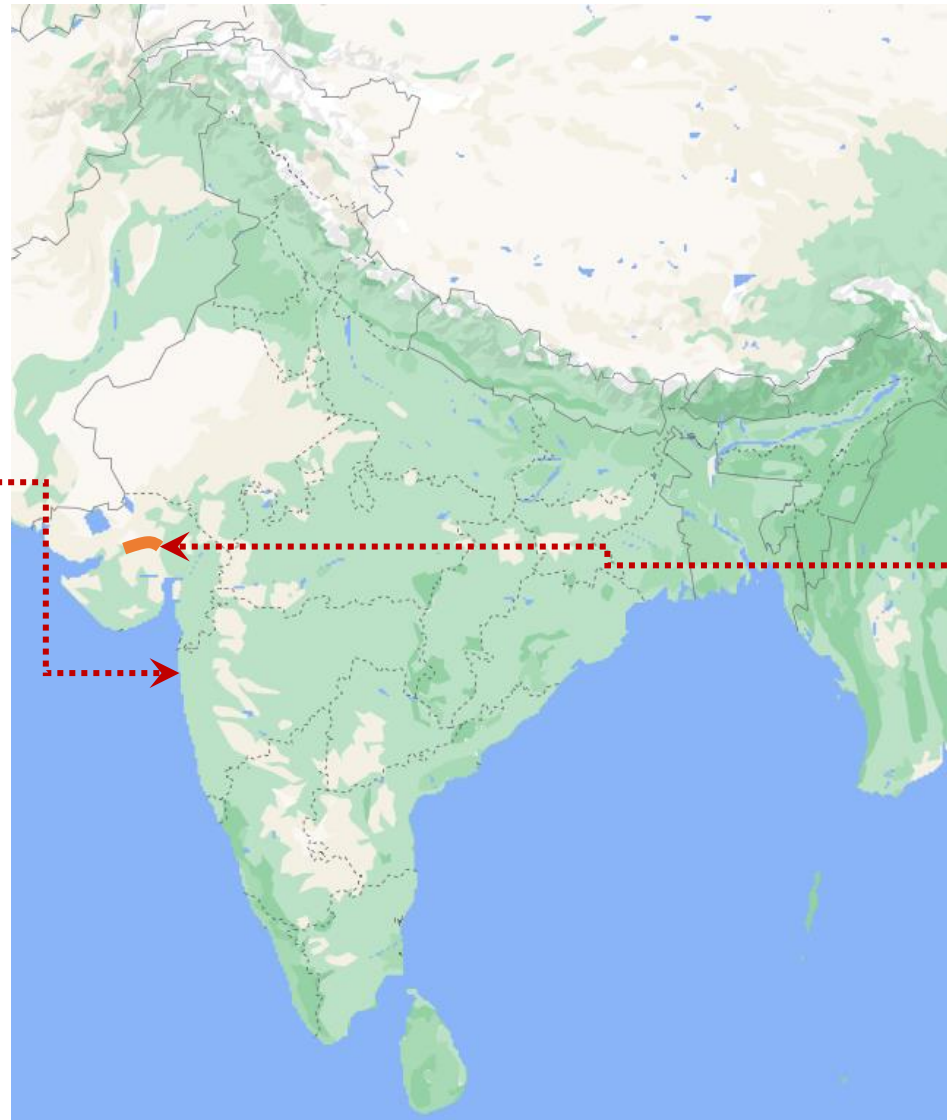
Confirmed with current fleet operators serving the mine

e-Truck model correlation using e-Truck claimed values	Unloaded	Loaded	Average
e-Truck model energy consumption for Mine 1 [kWh/km]	0.9	2.7	1.8
e-Truck claimed generic energy consumption [kWh/km]	1.0	1.5	1.25
Discrepancy [kWh/km]	0.1	1.2	0.55
e-Truck model energy consumption for ~27 kph mild cycles [kWh/km]	0.87	1.56	1.215
Discrepancy [kWh/km]	0.13	0.06	0.035

* Considering 10 tons overloading 51 tons instead of rated 41 tons



Illustrative Application 1: LPG / CNG Cylinders



Navi Mumbai – Thakurli – Navi Mumbai

Distance: 120 km (round trip)
 Trucks: 11 T
 Loading: 228 full cylinders (7.1 T) onward / 228 empty cylinders (3.55 T) return
 300 full cylinders (9.2 T) onward / 300 empty cylinders (4.6 T) return
 Energy Consumption: 228 cylinders - 0.76 kWh
 300 cylinders - 0.82 kWh/km
 Min. battery capacity (round trip): 107 kWh (228 cylinders) / 116 kWh (300 cylinders)
 Battery capacity of e-Truck: 124 kWh

Round trip in 1 charge, even with overloading

Soladi – Makarba – Soladi

Distance: 260 km (round trip)
 Trucks: 19 T
 Loading: 92 full cylinders (9.2 T) onward / 92 empty cylinders (4.6 T) return
 Energy Consumption: 1.05 kWh/km round trip & 1.08 kWh/km laden
 Min. battery capacity (1-way): 165 kWh laden
 Min. battery capacity (round trip): 322 kWh
 Battery capacity of e-Truck: 186 kWh

Requires charging at source & destination

Refer Annexure for remaining application

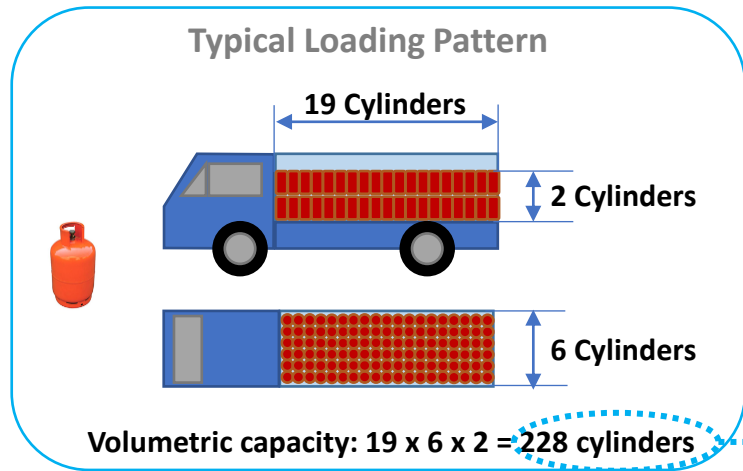


Impact of Overloading – LPG Cylinder Carrier Illustration

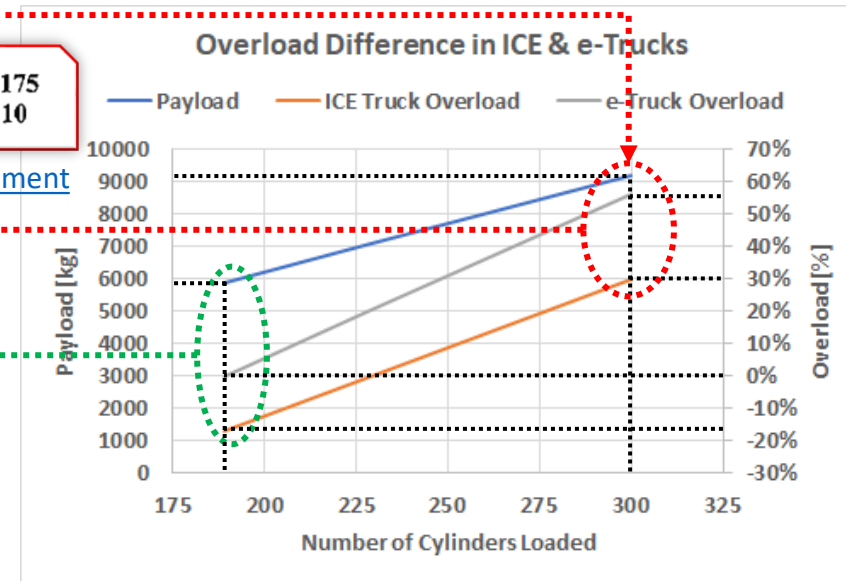


Total requirement of 300 cylinder capacity Trucks : 175
 Total requirement of 450 cylinders capacity trucks : 10

Source: [HPCL bid document](#)



Medium to long-distance application with overloading in ICE trucks are currently very difficult to electrify



Parameter	ICE Truck (160 L diesel tank)	e-Truck (124 kWh battery)
ICE Typical Loading (9.2 T) – 300 cylinders		
Overloading [%]	30%	56%
Range [km]	~600	116
ICE Permitted Payload Capacity (7.1 T) – 228 cylinders		
Overloading [%]	0%	20%
Range [km]	~700	127
eTruck Permitted Payload Capacity (5.9 T) – 189 cylinders		
Overloading [%]	-17%	0%
Range [km]	~750	136

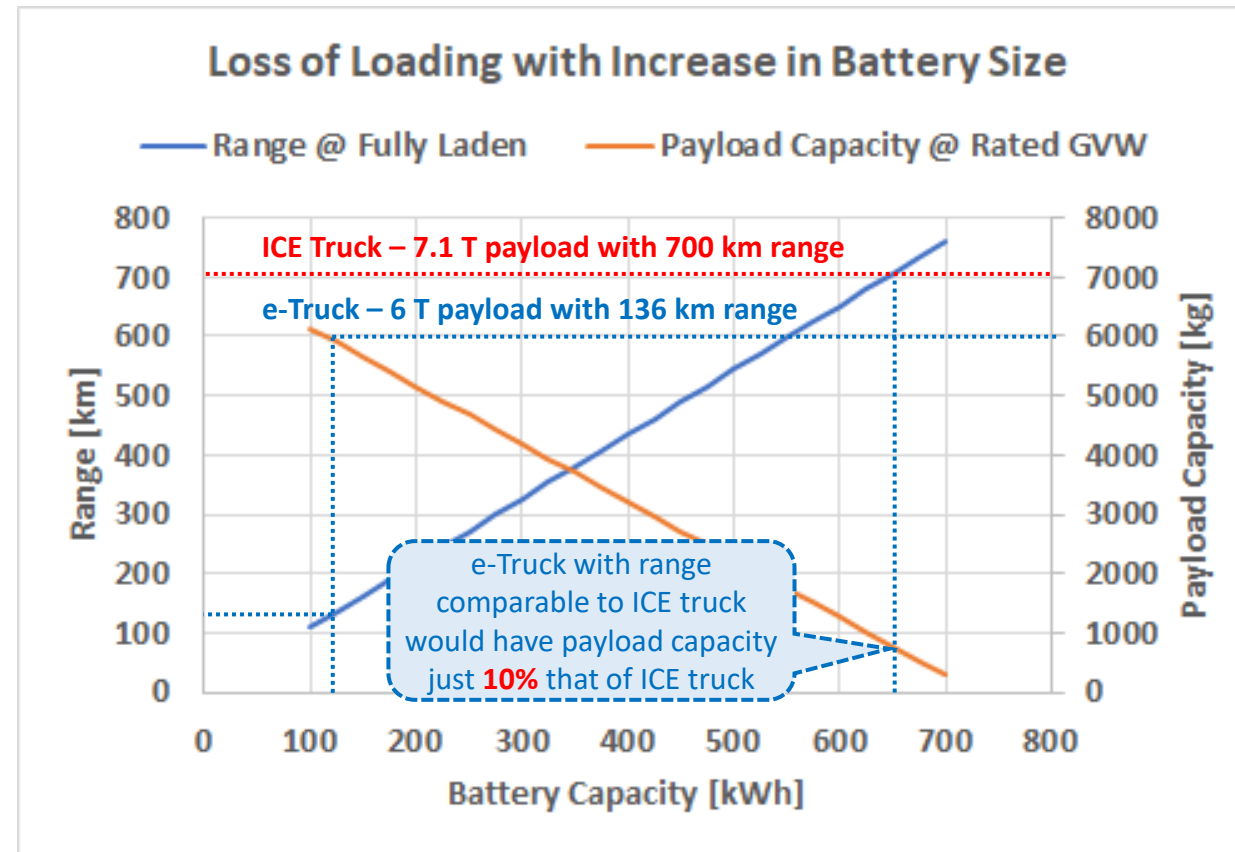
Most Likely Scenario

Possible Scenario

Unlikely Scenario



Battery Size & Payload – LPG Cylinder Carrier Illustration



Adding battery capacity results in a direct loss of payload capacity for the same rated GVW

Thus, other options like en-route charging and H2 fuel cells as range extenders, seem more practical



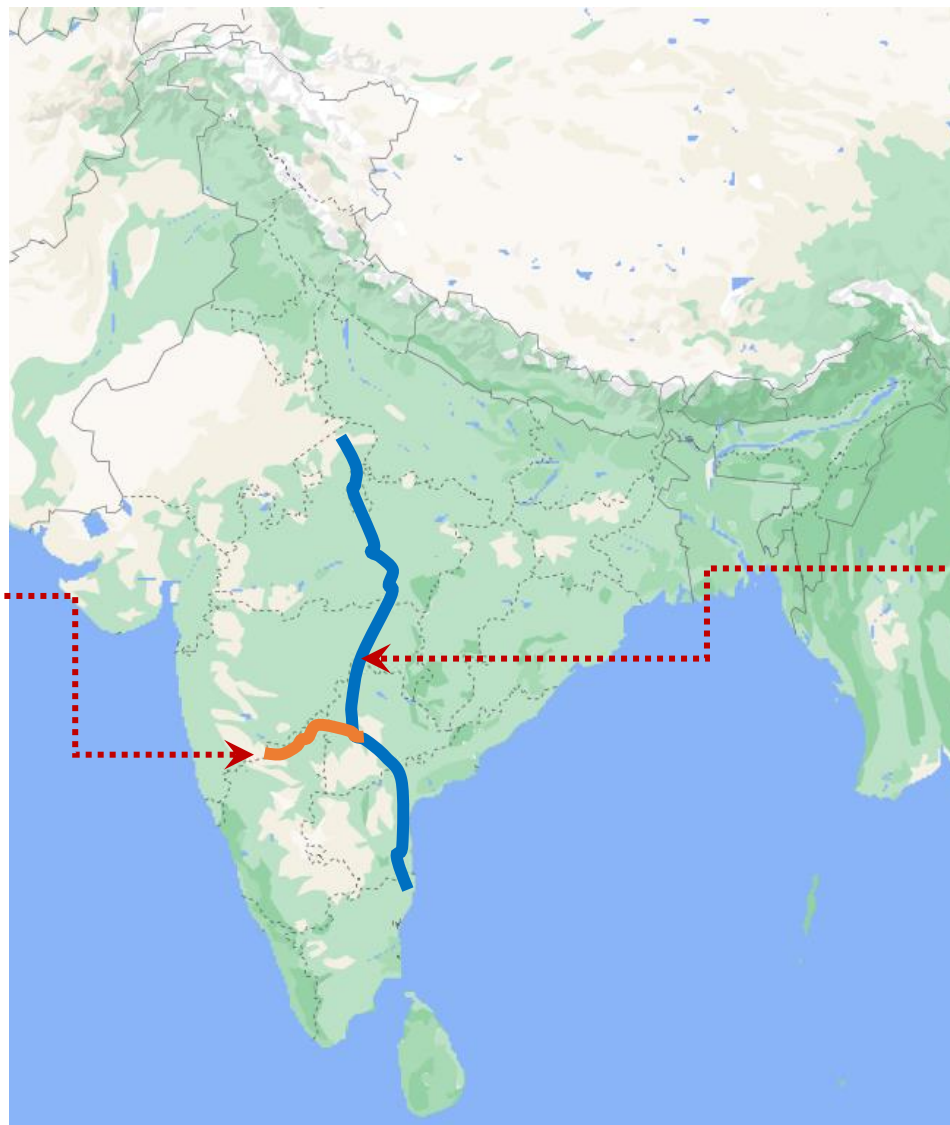
Illustrative Application 2: Parcel Load



Hyderabad – Vijayapura – Hyderabad

Distance: 710 km (round trip)
 Trucks: 11 T
 Loading: 80% (5.7 T) onward / 0% return
 Energy Consumption: 0.71 kWh/km
 Min. battery capacity (1-way): 300 kWh
 Payload capacity of e-Truck: 5.9 T @ 124 kWh
 4.2 T @ 300 kWh
 Payload capacity of ICE Truck: 7.1 T
 80% of payload capacity of ICE: 5.7 T (< 5.9 T)

Requires en-route charging



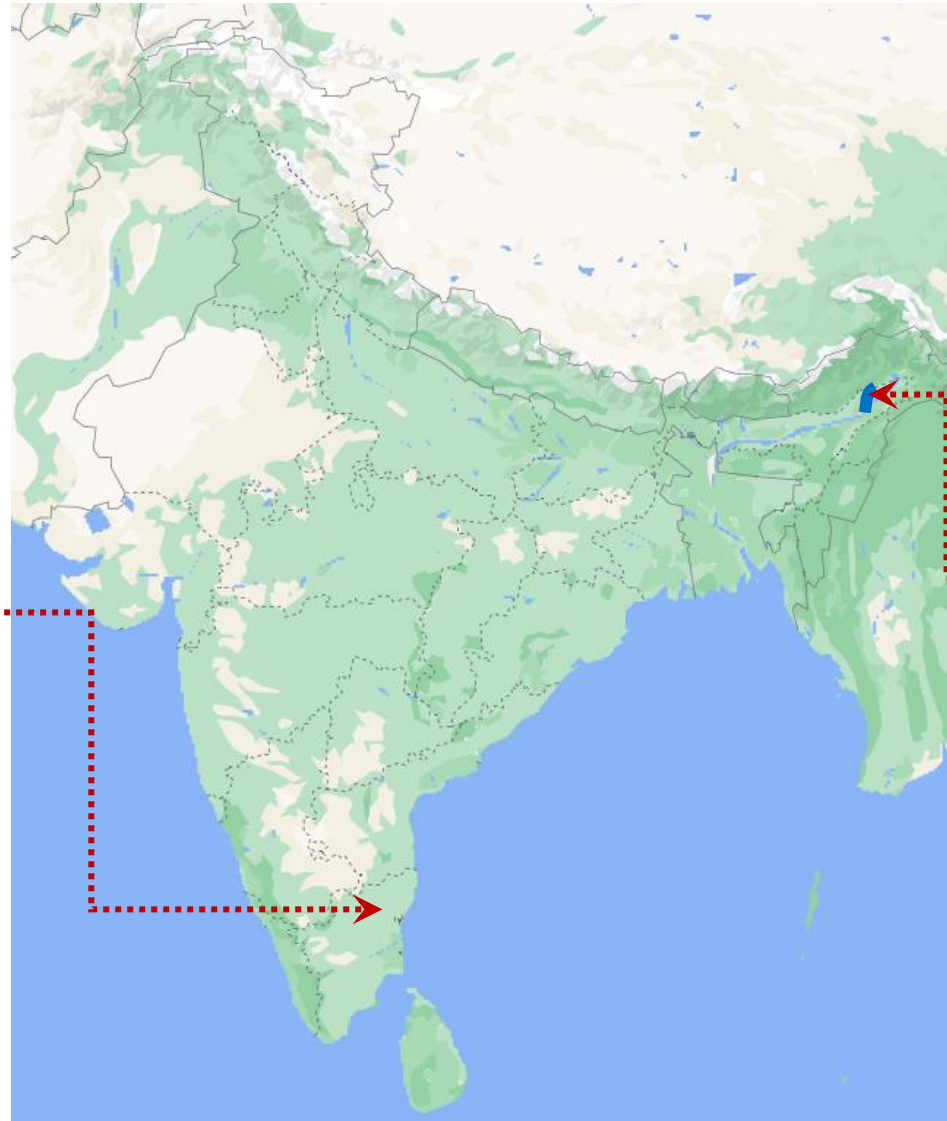
Chennai – Gwailor – Chennai

Distance: 3880 km (round trip in 4 days=970 km/day)
 Trucks: 29 T
 Loading: 80% (13.5 T) onward / 0% return
 Energy Consumption: 1.328 kWh/km
 Min. battery capacity (1/2-day): 750 kWh
 Payload capacity of e-Truck: 14.5 T @ 248 kWh
 9.6 T @ 1,500 kWh
 Payload capacity of ICE Truck: 17 T
 80% of payload capacity of ICE: 13.5 T (< 14.5 T)

Requires en-route charging



Illustrative Application 3: On-Road Tipper



Timiri – Polur – Timiri ●

Distance: 110 km (round trip)
Trucks: 11 T
Loading: 100% (5 T) onward & 0% return
Energy Consumption: 1.035 kWh/km round trip & 1.244 kWh/km laden
Min. battery capacity (1-way): 88 kWh laden
Min. battery capacity (round trip): 134 kWh
Battery capacity of e-Truck: 124 kWh

● Athabari – Gurmur – Athabari

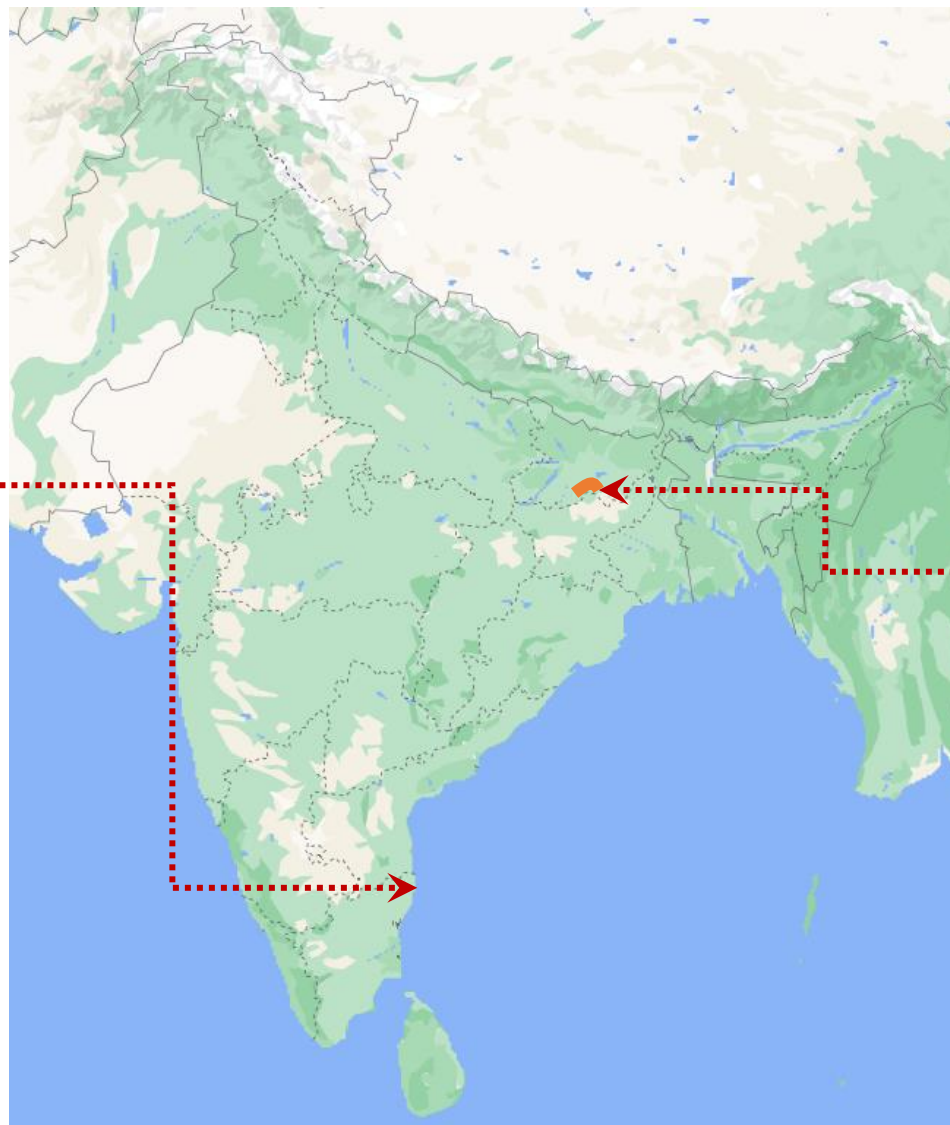
Distance: 230 km (round trip)
Trucks: 29 T
Loading: 100% (14.5 T) onward & 0% return
Energy Consumption: 1.315 kWh/km round trip & 2.01 kWh/km laden
Min. battery capacity (1-way): 307 kWh laden
Min. battery capacity (round trip): 322 kWh
Battery capacity of e-Truck: 248 kWh

Requires charging at source & destination and an e-PTO

Requires en-route charging and an e-PTO



Illustrative Application 4: Tankers



Water: Navalur – Thoraipakkam – Navalur ●

Distance: 70 km (round trip)
Trucks: 19 T
Loading: 7,000 L (7 T) onward / empty return
9,000 L (9 T) onward / empty return
Energy Consumption: 7,000 L – 0.86 kWh
9,000 L – 0.9 kWh/km
Min. battery capacity (round trip): 71 kWh
(7,000 L) / 75 kWh (9,000 L)
Battery capacity of e-Truck: 186 kWh

2 Round trip in 1 charge,
even with overloading

Milk: Begusarai – Biharsarif – Begusarai ●

Distance: 220 km (round trip)
Trucks: 19 T
Loading: 7,000 L (7.2 T) onward / empty return
Energy Consumption: 0.74 kWh/km
Min. battery capacity (1-way): 96 kWh
Min. battery capacity (round trip): 192 kWh
Battery capacity of e-Truck: 186 kWh

Requires charging at
source & destination



Application-Segment Matrix: Annual CO₂



	LDT	IDT	MDT 1	MDT 2	MDT 2	HDT 1	HDT 1	HDT 2	HDT 2	Total Application
	3.5 < GVW ≤ 7.5 T Rigid	7.5 < GVW ≤ 12 T Rigid	12 < GVW ≤ 19 T Rigid	19 < GVW ≤ 28.5 T Rigid	19 < GVW ≤ 31 T Tractor - Trailer	28.5 < GVW ≤ 40 T Rigid	31 < GTW ≤ 40 T Tractor - Trailer	>40 T GVW Rigid	>40 T GVW Tractor - Trailer	
Representative Vehicle -->	7.5 T	11 T	19 T	29 T		40 T		55 T		
Parcel Load	0.14%	1.94%	2.18%	3.78%	4.92%	2.65%				15.61%
LPG Cylinder		0.12%	0.51%	0.33%		0.31%				1.27%
On-Road Tipper						1.60%		1.74%		3.35%
LPG Bulker				0.07%	0.20%	0.12%	0.92%	0.36%	1.29%	2.96%
Cement Bulker						0.23%	0.76%	0.71%	2.09%	3.78%
Cement Bags		0.10%	0.13%	0.16%	0.30%	0.46%	0.57%	0.54%	0.44%	2.70%
Milk Tanker			0.46%	0.38%		0.50%				1.34%
Edible Oil			0.98%	0.55%		0.71%				2.24%
Petroleum Tanker			0.39%	0.52%	0.66%	1.33%		0.73%		3.64%
Water Tanker		0.52%	0.51%	0.72%		0.40%				2.15%
Vegetables & Fruits	0.65%	4.34%	2.74%	0.86%		1.00%				9.58%
Fish		1.27%	0.94%							2.21%
Steel			0.01%	0.08%	0.15%	0.25%	1.34%	0.88%	1.48%	4.19%
Metals & Finished Products		0.35%	0.21%	0.34%	0.63%	0.48%	1.55%	0.69%	2.98%	7.24%
Coal and Minerals			0.15%	0.47%		0.25%	0.68%	1.20%	0.40%	3.15%
Market Load	4.92%	3.16%	4.53%	5.62%	8.14%	6.56%		1.63%		34.56%



Application-Segment Matrix: Overload De-prioritization

Overload Deprioritization	LDT	IDT	MDT 1	MDT 2	MDT 2	HDT 1	HDT 1	HDT 2	HDT 2	Total Application
	3.5 < GVW ≤ 7.5 T Rigid	7.5 < GVW ≤ 12 T Rigid	12 < GVW ≤ 19 T Rigid	19 < GVW ≤ 28.5 T Rigid	19 < GVW ≤ 31 T Tractor - Trailer	28.5 < GVW ≤ 40 T Rigid	31 < GTW ≤ 40 T Tractor - Trailer	>40 T GVW Rigid	>40 T GVW Tractor - Trailer	
Representative Vehicle -->	7.5 T	11 T	19 T		29 T		40 T		55 T	
Parcel Load	0.14%	1.94%	2.18%	3.78%	4.92%	2.65%				15.61%
LPG Cylinder		0.12%	0.51%	0.33%		0.31%				1.27%
On-Road Tipper						1.60%		1.74%		3.35%
LPG Bulker				0.07%	0.20%	0.12%	0.92%	0.36%	1.29%	2.96%
Cement Bulker						0.23%	0.76%	0.71%	2.09%	3.78%
Cement Bags		0.10%	0.13%	0.16%	0.30%	0.46%	0.57%	0.54%	0.44%	2.70%
Milk Tanker			0.46%	0.38%		0.50%				1.34%
Edible Oil			0.98%	0.55%		0.71%				2.24%
Petroleum Tanker			0.39%	0.52%	0.66%	1.33%		0.73%		3.64%
Water Tanker		0.52%	0.51%	0.72%		0.40%				2.15%
Vegetables & Fruits	0.65%	4.34%	2.74%	0.86%		1.00%				9.58%
Fish		1.27%	0.94%							2.21%
Steel			0.01%	0.08%	0.15%	0.25%	1.34%	0.88%	1.48%	4.19%
Metals & Finished Products		0.35%	0.21%	0.34%	0.63%	0.48%	1.55%	0.69%	2.98%	7.24%
Coal and Minerals			0.15%	0.47%		0.25%	0.68%	1.20%	0.40%	3.15%
Market Load	4.92%	3.16%	4.53%	5.62%	8.14%	6.56%		1.63%		34.56%

De-prioritized due to overloading propensity	17.9%
Level-1 Prioritization	82.1%

Overload applications (~ 17.9% to annual CO₂) if strictly policed for overloading, can cause migration to different segments

Can be electrified in 5-7 years with second-use e-Trucks, higher energy density batteries and other technologies like H₂ fuel cells, etc.



Application-Segment Matrix: Duty-cycle Availability

Duty-Cycle Availability	LDT	IDT	MDT 1	MDT 2	MDT 2	HDT 1	HDT 1	HDT 2	HDT 2	Total Application
	[3.5 < GVW ≤ 7.5 T] Rigid	[7.5 < GVW ≤ 12 T] Rigid	[12 < GVW ≤ 19 T] Rigid	[19 < GVW ≤ 28.5 T] Rigid	[19 < GVW ≤ 31 T] Tractor - Trailer	[28.5 < GVW ≤ 40 T] Rigid	[31 < GTW ≤ 40 T] Tractor - Trailer	[>40 T GVW] Rigid	[>40 T GVW] Tractor - Trailer	
Representative Vehicle -->	7.5 T	11 T	19 T	29 T		40 T		55 T		
Parcel Load	0.14%	1.94%	2.18%	3.78%	4.92%	2.65%				15.61%
LPG Cylinder		0.12%	0.51%	0.33%		0.31%				1.27%
On-Road Tipper						1.60%		1.74%		3.35%
LPG Bulker				0.07%	0.20%	0.12%	0.92%	0.36%	1.29%	2.96%
Cement Bulker						0.23%	0.76%	0.71%	2.09%	3.78%
Cement Bags		0.10%	0.13%	0.16%	0.30%	0.46%	0.57%	0.54%	0.44%	2.70%
Milk Tanker			0.46%	0.38%		0.50%				1.34%
Edible Oil			0.98%	0.55%		0.71%				2.24%
Petroleum Tanker			0.39%	0.52%	0.66%	1.33%		0.73%		3.64%
Water Tanker		0.52%	0.51%	0.72%		0.40%				2.15%
Vegetables & Fruits	0.65%	4.34%	2.74%	0.86%		1.00%				9.58%
Fish		1.27%	0.94%							2.21%
Steel			0.01%	0.08%	0.15%	0.25%	1.34%	0.88%	1.48%	4.19%
Metals & Finished Products		0.35%	0.21%	0.34%	0.63%	0.48%	1.55%	0.69%	2.98%	7.24%
Coal and Minerals			0.15%	0.47%		0.25%	0.68%	1.20%	0.40%	3.15%
Market Load	4.92%	3.16%	4.53%	5.62%	8.14%	6.56%		1.63%		34.56%

De-prioritized due to Duty-Cycle unavailability	7.0%
Remaining applications	75.1%

Applications not studied (~ 7% to annual CO₂) don't have any special requirements and can be carried over to next step



Application-Segment Matrix: Range / Charge



Feasibility of available e-Trucks (including eBus) with spec battery capacity	LDT	IDT	MDT 1	MDT 2	MDT 2	HDT 1	HDT 1	HDT 2	HDT 2	Total Application
	[3.5 < GVW ≤ 7.5 T] Rigid	[7.5 < GVW ≤ 12 T] Rigid	[12 < GVW ≤ 19 T] Rigid	[19 < GVW ≤ 28.5 T] Rigid	[19 < GVW ≤ 31 T] Tractor - Trailer	[28.5 < GVW ≤ 40 T] Rigid	[31 < GTW ≤ 40 T] Tractor - Trailer	[>40 T GVW] Rigid	[>40 T GVW] Tractor - Trailer	
Representative Vehicle -->	7.5 T	11 T	19 T	29 T		40 T		55 T		
Parcel Load	0.14%	1.94%	2.18%	3.78%	4.92%	2.65%				15.61%
LPG Cylinder		0.12%	0.51%	0.33%		0.31%				1.27%
On-Road Tipper						1.60%		1.74%		3.35%
LPG Bulker				0.07%	0.20%	0.12%	0.92%	0.36%	1.29%	2.96%
Cement Bulker						0.23%	0.76%	0.71%	2.09%	3.78%
Cement Bags		0.10%	0.13%	0.16%	0.30%	0.46%	0.57%	0.54%	0.44%	2.70%
Milk Tanker			0.46%	0.38%		0.50%				1.34%
Edible Oil			0.98%	0.55%		0.71%				2.24%
Petroleum Tanker			0.39%	0.52%	0.66%	1.33%		0.73%		3.64%
Water Tanker		0.52%	0.51%	0.72%		0.40%				2.15%
Vegetables & Fruits	0.65%	4.34%	2.74%	0.86%		1.00%				9.58%
Fish		1.27%	0.94%							2.21%
Steel			0.01%	0.08%	0.15%	0.25%	1.34%	0.88%	1.48%	4.19%
Metals & Finished Products		0.35%	0.21%	0.34%	0.63%	0.48%	1.55%	0.69%	2.98%	7.24%
Coal and Minerals			0.15%	0.47%		0.25%	0.68%	1.20%	0.40%	3.15%
Market Load	4.92%	3.16%	4.53%	5.62%	8.14%	6.56%		1.63%		34.56%

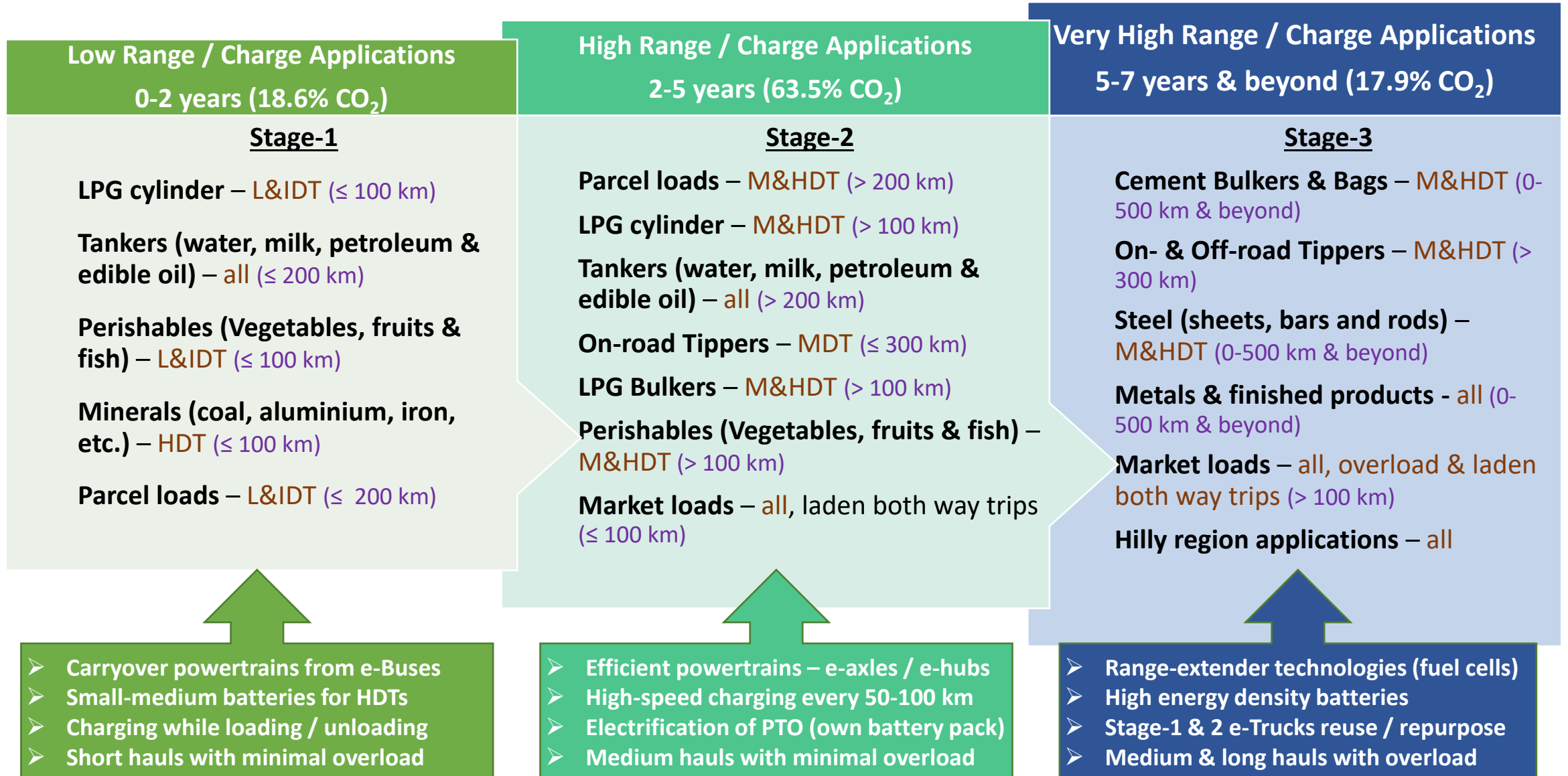
De-prioritized due to high battery capacity requirement	56.5%
Level-2 Prioritization	18.6%

High-energy applications (~56.5% to annual CO₂) can be electrified in 2-5 years, with e-PTOs & charging opportunity every 50-100 km

Level-2 prioritized applications (~18.6% to annual CO₂) can be electrified in 1-2 years, borrowing powertrains from e-Buses, etc.



Application-Segment: Electrification Summary



Total Cost of Ownership Analysis



TCO Common Assumptions



	Unit	ICE	CNG LDT & IDT only	e-Truck
Truck				
Vehicle Life	[Years]	10	10	10
Working days per year	#	300 - 330	300 - 330	300 - 330
Fuel (or Electricity) tariff	[INR]	95 per liter	45 per kg	6
Battery				
Weight	[kgs/kWh]			13.5
Cost	[INR/kWh]			16,500
Subsidy	[INR/kWh]	-	-	10,000 (Maximum 200k)
Life cycle				1,000
Battery DOD at start and end of life	%			85% and 80%
Range of Battery in Useful Lifecycles (start, end)	#			
Charging (Fueling) Infrastructure				
Charger Type	-	-	-	Fast DC
Charger size	[kW]			60 & 120
Charger cost	[INR/kW]			10,000
Charger Efficiency	%			90
Charger Utilization	%			40%
Charger Grid Infra cost	[INR/kW-peak]			4,000
Charger Installation & Commission	%			15
Switchyard/ Transformer Loss	%			3
Manpower and Maintenance Cost				
Man-power cost	[INR/month]		25,000	26,000
Annual Maintenance cost	[INR/km]		3 - 4.5	6 - 8.5
Annual Insurance cost	[%/year]		2% of vehicle purchase cost	



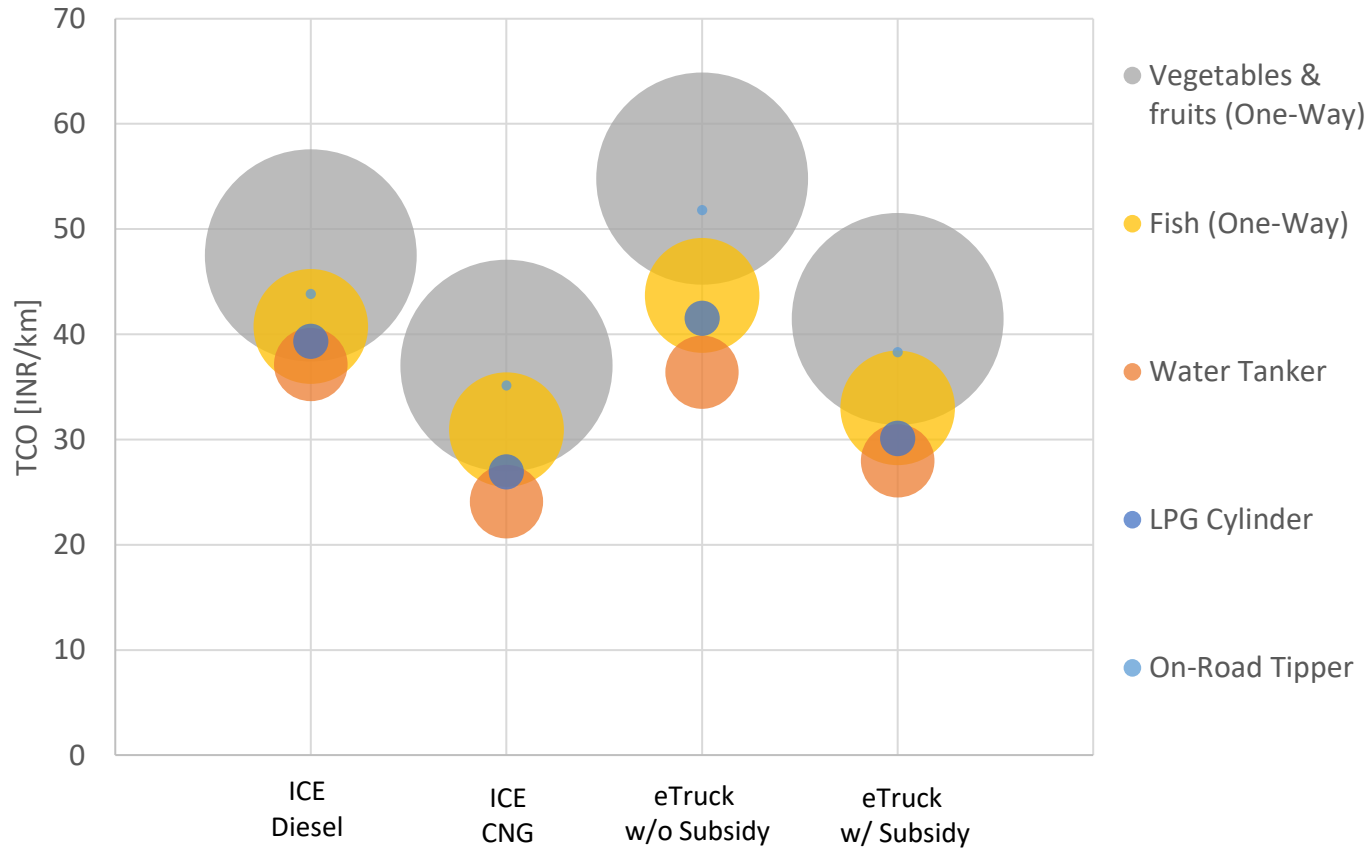
Inputs for TCO Analysis



Parameter	LDT 3.5 < GVW ≤ 7.5 T Rigid	IDT 7.5 < GVW ≤ 12 T Rigid	MDT 1 12 < GVW ≤ 19 T Rigid	MDT 2 19 < GVW ≤ 28.5 T Rigid	MDT 2 19 < GVW ≤ 31 T Tractor - Trailer	HDT 1 28.5 < GVW ≤ 40 T Rigid	HDT 1 31 < GTW ≤ 40 T Tractor - Trailer	HDT 2 >40 T GVW Rigid	HDT 2 >40 T GVW Tractor - Trailer
Battery Capacity [kWh]	62.5	124	186	211		225		256	
Motor Max. Power [kW]	220	245	245	330		360		360	
Charger Size [kW]	60	60	60	120		120		120	
Charging Time [hrs]	1.5	2.5	3.5	2		2		2.5	



TCO Comparison for 11 Ton GVW



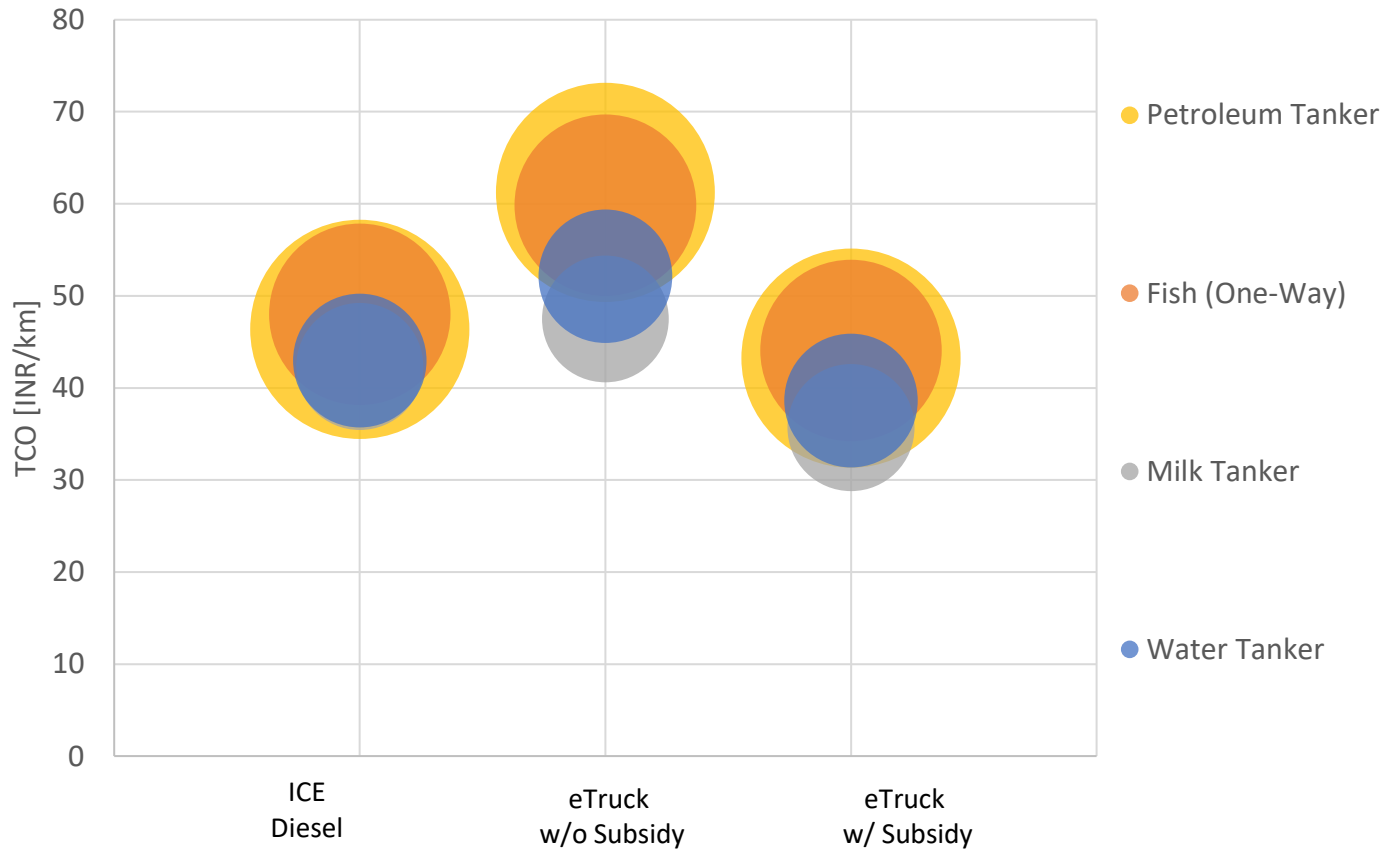
Assumption	
ICE-Truck Cost [INR]	1,900,000
e-Truck Cost w/o Subsidy [INR]	4,196,000
e-Truck Cost with Subsidy [INR]	2,956,000
Battery Size [kWh]	124
Charger Size [kW]	60
Distance per year [km]	30,000 – 65,000
Maintenance Cost ICE [INR/km]	2.5
Maintenance Cost EV [INR/km]	6.0

[Refer Annexure slide for detailed TCO](#)

**Currently e-Truck w/o subsidy has higher TCO than ICE-Diesel and ICE-CNG
 Subsidy similar to e-Bus is expected to make e-Truck TCO lower than ICE-Diesel, but still higher than ICE-CNG**



TCO Comparison for 19 Ton GVW



Size of Bubble represents relative CO2 share

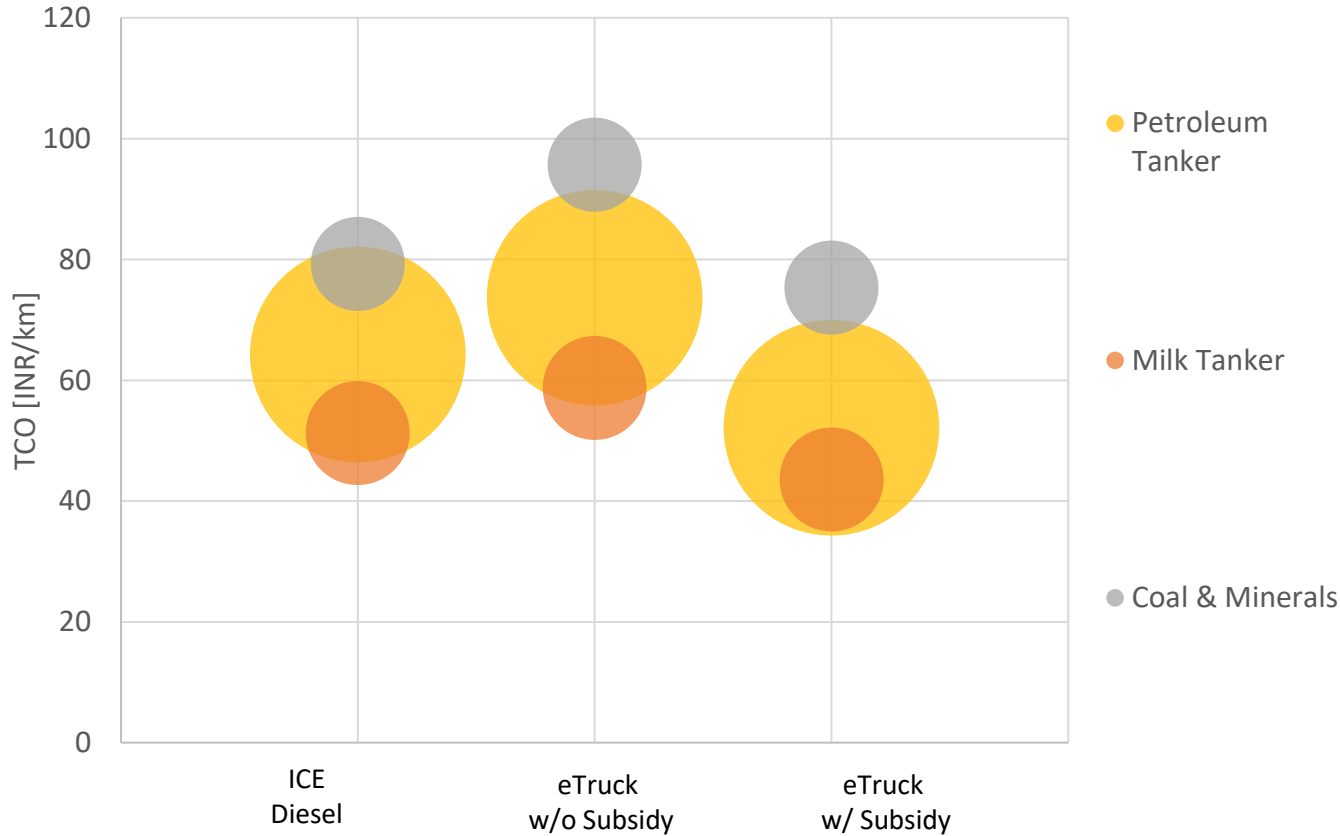
Assumption	
ICE-Truck Cost [INR]	2,500,000
e-Truck Cost w/o Subsidy [INR]	5,969,000
e-Truck Cost with Subsidy [INR]	4,109,000
Battery Size [kWh]	186
Charger Size [kW]	120
Distance per year [km]	50,000 – 60,000
Maintenance Cost ICE [INR/km]	3.0
Maintenance Cost EV [INR/km]	8.0

[Refer Annexure slide for detailed TCO](#)

Currently e-Truck w/o subsidy has higher TCO than ICE-Diesel
Subsidy similar to e-Bus is expected to make e-Truck TCO lower than ICE-Diesel



TCO Comparison for 29 Ton GVW



Size of Bubble represents relative CO2 share

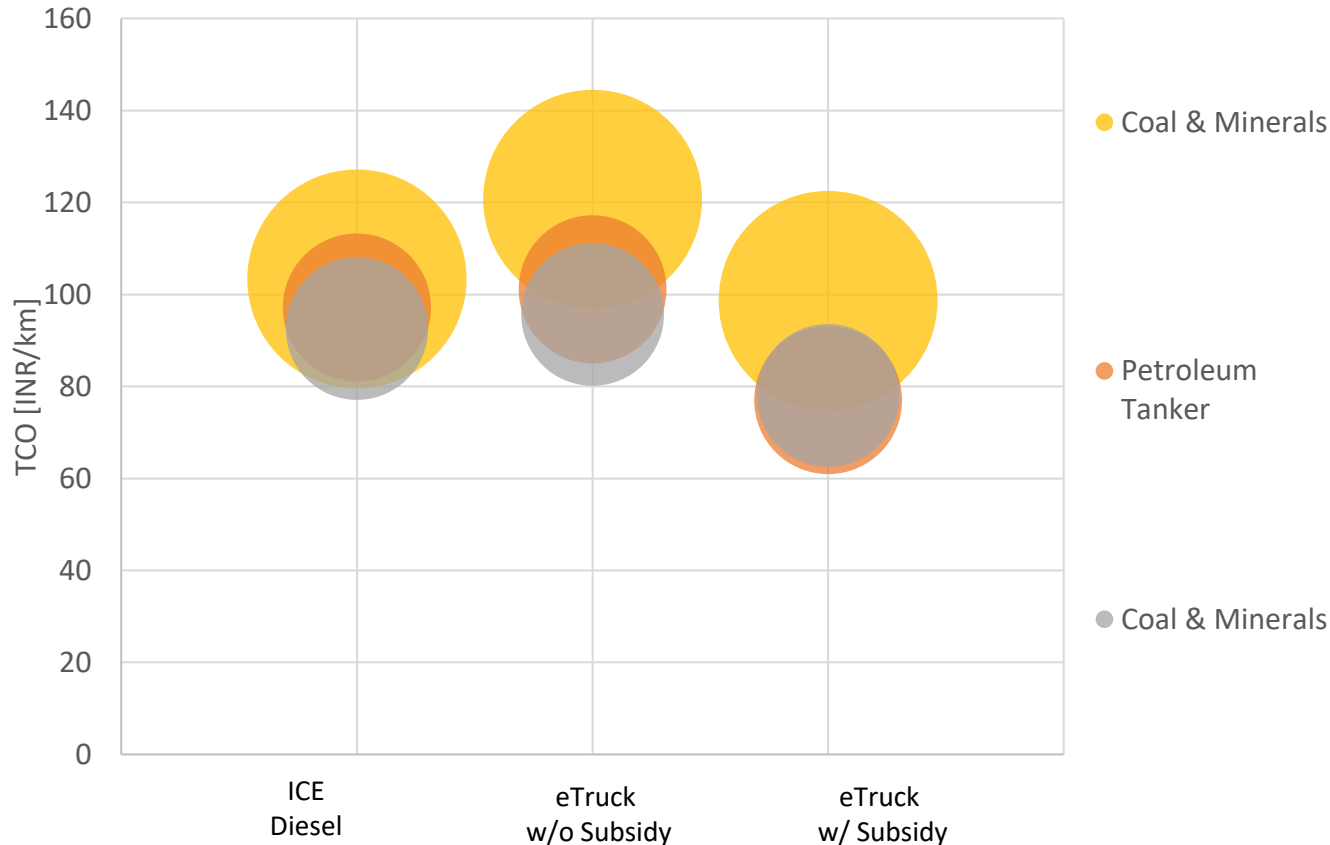
Assumption	
ICE-Truck Cost [INR]	3,200,000
e-Truck Cost w/o Subsidy [INR]	7,131,500
e-Truck Cost with Subsidy [INR]	5,131,500
Battery Size [kWh]	211
Charger Size [kW]	120
Distance per year [km]	30,000 – 60,000
Maintenance Cost ICE [INR/km]	3.5
Maintenance Cost EV [INR/km]	8.0

[Refer Annexure slide for detailed TCO](#)

**Currently e-Truck w/o subsidy has higher TCO than ICE-Diesel
Subsidy similar to e-Bus is expected to make e-Truck TCO lower than ICE-Diesel**



TCO Comparison for 40 & 55 Ton GVW



Size of Bubble represents relative CO2 share

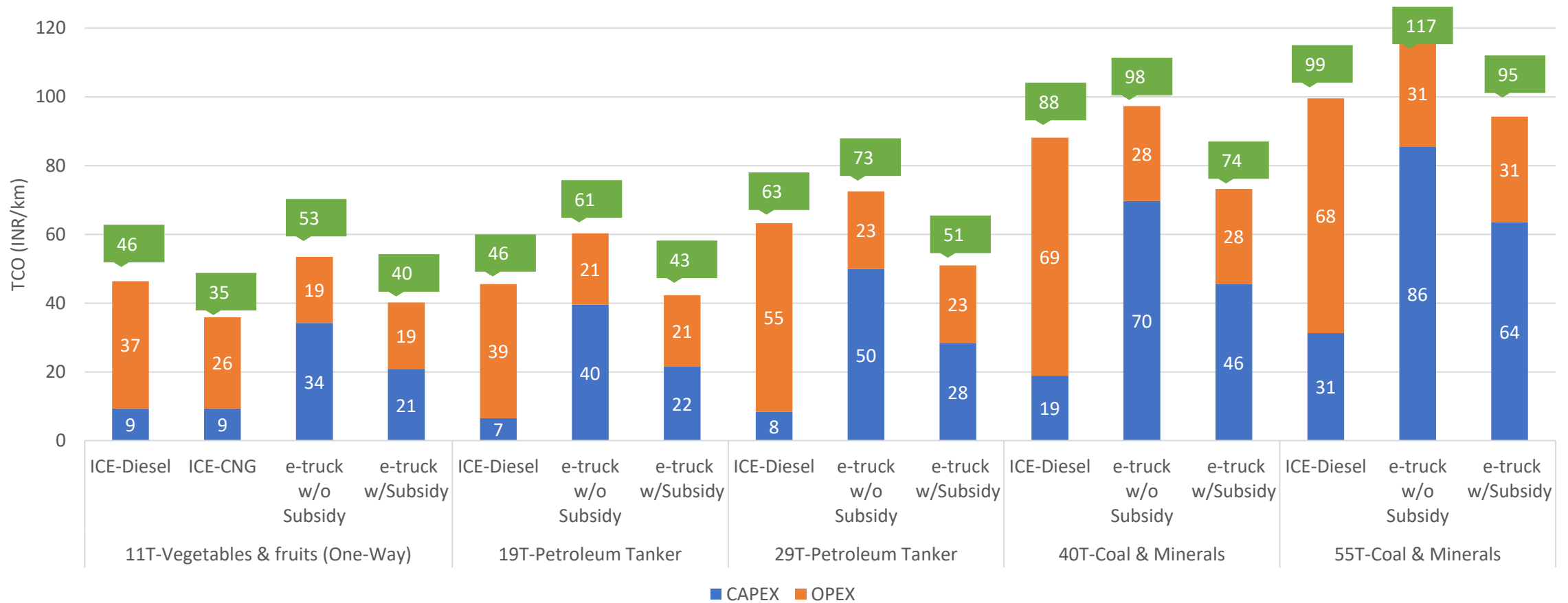
Assumption	
ICE-Truck Cost [INR]	3,600,000 – 40 T 4,200,000 – 55 T
e-Truck Cost w/o Subsidy [INR]	7,862,500 – 40 T 9,074,000 – 55 T
e-Truck Cost with Subsidy [INR]	5,862,500 – 40 T 7,074,000 – 55 T
Battery Size [kWh]	225 – 40 T 256 – 55 T
Charger Size [kW]	120
Distance per year [km]	20,000 – 30,000
Maintenance Cost ICE [INR/km]	4.0 – 40 T 4.5 – 55 T
Maintenance Cost EV [INR/km]	8.0 – 40 T 8.3 – 55 T

[Refer Annexure slide for detailed TCO](#)

**Currently e-Truck w/o subsidy has nearly same TCO as ICE-Diesel
Subsidy might not be required!**



TCO Analysis for select applications of prioritized segments (18%)



- All applications of 40 T & 55 T already seen to have TCO parity with ICE-Diesel
- Other truck segments (11T, 19 T & 29 T) require subsidy to match ICE-Diesel TCO
- To compete with ICE-CNG, even subsidy doesn't seem sufficient



Level-1 Beachhead Model (as shared in D2b)



Wave 1



E- 3 wheelers



E-Bus Intra City MCV

2021

Wave 2



Parcel load Rigid ZE-IDT & MDT 1



LPG Cylinders- Rigid ZE-IDT



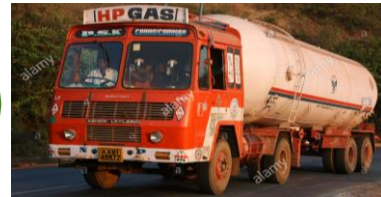
Garbage - Rigid ZE-MDT 1

2022

Wave 3



Parcel load Rigid ZE-MHDT 1



LPG Tankers - Rigid ZE_MDT



Milk Tankers - Rigid ZE-MDT

2024

Wave 4



Oil (Petroleum) Tankers - Rigid ZE-MDT



Steel Rigid ZE-HDT 1



Market load Rigid ZE-MDT

2026

Wave 5



Water tanker Rigid ZE-MDT



Coal & Mineral Rigid ZE-MHDT



Finished Products Rigid ZE-HDT

2028

2030



Level-2 Beachhead Model



Wave 1



E- 3 wheelers



E-Bus Intra City MCV

2021

Wave 2



Parcel loads – L&IDT (≤ 200 km)



LPG cylinder – L&IDT (≤ 100 km)



Tankers (water, milk, petroleum & edible oil) – all (≤ 200 km)



Minerals (coal, aluminium, iron, etc.) – HDT (≤ 100 km)

2023

Wave 3



Perishables (Vegetables, fruits & fish) – L&IDT (≤ 100 km)



On-road Tipper – MDT (≤ 300 km)



Market loads – all, laden both way trips (≤ 100 km)

Parcel loads – M&HDT (> 200 km)
LPG cylinder – M&HDT (> 100 km)
Tankers – all (> 200 km)
LPG Bulkers – M&HDT (> 100 km)

2026

Wave 4



Cement Bulkers & Bags – M&HDT (0-500 km & beyond)



On- & Off-road Tipper – M&HDT (> 300 km)



Steel (sheets, bars and rods) – M&HDT (0-500 km & beyond)

2028

Wave 5



Metals & finished products - all (0-500 km & beyond)



Metals & finished products - all (0-500 km & beyond)

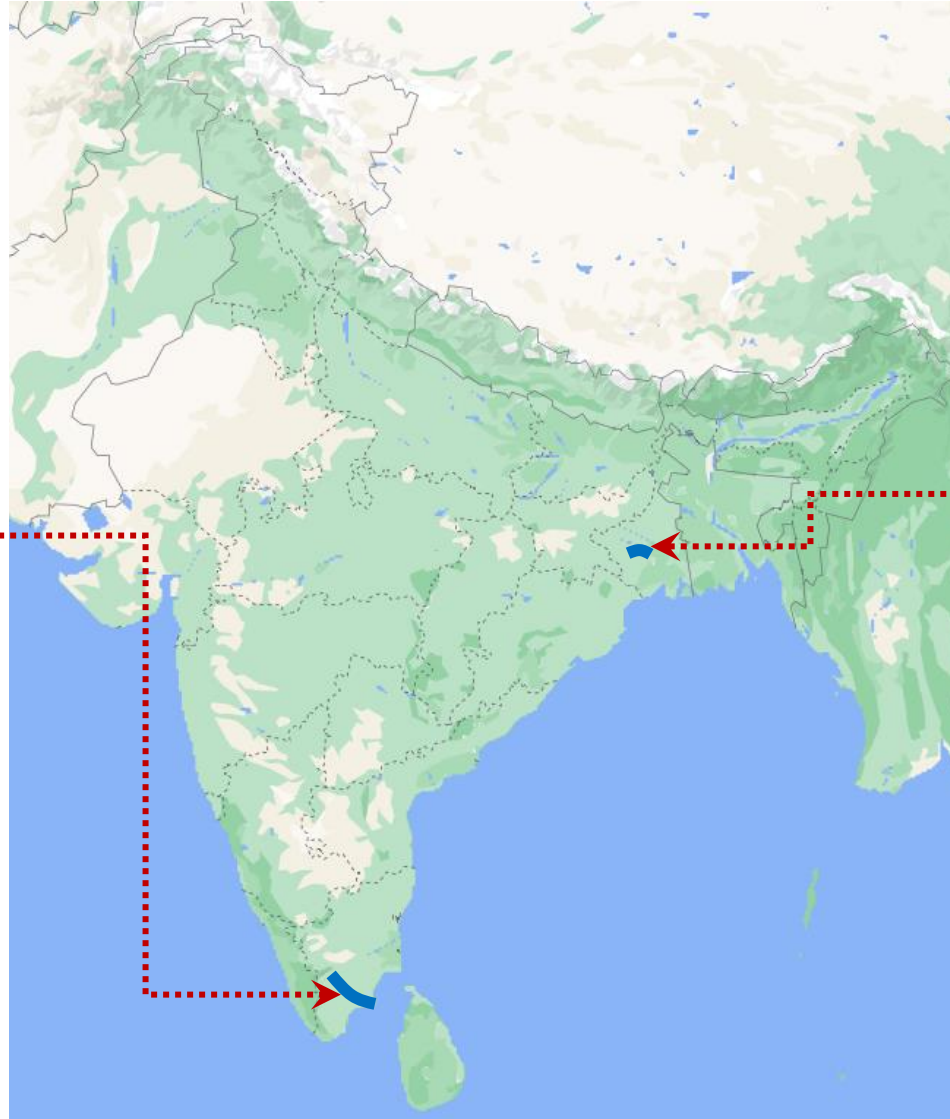
Hilly region applications – all

2030

Annexure



Illustrative Application 5: Perishables



Fish: Rameshwaram – Madurai – Rameshwaram

Distance: 345 km (round trip)
 Trucks: 11 T
 Loading: 100% (5.9 T) onward & 33% (2 T empty trays) return
 Energy Consumption: 0.628 kWh/km round trip & 0.68 kWh/km laden
 Min. battery capacity (1-way): 141 kWh laden
 Min. battery capacity (round trip): 255 kWh
 Battery capacity of e-Truck: 124 kWh

Requires en-route charging

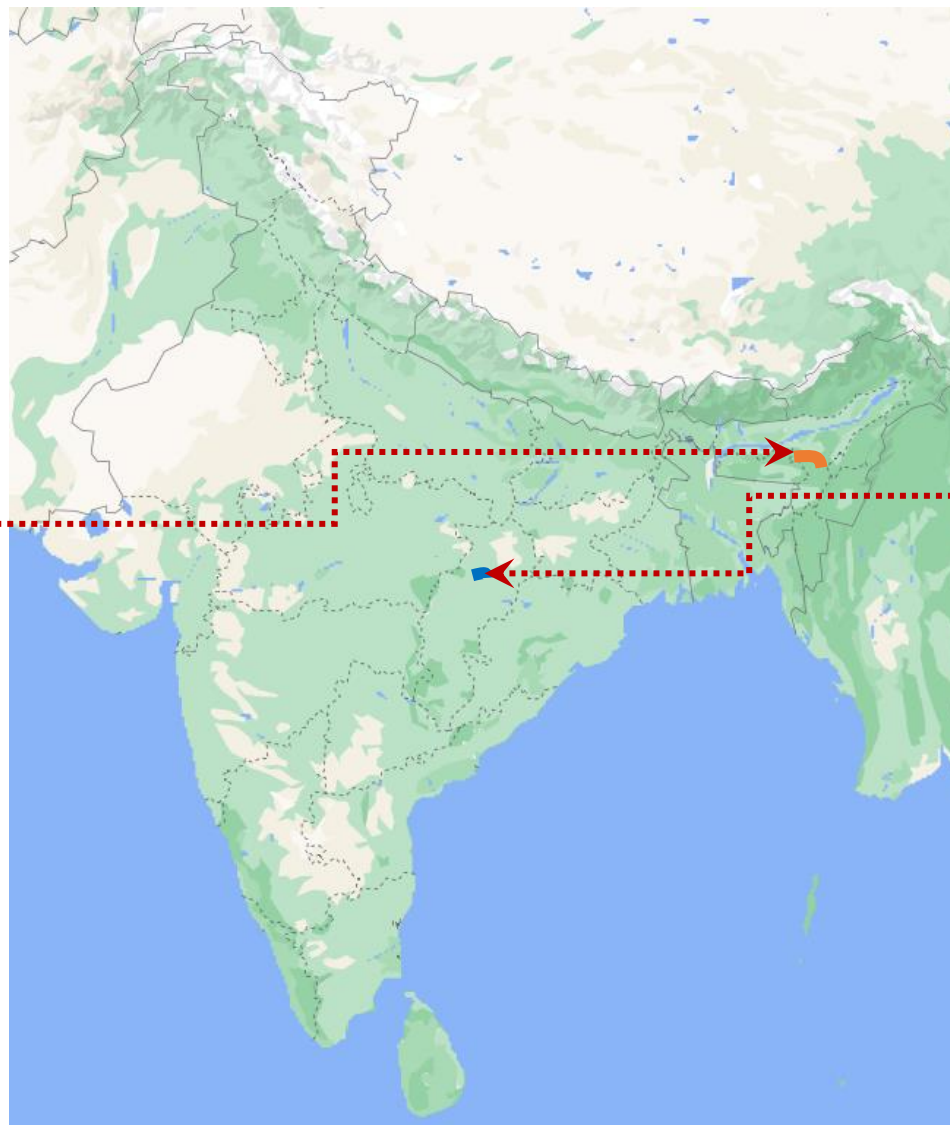
Fruits & Vegetables: Ramjibanpur – Champadanga – Ramjibanpur

Distance: 135 km (round trip)
 Trucks: 11 T
 Loading: 100% (5.9 T) onward & 0% return
 Energy Consumption: 0.828 kWh/km round trip & 0.883 kWh/km laden
 Min. battery capacity (1-way): 64 kWh
 Min. battery capacity (round trip): 132 kWh
 Battery capacity of e-Truck: 124 kWh

Requires charging at source & destination



Illustrative Application 6: Petroleum Tanker & Coal



Petroleum Tanker:
Lumding – Baithlangso – Lumding

Distance: 230 km (round trip)
Trucks: 19 T
Loading: 8,000 L (7 T) onward / empty return
Energy Consumption: 1.2 kWh round trip & 1.48 kWh laden
Min. battery capacity (1-way): 200 kWh
Min. battery capacity (round trip): 324 kWh
Battery capacity of e-Truck: 186 kWh

Requires en-route charging

Coal: Dipka – Korba – Dipka

Distance: 82 km (round trip)
Trucks: 29 T & 55 T
Loading: 29 T - 100% (18 T) onward / empty return
55 T - 100% (41 T) onward / empty return
Energy Consumption: 29 T – 1.18 kWh/km
55 T – 1.59 kWh/km
Min. battery capacity (round trip): 29 T 114 kWh
55 T 154 kWh
Battery capacity of e-Truck: 29 T 248 kWh
55 T 256 kWh

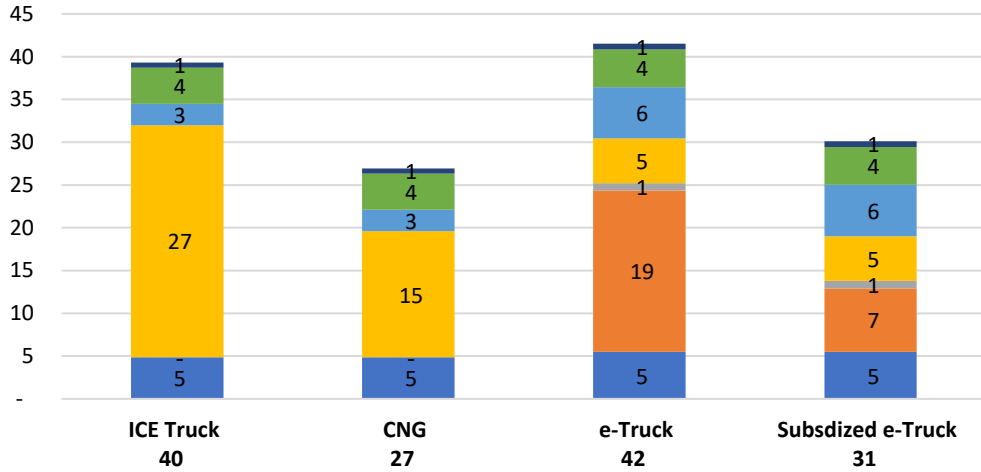
Round trip in 1 charge



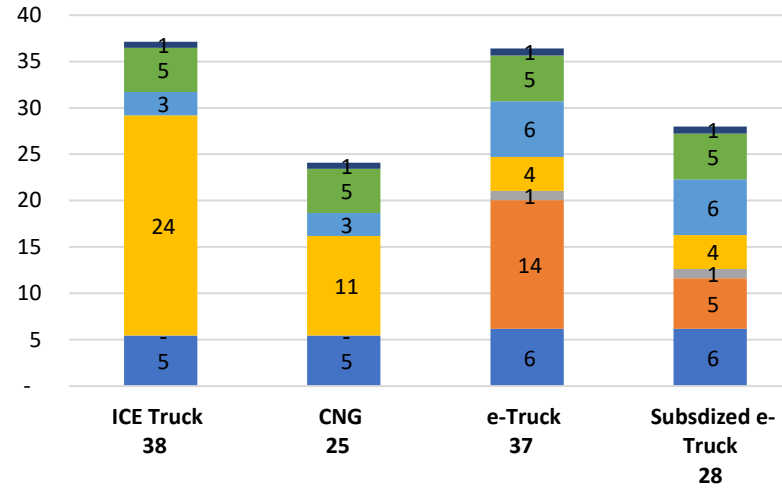
TCO Comparison for 11 Ton GVW



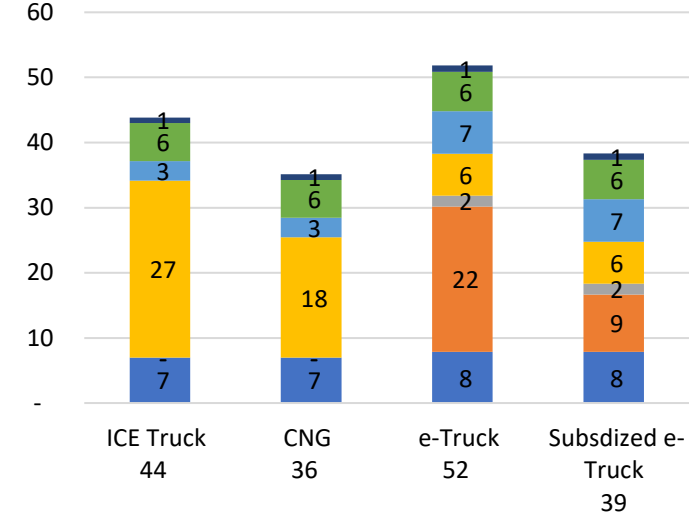
11T-LPG Cylinder



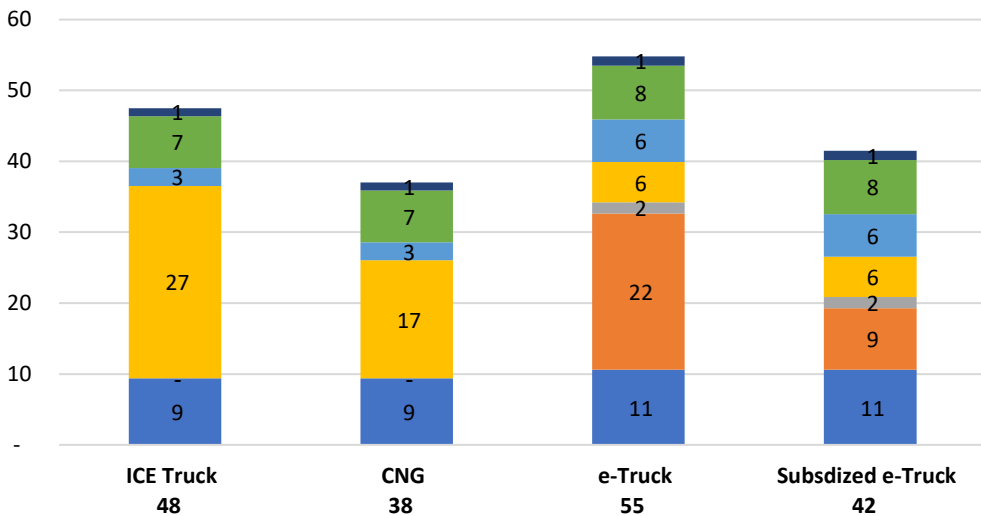
11T-water



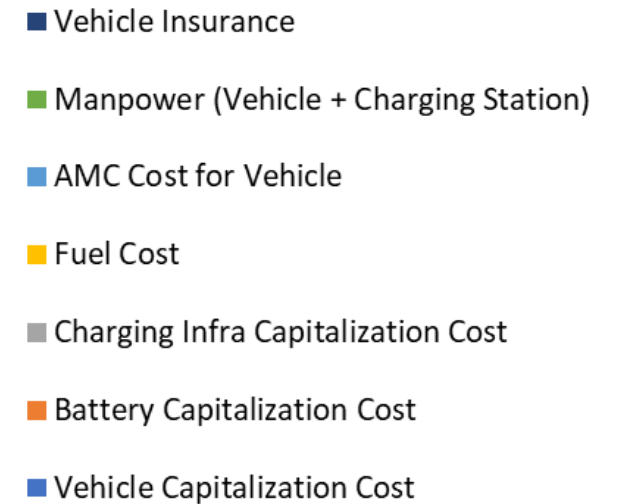
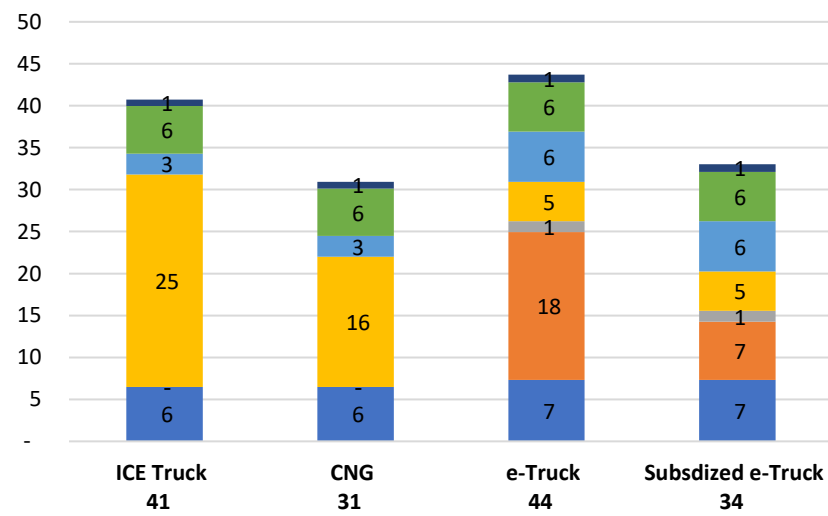
11T on-Road Tipper



11T-Veg & fruits-OW



11T-Fish-OW

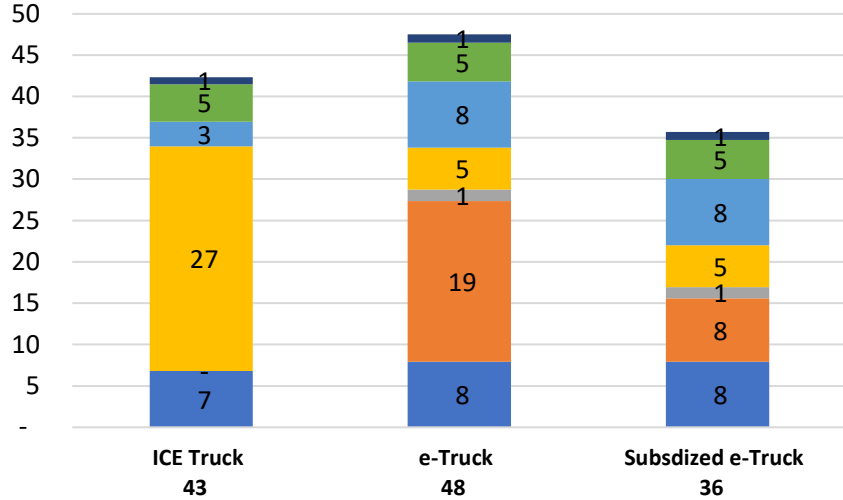




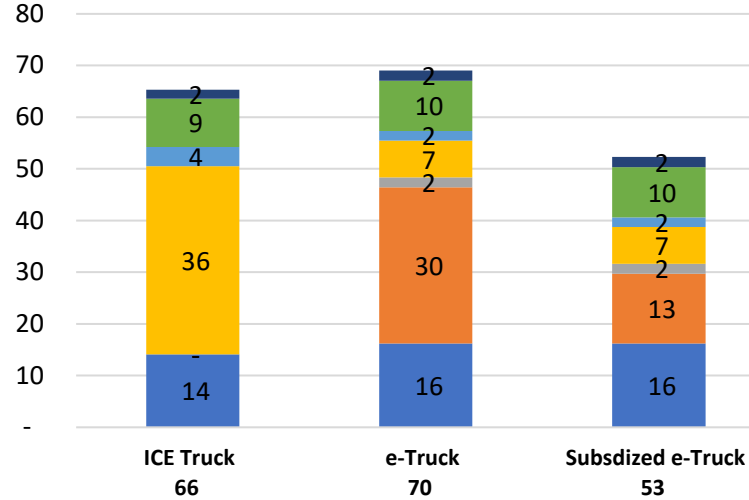
TCO Comparison for 19 Ton GVW



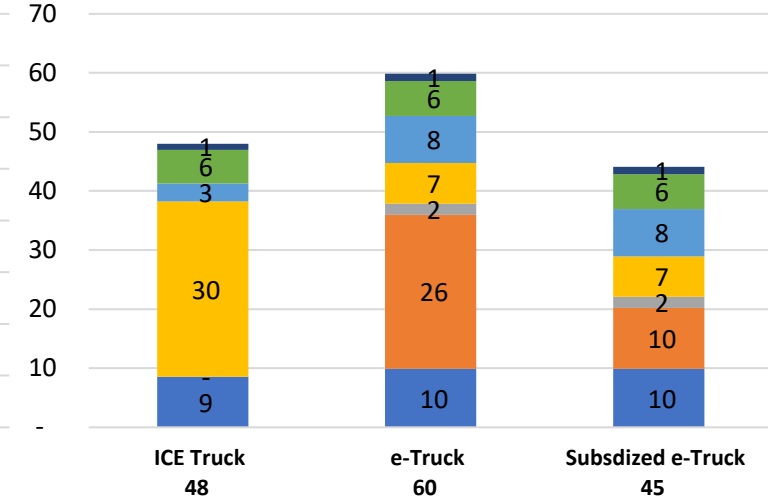
19T-Milk



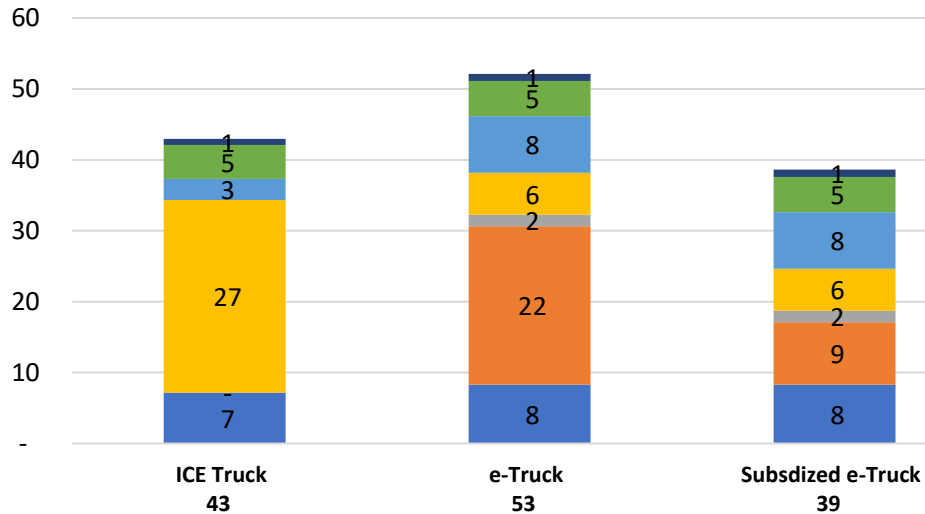
19T-On road Tipper



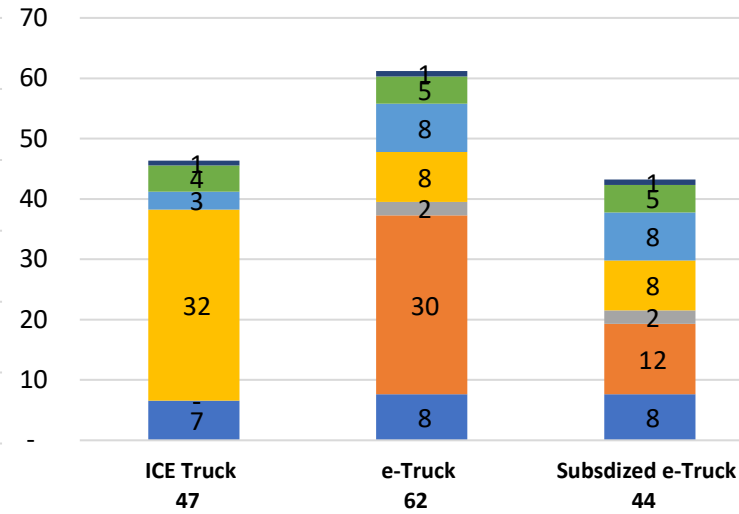
19T-Fish(OW)



19T-Water



19T-Petroleum Tanker



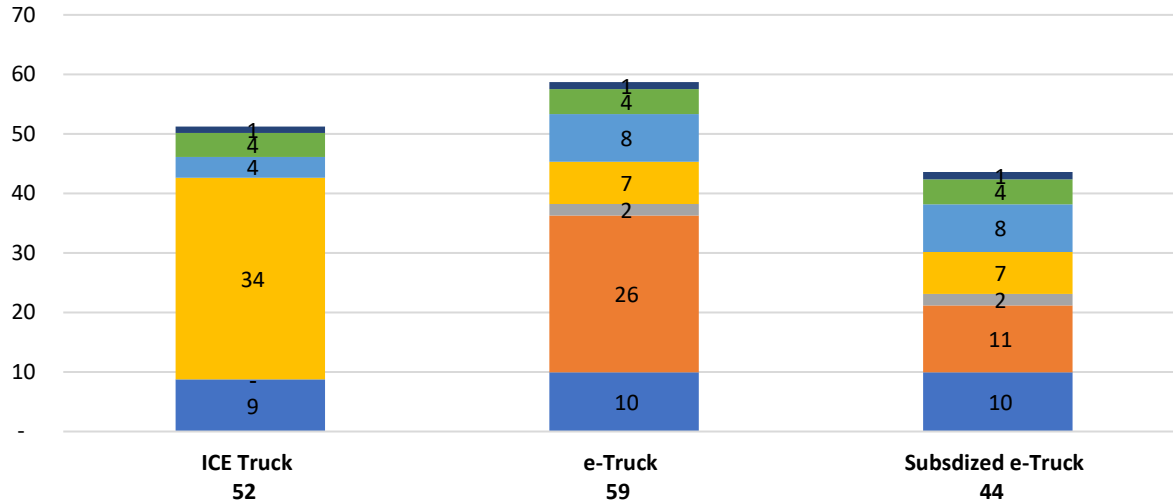
- Vehicle Insurance
- Manpower (Vehicle + Charging Station)
- AMC Cost for Vehicle
- Fuel Cost
- Charging Infra Capitalization Cost
- Battery Capitalization Cost
- Vehicle Capitalization Cost



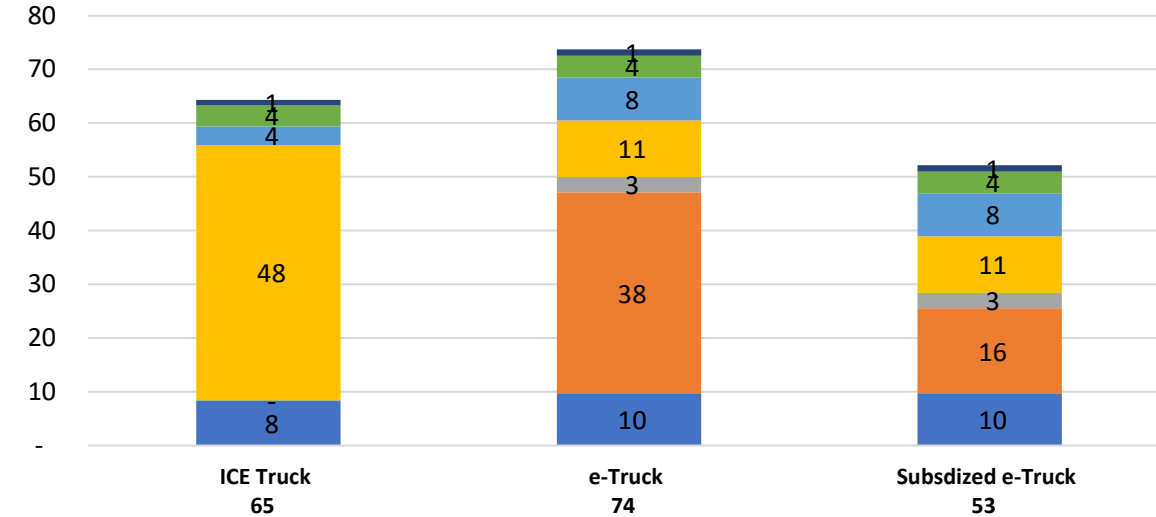
TCO Comparison for 29 Ton GVW



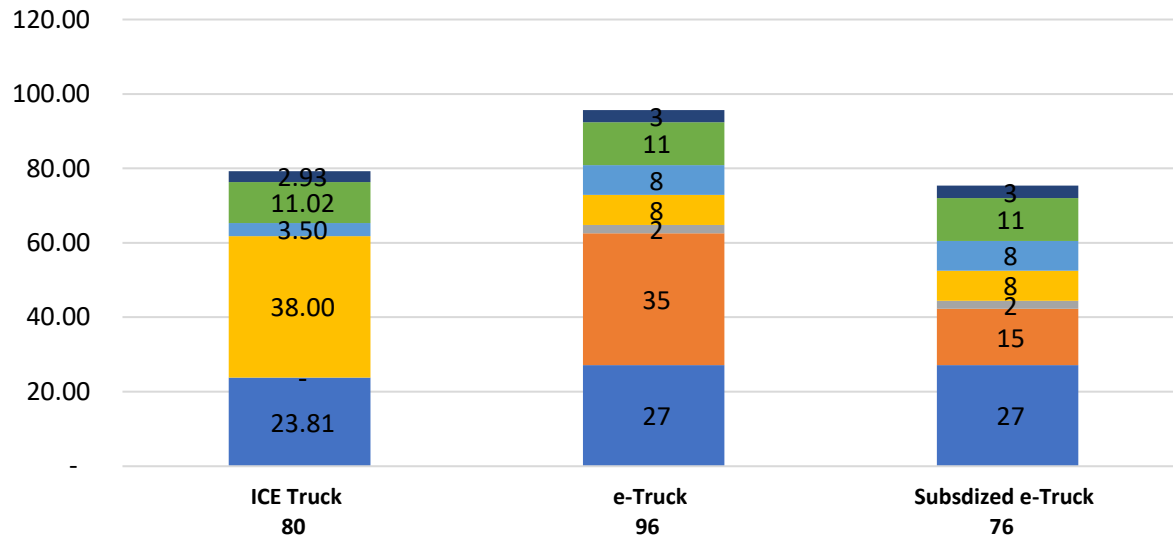
29T-Milk



29T-Petroleum Tanker



29T-Coal



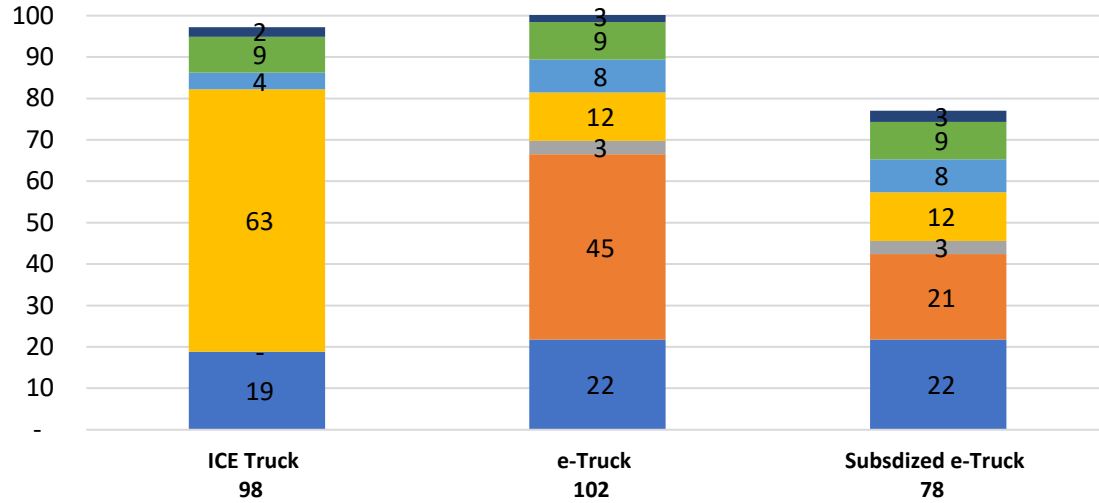
- Vehicle Insurance
- Manpower (Vehicle + Charging Station)
- AMC Cost for Vehicle
- Fuel Cost
- Charging Infra Capitalization Cost
- Battery Capitalization Cost
- Vehicle Capitalization Cost



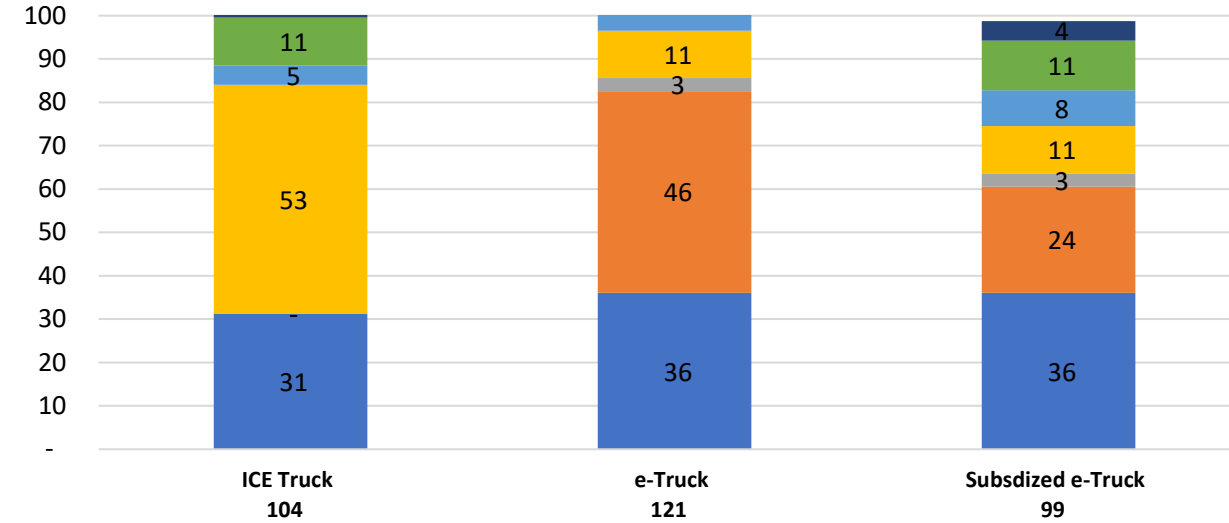
TCO Comparison for 40 & 55 Ton GVW



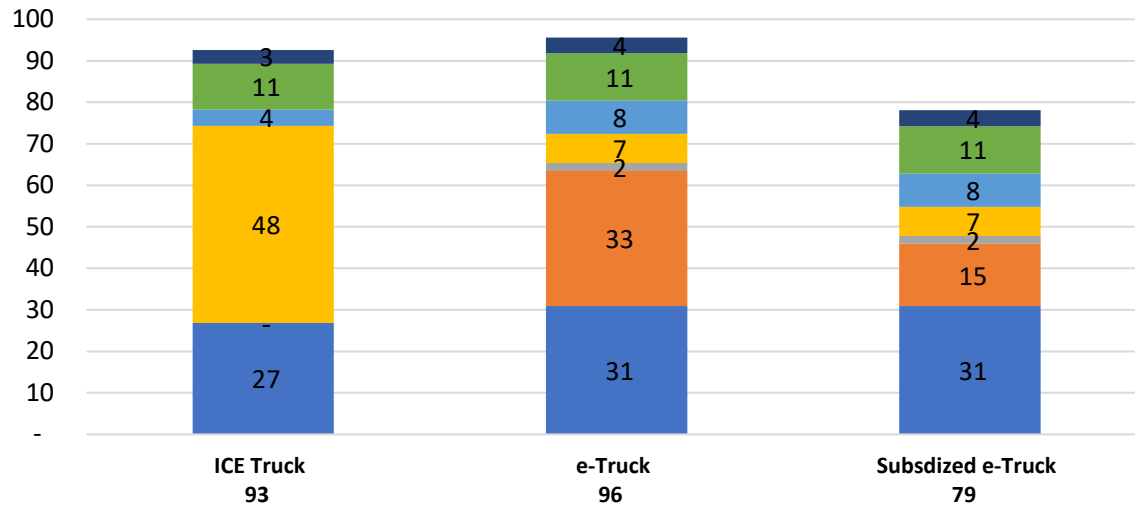
40T- Petroleum Tanker



55 T - Coal

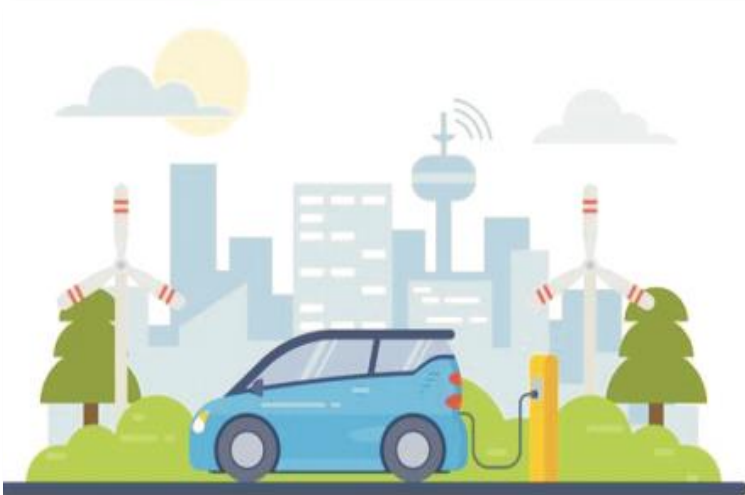


40T - Coal



- Vehicle Insurance
- Manpower (Vehicle + Charging Station)
- AMC Cost for Vehicle
- Fuel Cost
- Charging Infra Capitalization Cost
- Battery Capitalization Cost
- Vehicle Capitalization Cost

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Rahul Bagdia
Managing Director

+91 95610 94490
rahul.bagdia@pManifest.com

Vikrant Vaidya
Partner and Lead EV Systems Engineering

+91 99002 43650
vikrant.vaidya@pManifest.com

Ankit Agrawal
Principal Consultant

+91 98811 35712
ankit.agrawal@pManifest.com

Sayali Agade
Engagement Manager

+91 84128 98198
sayali.agade@pManifest.com

Rameshwar Metage
Senior Analyst - E-Mobility

+91 8208046650
rameshwar.metage@pmanifest.com

Strategy	Reports	Business Plans
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Industry Outlook	Pilots Management	Policy