NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

ESTD 2024
SOLUS PRIME
• WE CREATE, WE SUSTAIN •

Optimizing Fleets, Minimizing Impact: Optimus Prime's Creation for a Greener Tomorrow

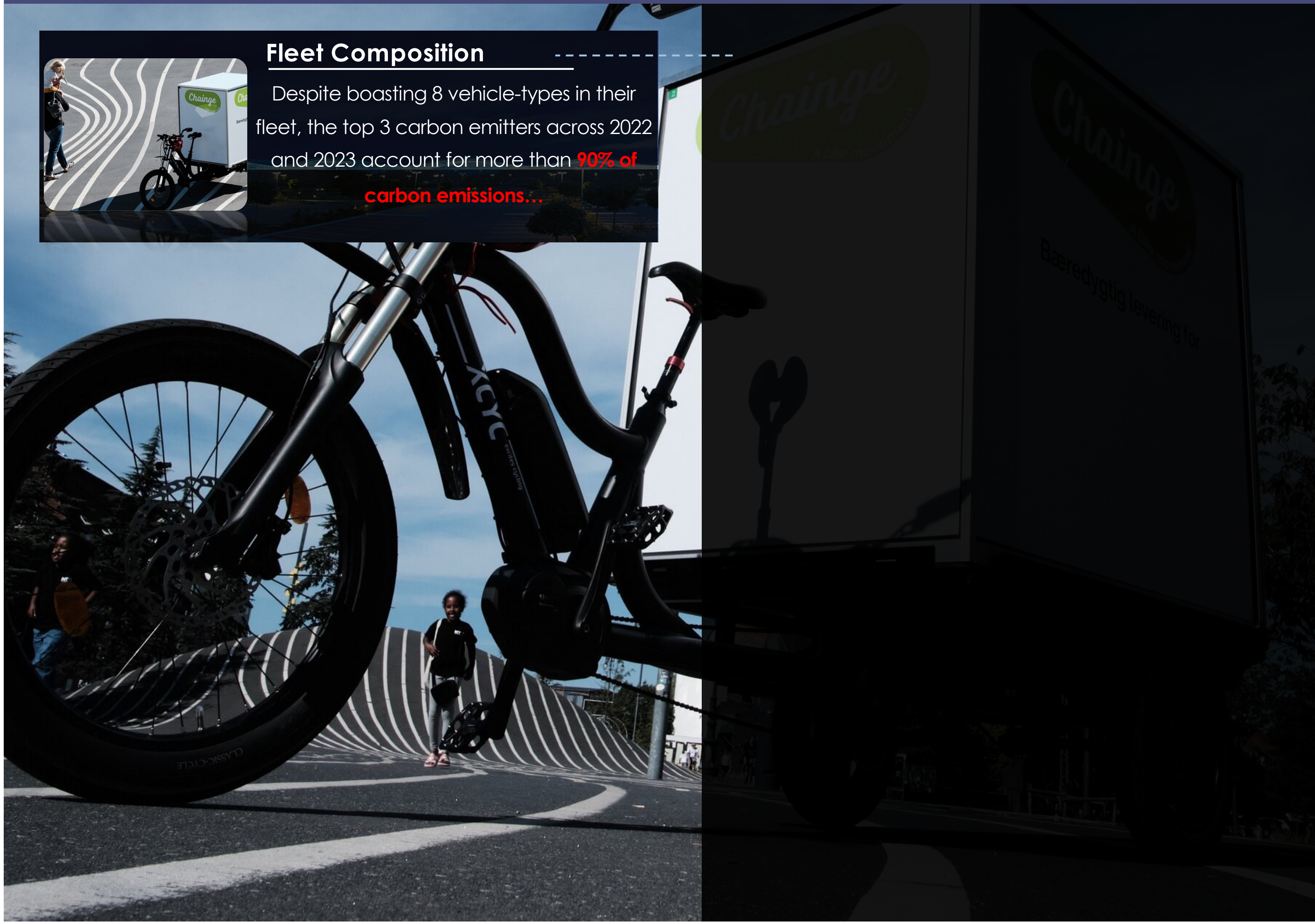
With special thanks to:

accenture

BAC

Company Snapshot:

Evolution of Optimus Prime: Fleet Composition Breakdown and Success Factors



Fleet Composition

Despite boasting 8 vehicle-types in their fleet, the top 3 carbon emitters across 2022 and 2023 account for more than **90% of carbon emissions…**

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Company Overview

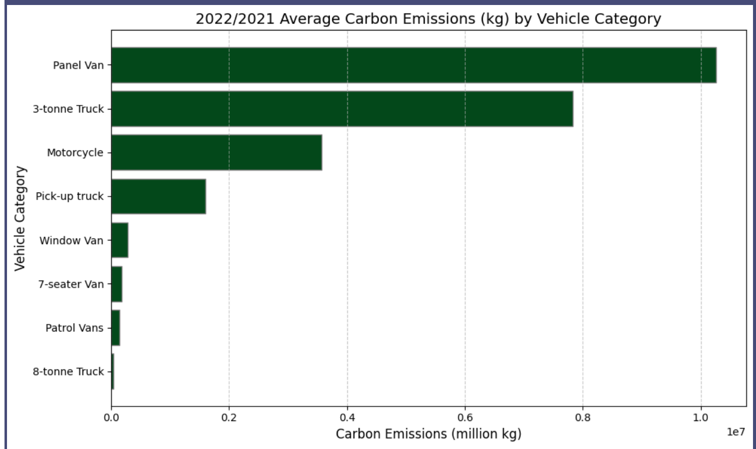
- **Vision and Mission:** Value for Users, Tech for Good
- **Key Products:** Productive use of ICE Vehicle Fleet

Percentage of CO2 Emissions for all vehicle types

Root Causes

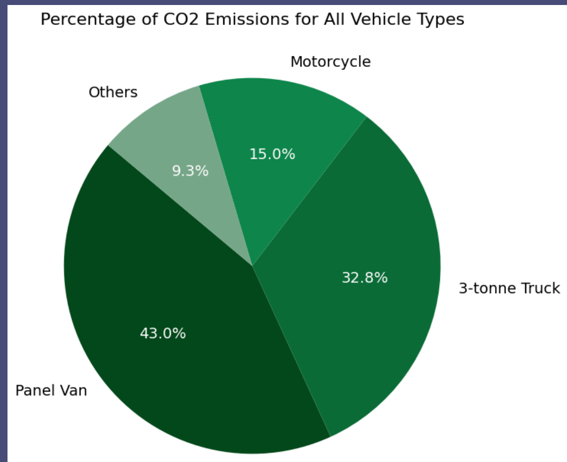
- Poor Incentive control, with uncertainty around government initiatives, misaligned priorities with fleet owners
- Poor Spending/Market Control, with financial

Fleet Composition



Panel Van, 3-tonne Trucks, Motorcycles

CO_2 Emissions Per Vehicle Class



Panel Van (43%), 3-tonne Trucks (32.8%), Motorcycles (15%)

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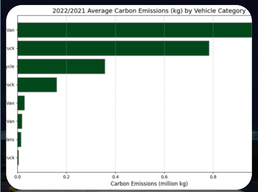

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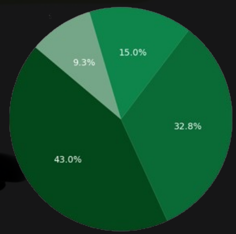

Percentage of CO_2 Emissions for all vehicle types

Panel Van (43%), 3-tonne Trucks (32.8%), Motorcycles (15%)

Mobilization Issues

…and it is these exact same 3 vehicle classes that incur the **highest fuel cost ($P) as well…**

Focus of Decarbonization Plan

2023 Case Study

McKinsey&Company

Fleet Decarbonization

With increased vehicle age past serviceability, there is increased carbon emission

Root Causes

- Poor Incentive control, with uncertainty around government initiatives, misaligned priorities with fleet owners
- Poor Spending/Market Control, with financial strain hampering upfront investments in sustainable infrastructure
- Poor feedback control, limited visibility on efficiency gains through decarbonization

SWOT Analysis

- Strengths – Established and Extensive Network, Adaptability, Strong Brand Image
- Weaknesses – Predominant focus on traditional ICE fleets, Limited expertise in sustainable practices, financial woes
- Opportunity – Favorable Government Regulations, Consumer Demand
- Threats – Competition, Infrastructure Limitation

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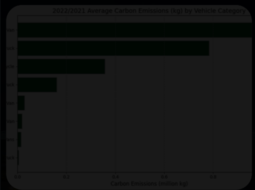

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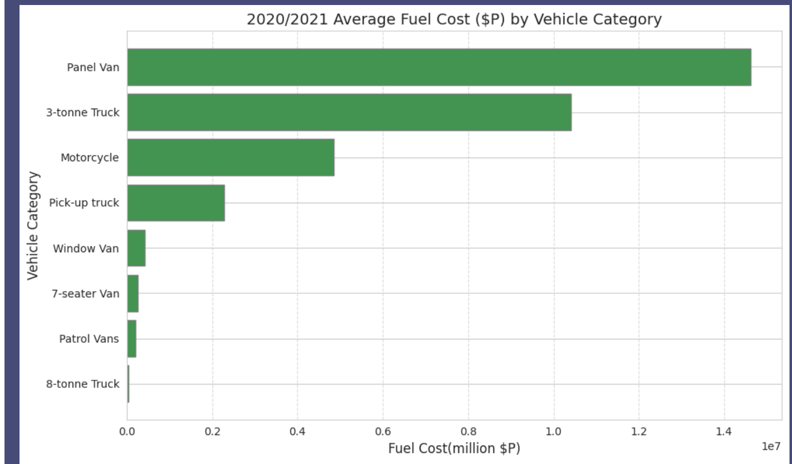
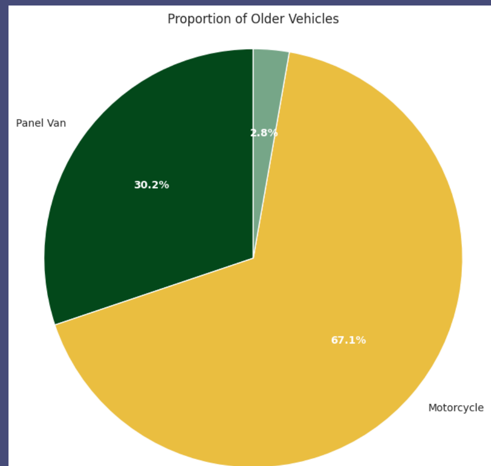
Fuel Cost



Panel Van, 3-tonne Trucks, Motorcycles

Service Duration



A total of **21%** of the vehicles in Optimus Prime's fleet have **exceeded their expected service duration…**

Within the fleet of aged vehicles, **Motorcycles** make up a significant **majority at 67%,** while **Panel Vans represent 30%.**

- Threats – Competition, Infrastructure Limitation

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Consumer Trends

- Growing Demand for eco-friendly and sustainable delivery options
- Increased focus on advancements in fleet telematics and EV adoption

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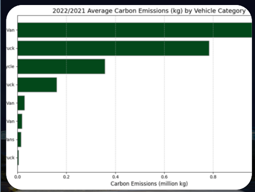

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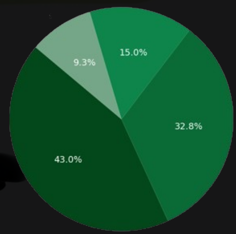

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Into the Future

- Firstly, target high carbon emitters and aged vehicles
- Secondly, target OP's poor finance by ensuring cost savings and generate revenue for profitability

Root Causes

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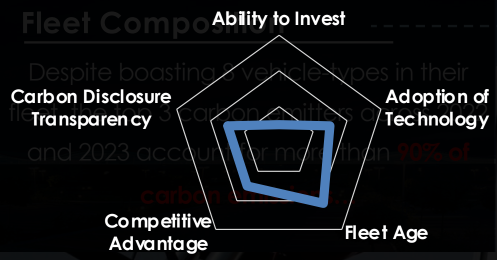
Sustainability

- Goal of becoming carbon-neutral by 2030
- Net Zero by 2050
- Investment in solid-state batteries and electric motors

Fleet and safety technology are transforming the industry at a foundational level…

Competitive Position



Main Objective

How can we maintain profitability, strategically diversifying and phase in decarbonization plans whilst minimizing disruption and cost?

Company Snapshot:
Evolution of Optimus Prime: Fleet Composition Breakdown and Success Factors

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Despite boasting 9 vehicle types in their fleet… 3 carbon emitters … and 2023 account for more than 90% of carbon …

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Into the Future

- Expansion to Electric Fleet Management
- Partnership with renewable energy providers
- Next generation motor technology, intelligent products, machine learning

Root Causes

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- Goal of becoming carbon-neutral by 2030
- Investment in solid-state batteries and electric motors
- Achieving 100% electrification of key identified vehicle types

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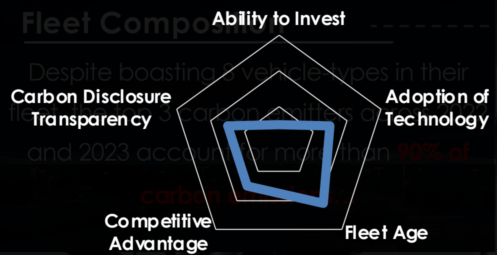

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Case Study

Forbes Technology Council

Fleet Management 2022

Artificial intelligence and analytics are maturing at an incredible rate, driving efficiency among fleets large and small

Changes experienced in the industry force Optimus Prime to implement new strategies to realize its business potentials…

…With this pace of growth, these ambitious plans, and the complexities of decarbonization, what are the best ways to organize fleet management to best effect?

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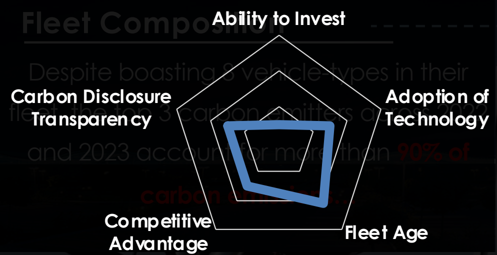

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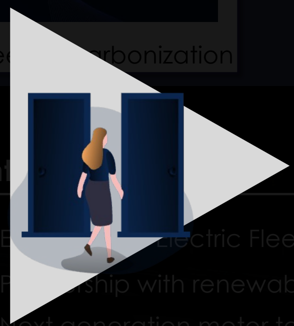
Opportunities

Fast-Growing APAC

- Outcompete competition- DHL and JD Logistics that have been gunning for sustainable shipping options through their own variables

DHL

京东物流 JD Logistics



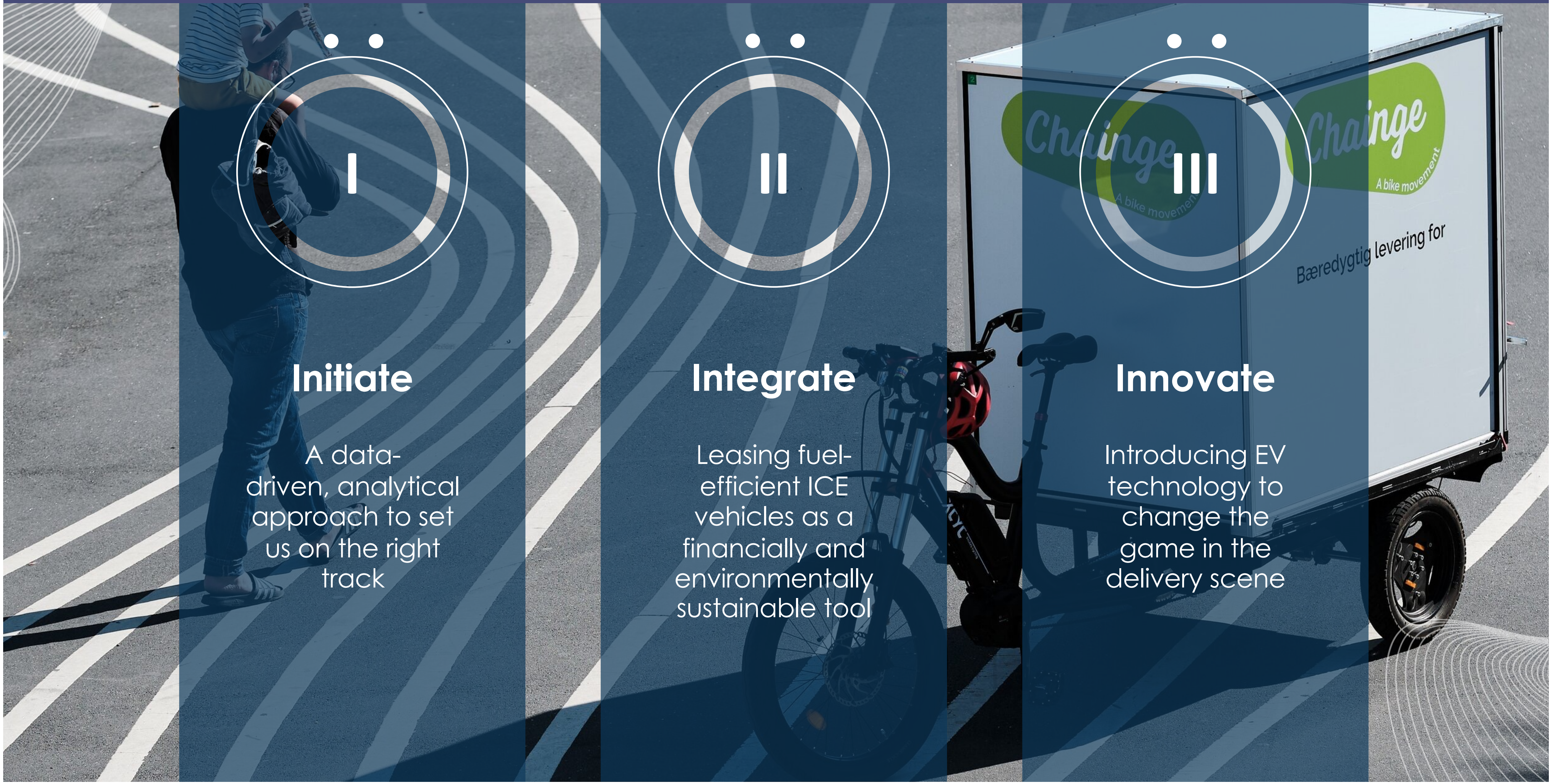
Impact

Micro Steps, Macro Impact

- Introduce incremental upgrades in fleet efficiency as small but strategic steps, leading to significant sustainability achievements and market competitiveness.
- Streamlining operations to focus on energy-efficient practices

Solus Prime’s Strategy:

Project Emerald: A Tri-Prime Ecodrive Strategy



I

Initiate

A data-driven, analytical approach to set us on the right track

Aims of Phase 1- Initiate

itiate aims to lay down a solid foundation which subsequent phases can benefit from or build upon

Macro View of our Implementation Roadmap – KPIs, Objectives, Outcome

David Lim

29 y/o Fleet Manager

Professional Business Development Director

Solus Prime

1.5 years

Initiate → Integrate → Innovate

Key Objectives

1 Scalability

Increasing effectiveness further down the road

2 Low-Cost

Minimal Initial Investment. Profit-driven company

3 Responsive

Quickly strengthening the company's financial reserves

Outcome

Lay a solid foundation for our subsequent phases to build upon, strengthen financial reserves

Timeline to Target

2025, and beyond

Introduction | The Challenge | **Current Approach** | Proposed Solution I | Proposed Solution II | Proposed Solution III | Grants, Evaluation & Selection | Action Plan | The Road Ahead

II

Integrate

Leasing fuel-efficient ICE vehicles as a financially and environmentally sustainable tool

Macro View of our Implementation Roadmap – KPIs, Objectives, Outcome

David Lim

29 y/o Fleet Manager

Professional Business Development Director

Solus Prime

7 years

Initiate → Integrate → Innovate

Key Objectives

1. **Carbon Emissions**
   40% decrease

2. **Generate Revenue**
   70% of Phase 3 Budget

3. ★★★★☆ **Responsive**
   Phase out the old, bring in the new

Outcome

Replace fuel inefficient 3-tonne ICE trucks with fuel efficient leasings

Timeline to Target

2031

III

Innovate

Introducing EV technology to change the game in the delivery scene

Aims of Phase 1- Initiate

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Macro View of our Implementation Roadmap – KPIs, Objectives, Outcome

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David Lim

29 y/o Fleet Manager

Professional Business Development Director

Solus Prime

18 years

Initiate

Integrate

Innovate

Key Objectives

1 **Scalability**

Expand to replace panel vans and motorcycles

2 **Electric Fleet**

Transition from ICE to EV

3 **Profitability**

Maintain Profitability

Outcome

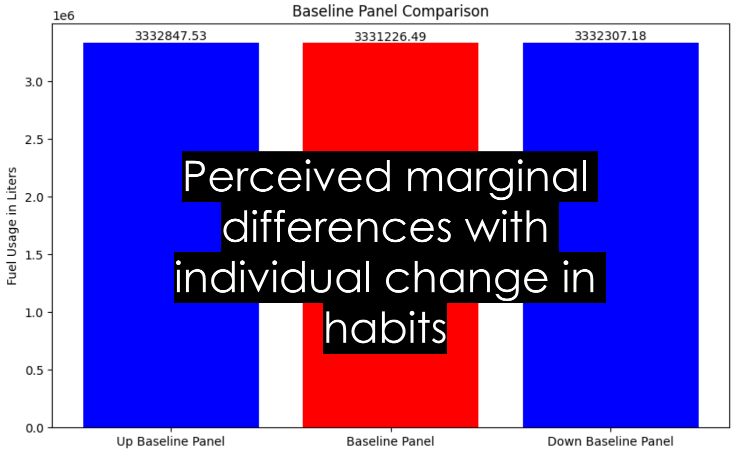
Achieve Net Zero Carbon Emissions

Timeline to Target

2032-2050

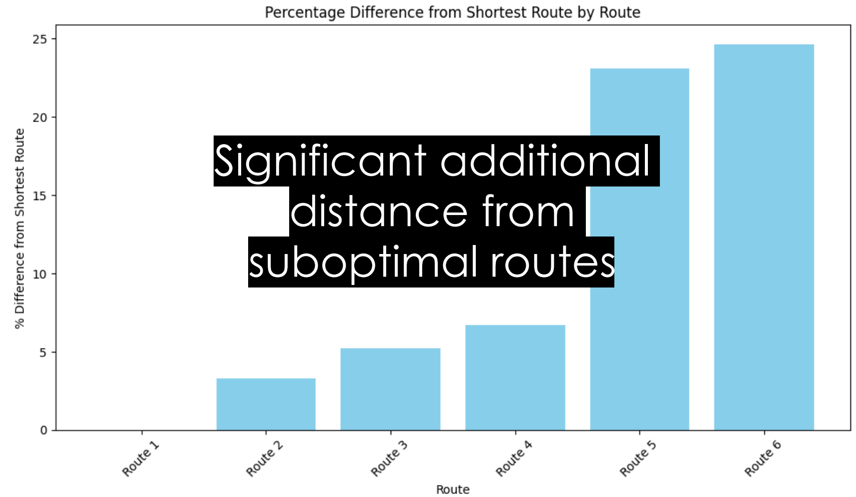
Phase 1-Initiate: Addressing existing gaps

Poor individual accountability and proactivity



- **Data aggregation** enables individual drivers/riders with bad habits to seek **safety in the masses** with marginal differences
- **Lack of individual recognition** deters drivers to expend additional proactive efforts to perform better

Inefficient Fleet Operations



- **Lack of objective method** to enhance existing operations or identify areas of improvement (e.g Optimal Routes)
- **High administrative costs** involved with manual report generation

Phase 1 – Initiate: Proposed Solution (Fleet Monitoring System)

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Overview of Comprehensive Fleet Monitoring System

- A unique company-wide fleet performance monitoring system integrating both **Fleet Telematics** and a **Fuel Card Management System (FCMS) using an App**, to **reduce carbon emissions** in a **cost-effective** yet **non-disruptive manner** at an **individual level.**

Fleet Management App
- Real-Time Tracking
- Route Planner
- History, KPIs and Insights
- Dynamic Fuel Limit Tracker

Use Case Scenario

1 **Fuel Card and User Account**
Each driver is provided with a fuel card and an account for the Application.

2 **Pre-Delivery Planning**
Driver inputs details of his delivery locations, Telematic-enhanced vehicle model.

3 **Optimal Route and Dynamic Fuel Limit Calculation**
Optimal Route and dynamic fuel Limit is determined, accounting for distance, weather and road conditions.

4 **Real-time Data Logging and Automated Alerts**
Telematics data is uploaded on the fleet monitoring app, and alerts are sent to driver/supervisor for trigger events.

5 **Performance Review**
Historical Telematic Data, KPIs and Analytics are made available for driver self-review, or for reward or correction purposes by supervisors.

Phase 1 – Initiate: Roadmap

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2024 Q1 — Planning & Vendor Selection

- Define Project Scope, Objectives, KPIs
- Identify required FMS functionalities
- Identify potential vendors for FMS
- Vendor/Partner Evaluation and Selection

Q2 — System Design & Integration

- Collaborate with partners for system architecture
- Plan integration process
- Develop implementation timeline and milestones with vendors

Q3 - 4 — Development & Purchases

- Commence software development, with checkpoints to ensure alignment with goals
- Thorough testing with stakeholders to validate capabilities
- Purchase telematic devices

Q5 — Pilot Program

- Deploy FMS for pilot segment
- Train pilot group and staff to use FMS
- Gather user feedback to refine software system
- Introduce FMS to all drivers and staff

2025 Q1 - 2 — Full-scale Deployment

- Roll-out FMS across the entire fleet
- Expand training programs to include all staff
- Gather feedback, and make refinements to software

Continued Optimisation

- Establish schedule for software updates to add new features
- Perform data analysis to refine existing operations or parameters
- Gather insights from data to enhance future phase implementations

Phase 1 – Initiate: Key Performance Indicators (KPIs)

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The following metrics will be evaluated on an annual basis:

Financial Metric

Fuel Expenditure
"Fuel Costs in $"

Aim:
To ensure that FMS investments are yielding positive returns

Operational Metric

Fuel Efficiency
"Distance Travelled per Liter"

Aim:
To monitor increases in operational efficiency

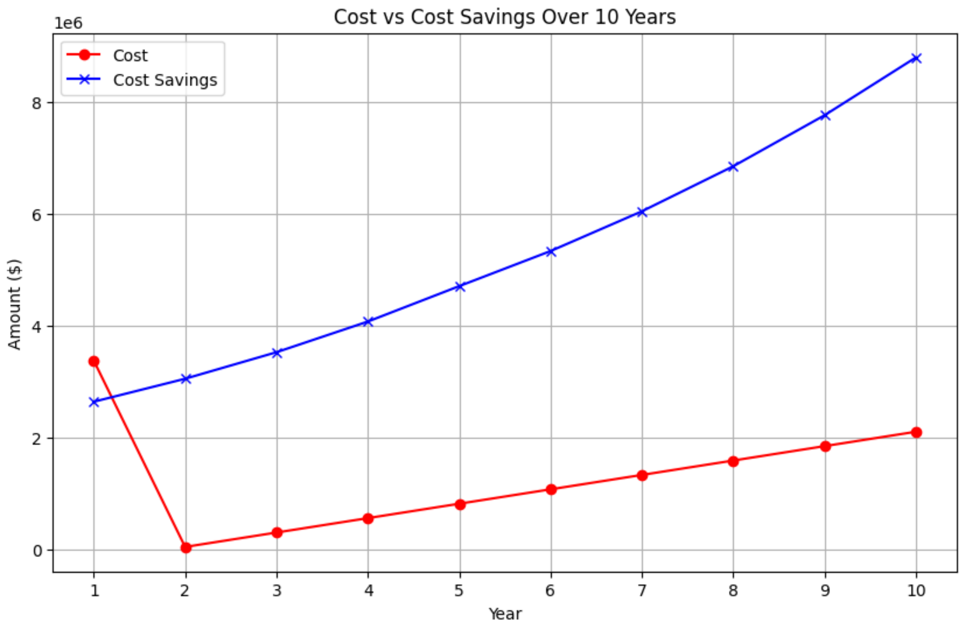
Behavioural Metric

Driver Compliance Rate
"% of drivers adhering to recommendations"

Aim:
To measure impact on an individual level.

Phase 1 – Initiate: Feasibility

Financially Feasible



Payback Period: 1.93 Years

Operationally Feasible

1. Compatible with existing vehicles

- Plug and Play Telematics relies on a vehicle's OBD-II port, which is found in all the fleet vehicles
- No specialised installation or vehicular modification required.

2. Scalable and Flexible

- OBD-II ports are present in most ICE vehicles and EVs, permitting easy transfer between vehicles
- New telematic devices can be easily installed and integrated during future fleet expansion

3. Little Additional skills required

- Additional training is only for drivers/riders to access the online platform
- No additional skills required that will disrupt day-to-day delivery operations

Phase 1 – Initiate: Risks and Mitigations

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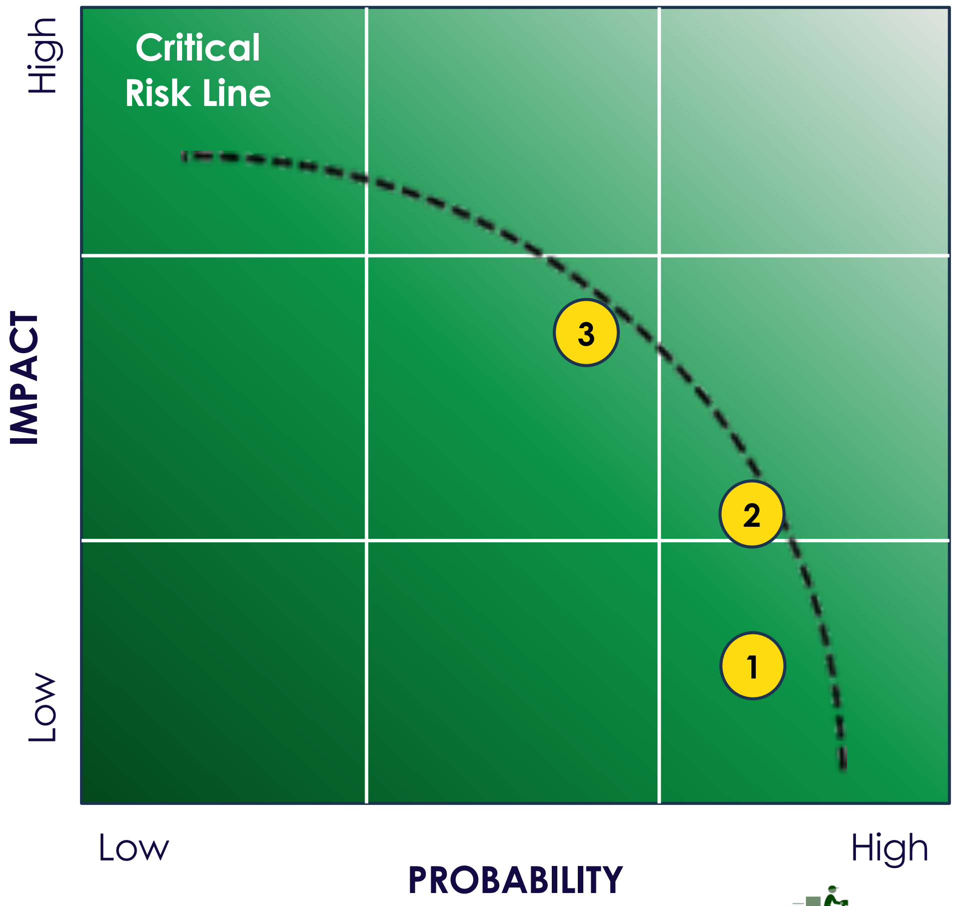

RISKS	MITIGATIONS
1 Operational Risk: **Misuse of Fuel Card or tampering with Telematic Devices**	Use automated alert system to alert supervisors when detecting irregularities.
2 Compliance Risk: **Driver Resistance**	Introduce incentivization system to encourage individual proactivity.
3 Technical Risk: **Inaccurate Dynamic Fuel Limits**	Conduct periodic review and adjustment of system parameters to ensure fairness and accuracy.

Phase 2-Integrate: Replacing fuel inefficient vehicles with more fuel-efficient leasings to enjoy reduction in costs and emissions

Comparison of cost of owning and leasing per vehicle

Costs Associated	Owning	Leasing
Acquisition cost of vehicle	Vehicle costs ranges from **$6,000 - $200,000, depreciated over a period of 10 – 20 years**	Monthly lease ranges from **$400 - $2,050**
Maintenance cost (inclusive of Insurance)	Projected to be between **$10 - $580+ monthly**	Covered by leasing company
Road tax	**Between $62.6 - $656 monthly**	
Certificate of Entitlement	COE ranges from **$9,689 - $70,112, depreciated over a period of 10-20 years**	
Registration Fees	Once-off fee, between **$350 - 575**	

Leasing, as compared to owning the vehicle, is

UP TO $3,549 CHEAPER

per unit annually, *without considering reduced fuel costs or sale of old vehicles*

Phase 2-Integrate: Replacing fuel inefficient vehicles with more fuel-efficient leasings to enjoy reduction in costs and emissions

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Decision criteria for choosing vehicle type for piloting replacement

	Motorcycle	Panel Van	Window Van	Pick Up Truck	Patrol Van	3-tonne Truck	7-Seater Van	8-tonne Truck
Carbon Savings (tCO_2)	4,488	3,104	42	194	20	3,464	37	4
Score	5	3	1	1	1	4	1	0
Cost Savings (SP)	-1,141	8,780	1,706	3,737	1,581	3,265	1,551	519
Score	0	5	2	3	2	3	2	1
Fleet Size	6,628	2,466	48	552	49	331	69	24
Score	1	1	5	4	5	4	5	5

Carbon Savings (tCO_2)

- Amount carbon dioxide saved per vehicle due to leased vehicle's **improved fuel efficiency**
- Measures **environmental impact**

Cost Savings

- Amount of cost savings per vehicle considering **depreciation, maintenance costs, insurance costs and road tax**
- Measures **financial impact**

Fleet Size

- Size of fleet by vehicle type
- Measures **logistical ease**

Phase out **3-tonne trucks first** to **maximise environmental impact and minimise costs**, proceeding with panel vans and motorcycles next

Phase 2-Integrate: Replacing fuel inefficient vehicles with more fuel-efficient leasings to enjoy reduction in costs and emissions

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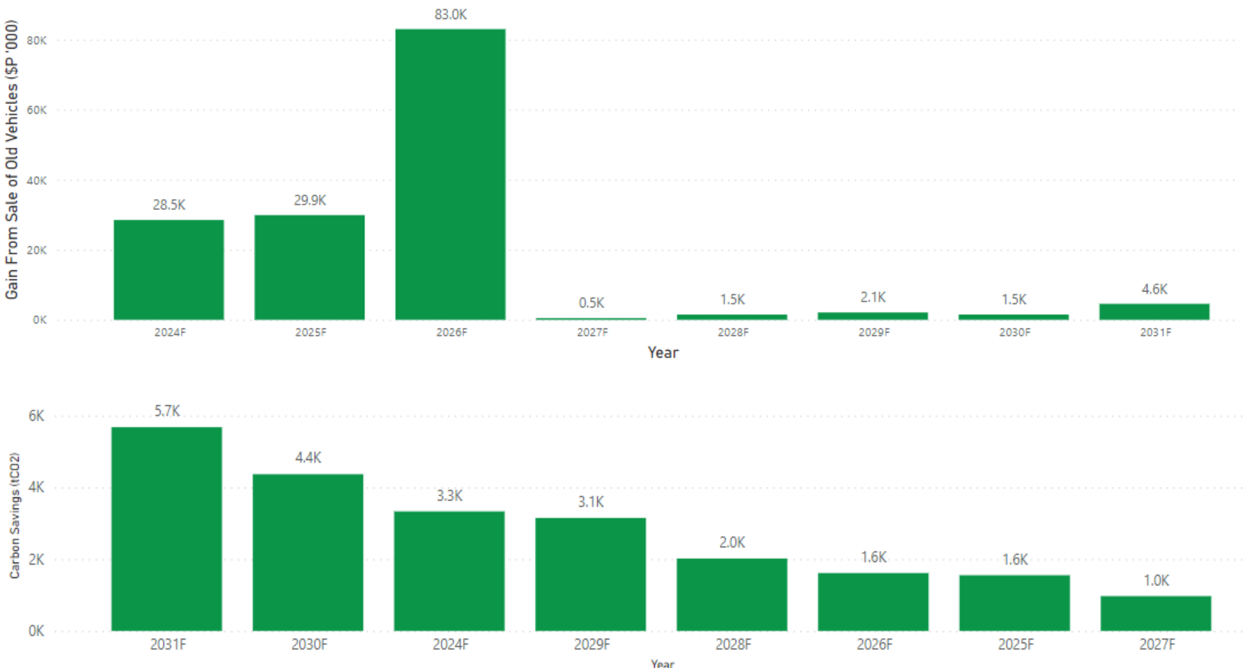
Phase out **3-tonne trucks** | Phase out **panel vans** | Phase out **motorcycles**



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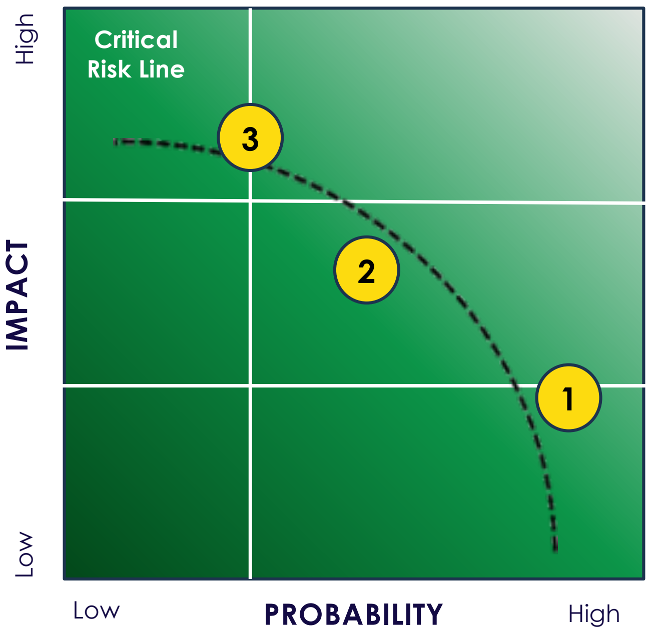
Key Objectives by 2031

1. Accumulate **100% of phase 3's budget**
2. Achieve **47% reduction in carbon emissions**

Phase 2-Integrate: Replacing fuel inefficient vehicles with more fuel-efficient leasings to enjoy reduction in costs and emissions

Risks & Mitigation



1. **Long Procurement Lead Times**
   Conduct thorough forecasting and planning to anticipate leasing needs well in advance

2. **Delay in Resale or Disposal of Old Vehicles**
   Explore trade-in programs offered by vehicle manufacturers or dealerships

3. **Operational Constraints in Lease Agreements**
   Thoroughly plan and forecast operational needs, negotiating flexible lease terms to accommodate them

Phase 3-Innovate: Transitioning from ICE Vehicles to Electric Vehicles (EVs) to lower carbon emissions and operational costs

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Selecting Fleet Replacement Option

	1. Full Fleet Replacement	(2) High Emissions Vehicle Replacement (3-tonne Trucks, Panel Vans Motorcycless)
Replacement Size		
Reduce Carbon Emissions	21% Reduction in carbon emissions	14% Reduction in carbon emissions
Fuel cost-savings	61% Reduction in fuel cost	24% Reduction in fuel cost
Maintenance cost-savings	23% Reduction in maintenance cost	13% Reduction in maintenance cost
Purchase Cost	**High Purchase Cost of $700 million:** • 296% more than the cost of Fleet Telematics • Not a financially feasible solution	**Purchase Cost of $579 million:** • Not a financially feasible solution

Additional Insights:

COST

Increased fuel cost for:
- Pickup truck and 8-tonne truck
- Not every vehicle type will enjoy cost-savings

Phase 3-Innovate: Transitioning from ICE Vehicles to Electric Vehicles (EVs) to lower carbon emissions and operational costs

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Rating of Fleet Replacement Options

With respect to Purchase Cost

	1. Full Fleet Replacement	2. High Emissions Vehicle Replacement (3-tonne Trucks, Panel Vans Motorcycless)
Replacement Size	🚗🚗🚗🚗🚗	🚗🚗🚗
Reduce Carbon Emissions	✓✓✓	✓✓
Fuel cost-savings	✓	✓✓
Maintenance cost-savings		✓

Given Optimus Prime's financial constraints, a more affordable option that prioritizes high carbon emitters in the fleet such as: **Panel Vans, 3-tonne Trucks and Motorcycles** can be adopted

Phase 3-Innovate: Transitioning from ICE Vehicles to Electric Vehicles (EVs) to lower carbon emissions and operational costs

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Replacing leased ICE 3-tonne trucks with new Electric 3-tonne trucks

Building an EV Infrastructure

To facilitate initial EV fleet operations, Optimus Prime needs:

166 **22 kW DC Stations**

High-density Station Placements:
Eagle Beach, Home Valley and Serenity Coast

Infrastructural Cost

To facilitate initial EV fleet operations, Optimus Prime needs:

Infrastructure Cost: **36 million ($P)**

EVs Purchase Costs: **82 million ($P)**

Transitioning from ICE Vehicles to EVs is a costly but **necessary** solution to lower Optimus Prime's Carbon Baseline.

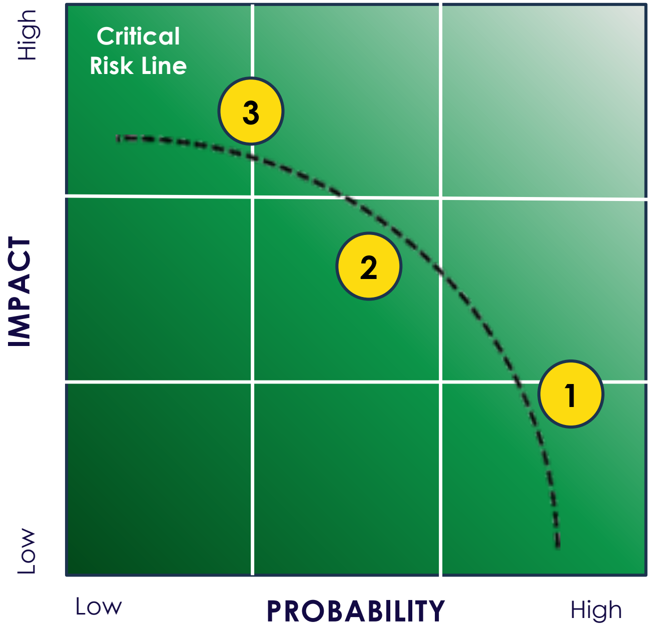
Phase 3-Innovate: Transitioning from ICE Vehicles to Electric Vehicles (EVs) to lower carbon emissions and operational costs

Key Objectives (2032 – 2050)

1. Expand to replace **panel vans** and **motorcycles**

2. Achieve **net zero carbon emissions**

Risks & Mitigation



1. **Battery Degradation**
   Implement proactive battery management strategies to identify and address signs of degradation

2. **Limited Charging Infrastructure**
   Explore innovative solutions such as mobile charging units and battery swapping stations

3. **Grid Capacity Limitations**
   Research has shown that existing electricity grids can handle EVs with proper management (Forbes, 2022)

Grants & Financial Analysis

Grants to Finance Costs

Energy Efficiency National Grant

Offered by **National Environment Agency (NEA)**

Up to 70% to invest in energy-efficient equipment / technologies

Commercial Vehicle Emissions Scheme And Early Turnover Scheme

Offered by **National Environment Agency (NEA)** and **Land Transport Authority (LTA)**

Grants of $15,000 per vehicle when transitioning to Electric Vehicles

P&L Analysis

Key Assumptions Made for Cost Analysis

Revenue = $505.546M
As per SingPost's parcel and post revenue of 2023

Compound Annual Growth Rate (CAGR) = 8%
Based on study done by Mordor Intelligence

Cost per Parcel = $5

Mileage Growth Rate = 4%
Load capacity and route optimisation counters greater delivery count

Gross Profit Margin = 30%
Based on industry average

WACC = 10.5%
Assuming same as SingPost

Key Milestones

2024	Breaking Even in 1st year
2032	$1B Revenue
2033	$1B Profit
2041	$2B Revenue
2047	$3B Revenue
2050	$4B Revenue

Action Plan

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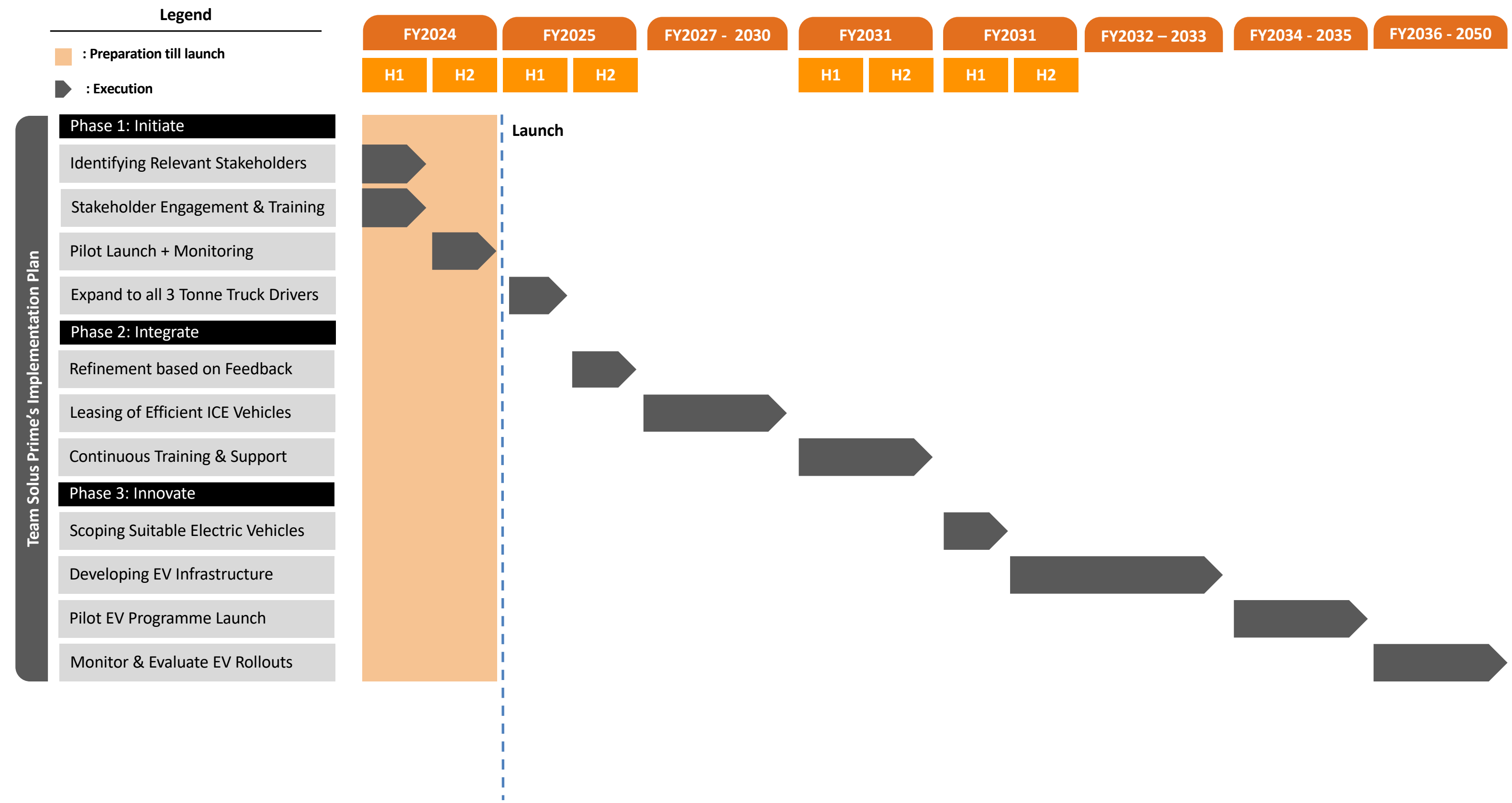
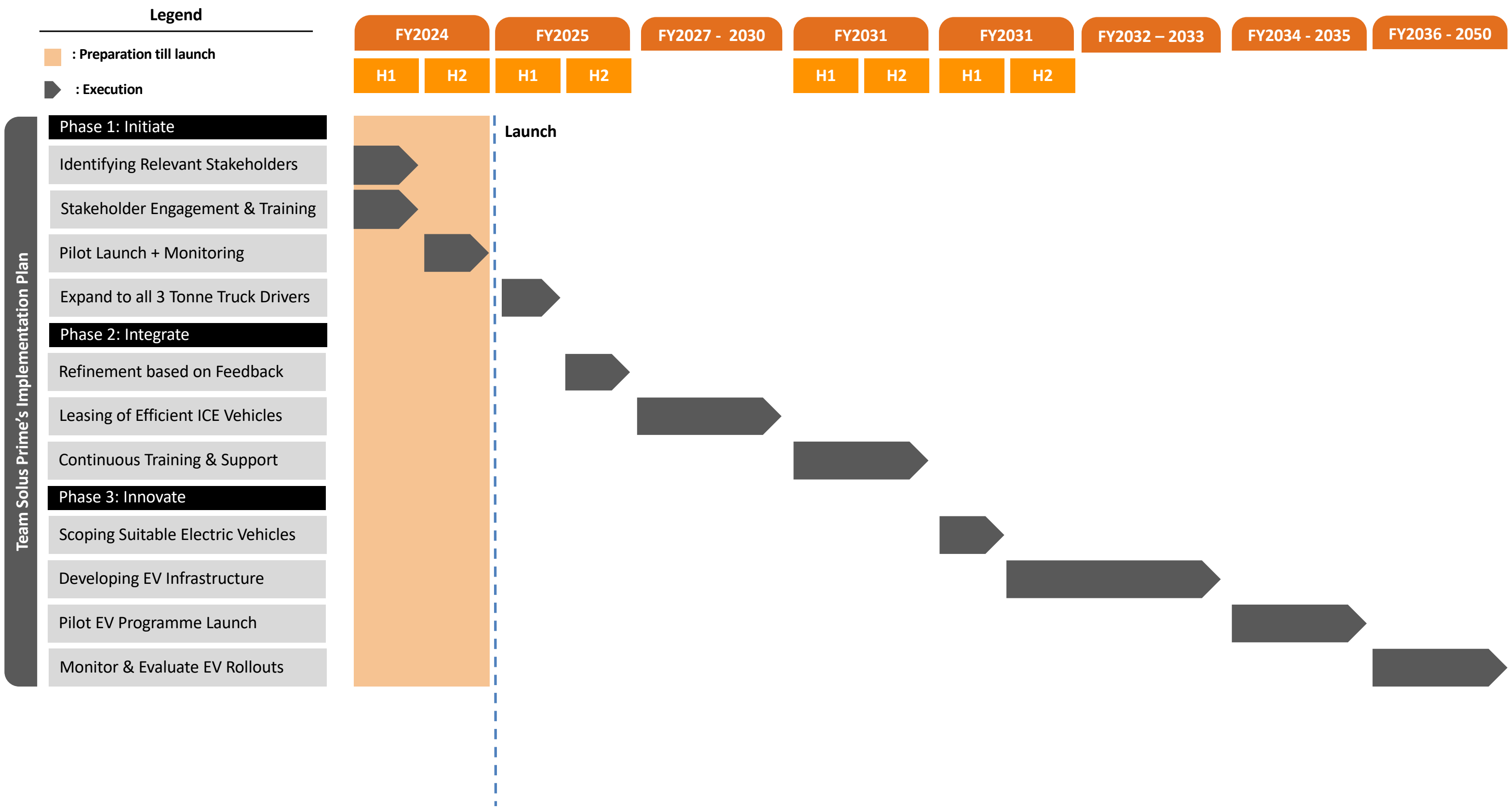


Phase 1: Initiate

- Aim of Phase 1 is to lay the foundation for scaling up by implementing a Fleet Management System (FMS) for 3 tonne trucks
- This phase focuses on the implementation of the FMS for all 3 tonne trucks
- This phase begins with a pilot programme to gauge feasibility and identify potential blockers to be rectified
- Success at this phase would be the enablement of vehicle tracking

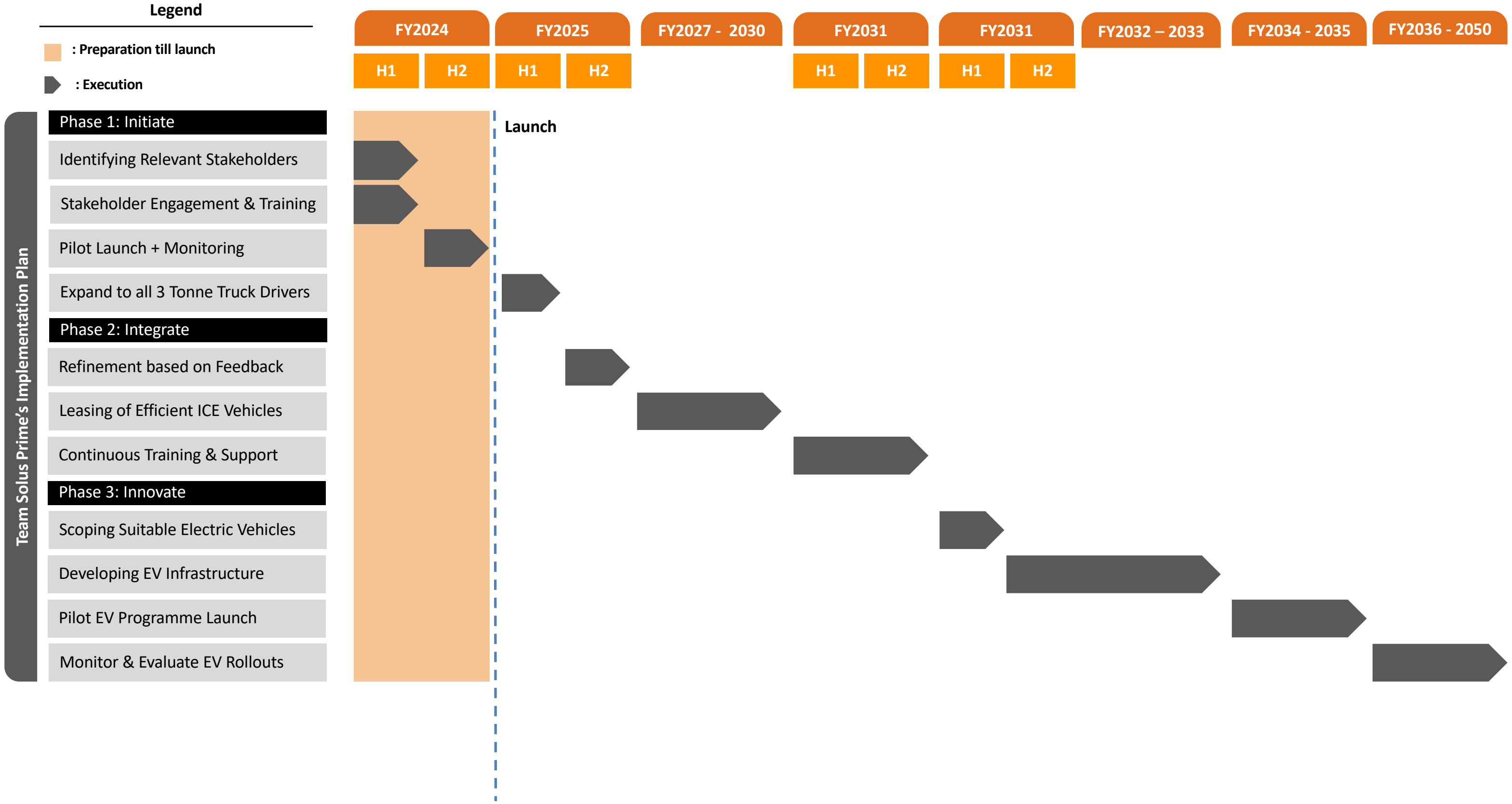
Action Plan



Phase 2: Integrate

- Aim of Phase 2 is to transition to more fuel-efficient ICE vehicles
- This phase focuses on the replacement of current ICE vehicles with their more fuel-efficient counterparts via leasing
- Success at this phase would be the complete transformation of the existing ICE vehicles into more fuel-efficient versions

Action Plan



Phase 3: Innovate

- Aim of Phase 3 is to convert the ICE vehicles into Electric Vehicles (EVs)
- This phase focuses on the introduction of EVs to replace 3 tonne trucks
- This phase begins with the scoping out and development of the support infrastructure for the EVs, before commencing with a pilot testing phase
- Success at this phase would be the complete electrification of the 3 tonne truck fleet of Optimus Prime with no issues

Outcome Evaluation, Critical Success Factors

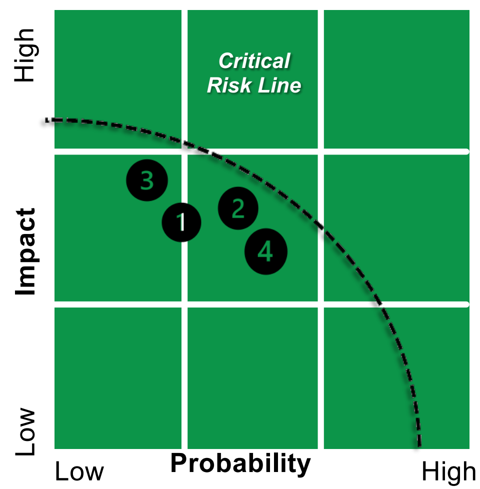
Intended Outcome

- Successfully transitioned to a net zero-carbon emissions company
- Achieve cost savings through lower operational costs due to telematics and EVs
- Gaining a competitive edge by leading green initiatives and advanced EV technology.

Overall Advantages

- Net Zero Carbon Emissions by 2050
- Positive cash flow generated in 25 years
- Breakeven by the end of the first year under base market conditions
- Effective prioritisation of vehicle replacement

Note: Within China



	Risk
1	**Stakeholder Risk:** Drivers are unable to adapt to new vehicles
2	**Infrastructure Risk:** Inadequate support for EV transition leads to operational failures
3	**Financial Risk:** Financial losses hinder company's long-term EV transition.
4	**Procurement Risk:** Uncertain EV supply chain may disrupt company plans

4 major risks all fall below critical risk line

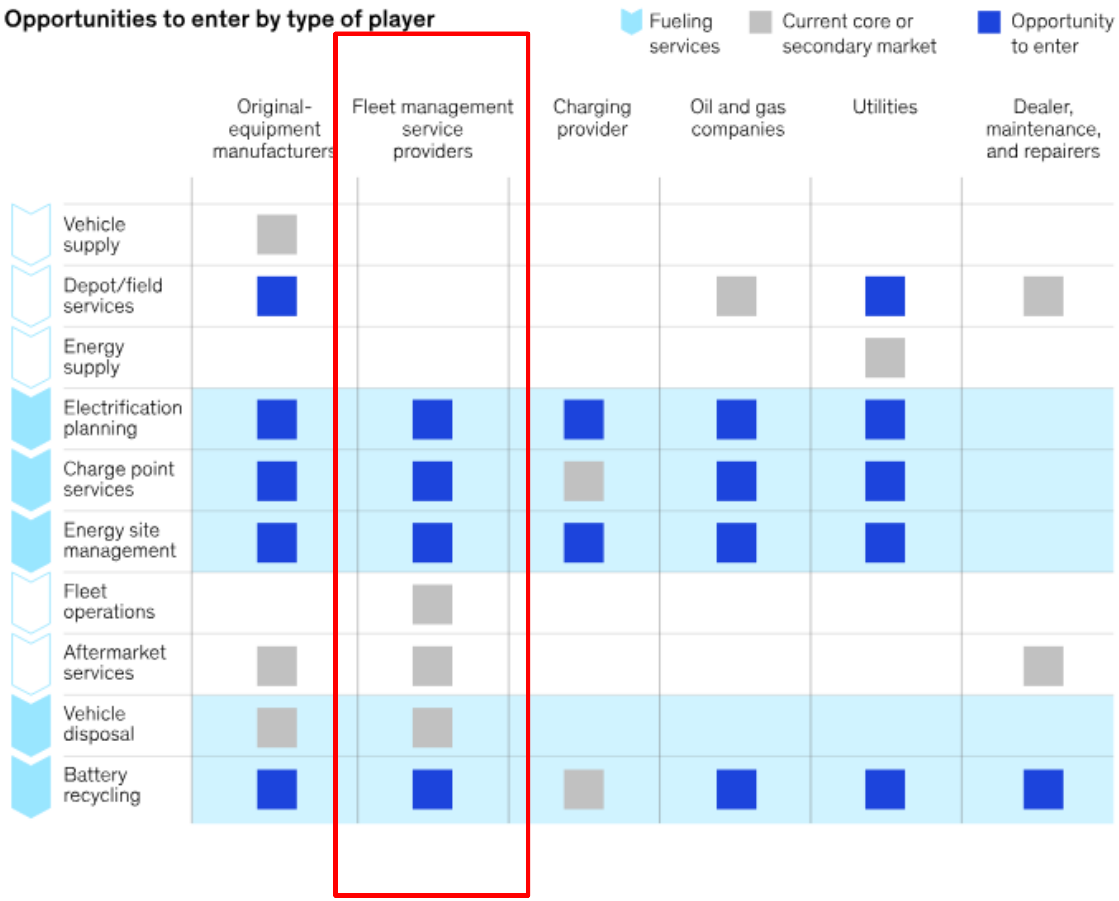

CO2
100
90
80
70
60
50
40
30
20
10
0
NANYANG
TECHNOLOGICAL
UNIVERSITY
SINGAPORE
ESTD 2024
SOLUS PRIME
• WE CREATE, WE SUSTAIN •
Thank you!
With special thanks to:
accenture
BAC

Appendix: Estimating the potential evolution of the value chain

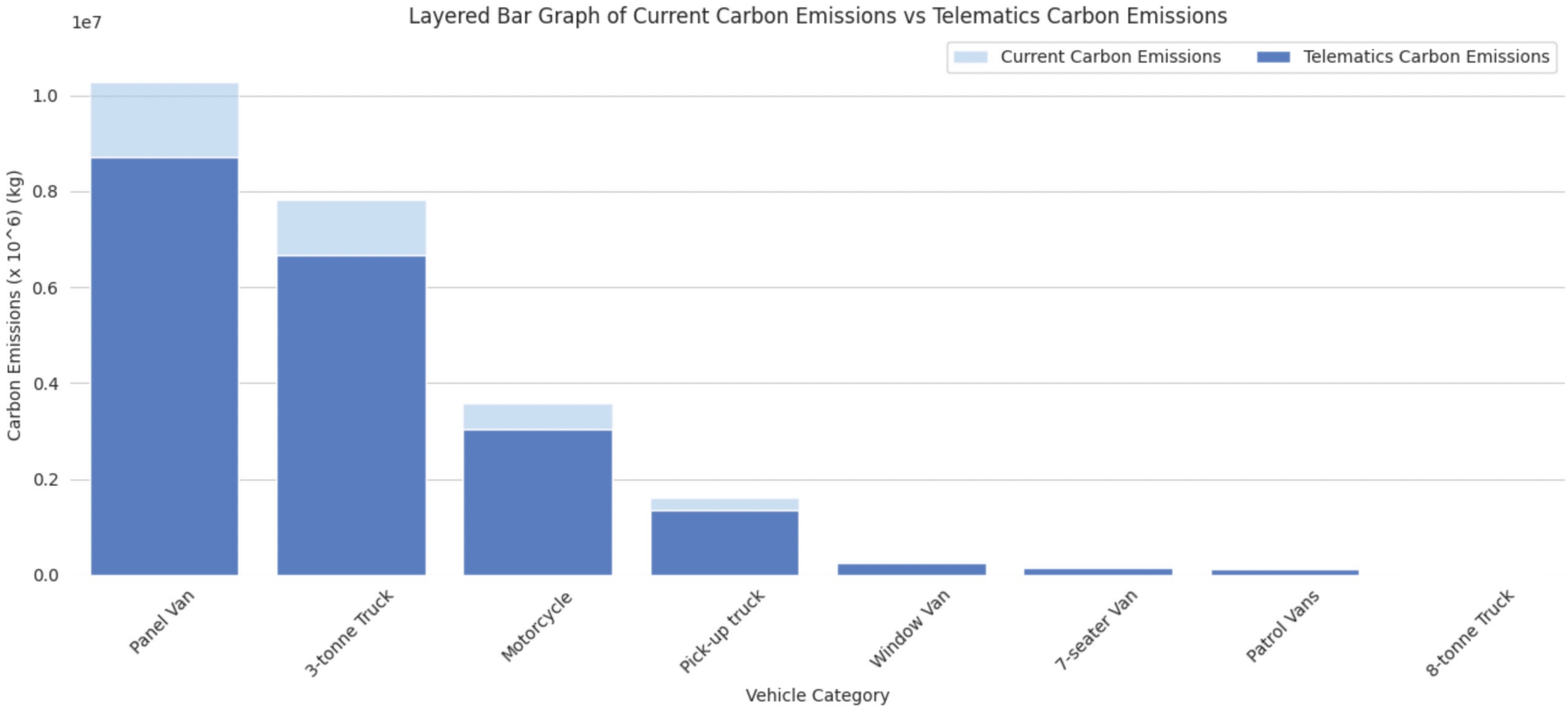
2023 Case Study

Fleet Decarbonization

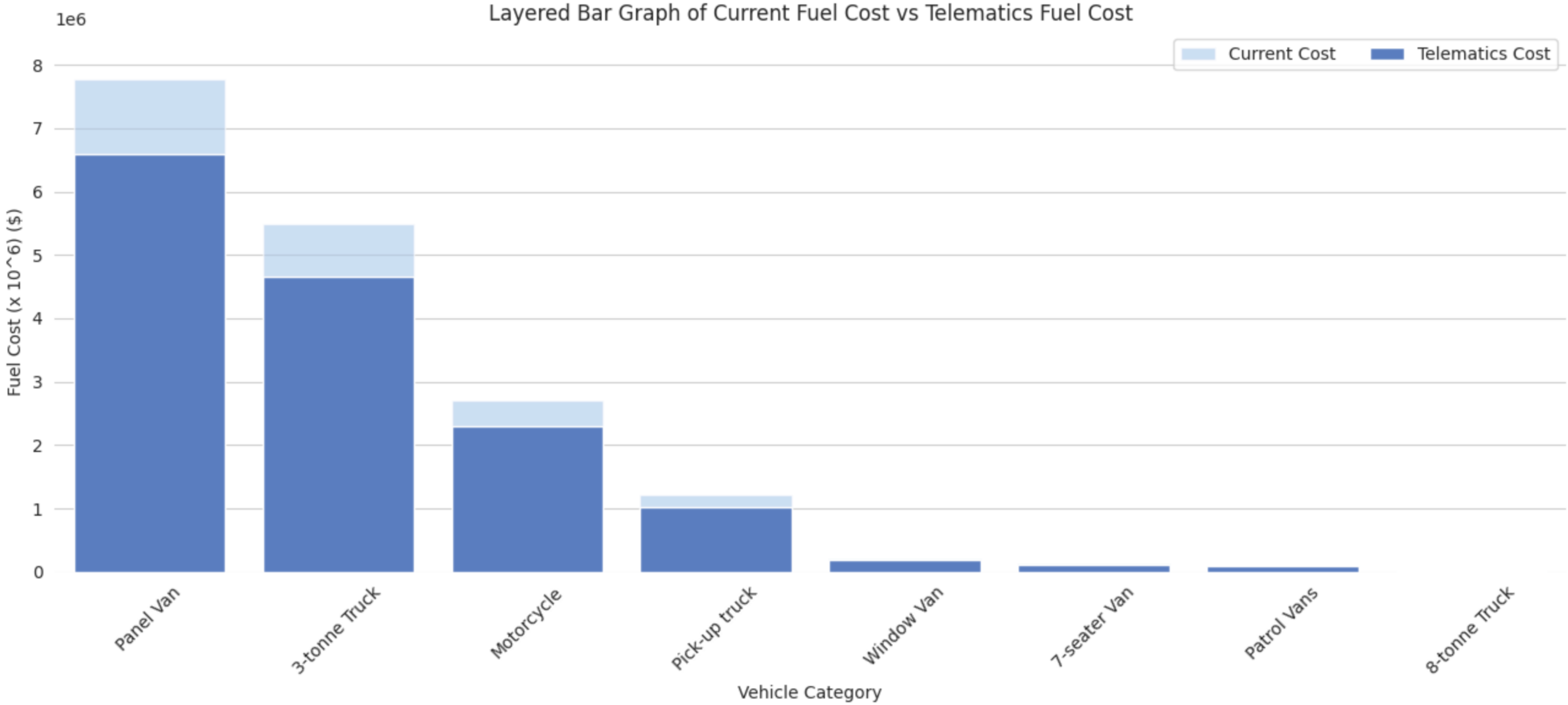
There are significant opportunities in electrification planning, battery recycling, energy management



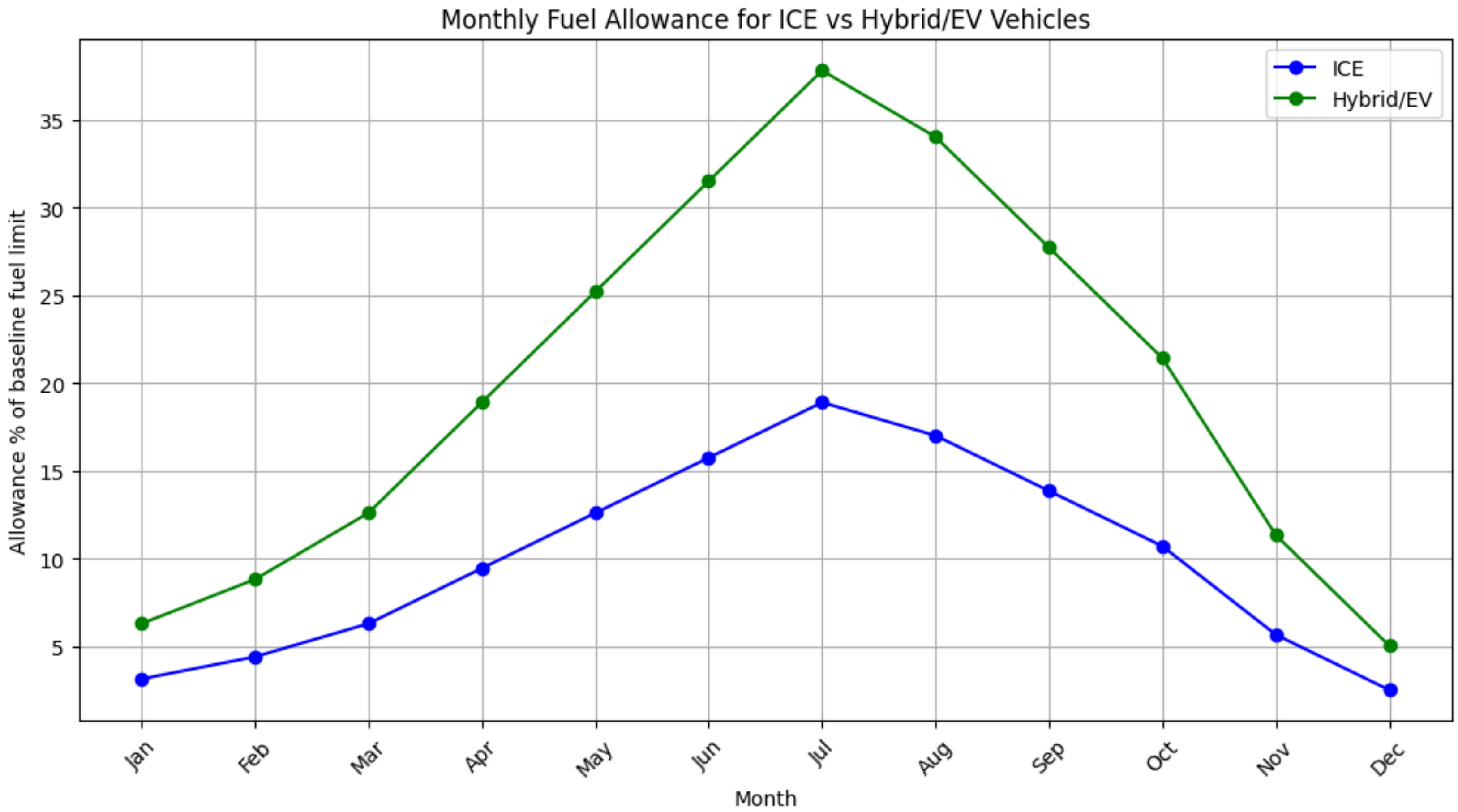
Appendix: Carbon Emissions Reduction of Fleet Telematics



Appendix: Fuel Cost Savings of Fleet Telematics



Appendix: Allowance for ICE vs Hybrid Vehicles by Month



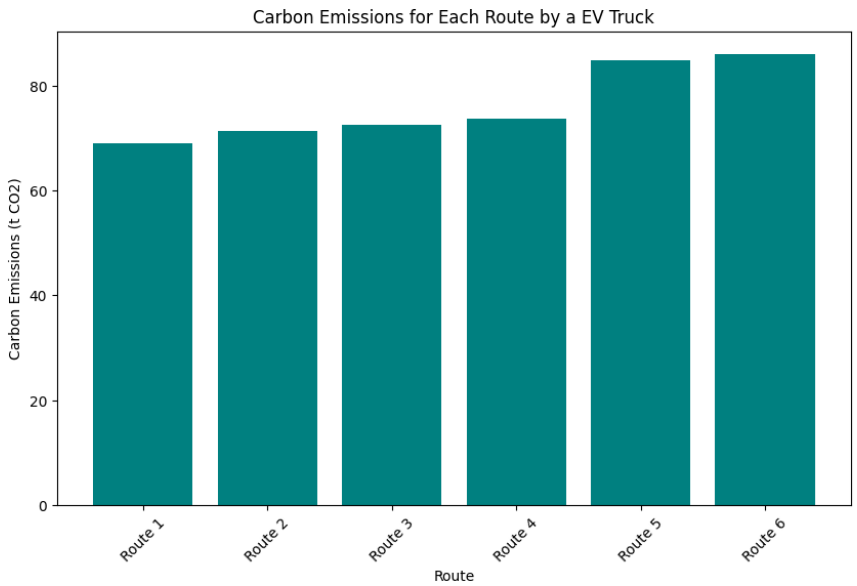
Appendix: Real-Time Simulation – Effects of choosing suboptimal routes

```
Distance: 83677 meters, Route: ['NTU', 'NUS', 'SMU', 'SUTD', 'NTU']
Distance: 86426 meters, Route: ['NTU', 'SUTD', 'SMU', 'NUS', 'NTU']
Distance: 88025 meters, Route: ['NTU', 'SMU', 'SUTD', 'NUS', 'NTU']
Distance: 89275 meters, Route: ['NTU', 'NUS', 'SUTD', 'SMU', 'NTU']
Distance: 102993 meters, Route: ['NTU', 'SUTD', 'NUS', 'SMU', 'NTU']
Distance: 104302 meters, Route: ['NTU', 'SMU', 'NUS', 'SUTD', 'NTU']
```

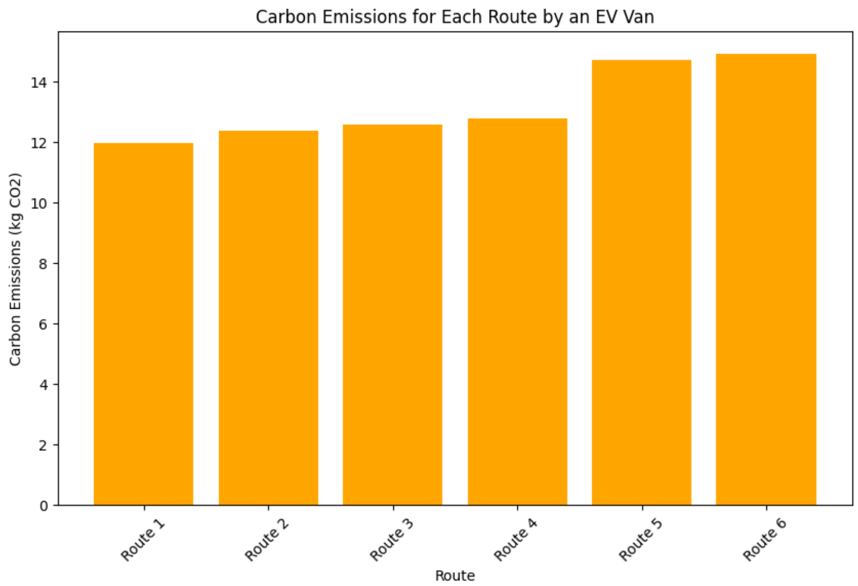
Simulation results: Distances for different delivery routes

Simulation Details

- We simulated a scenario where delivery was made starting at NTU, with stops having to be made at NUS, SMU and SUTD.
- Using Google Maps Real-time API, the distances of each route was calculated.



Difference in Carbon Emissions (kg CO2) for different routes for an EV truck



Difference in Carbon Emissions (kg CO2) for different routes for an EV Van

Appendix: Real-Time Simulation – Dynamic Fuel Limit Determination

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```
Electric Tariff ($P/kWh): 0.4
Average Distance travelled among top 3 routes: 86042.67km
Fuel Limit for the scenario: $34.42
```

Calculation of Baseline limit

Baseline Limit

- Taking the average distance of the top 3 shortest routes, we calculate the dynamic fuel limit by multiplying the average distance with the electric tariff.

```
Current Allowance for Rain is: 12.6%
Current Forecast: {'City': 'Partly Cloudy (Night)', 'Queenstown': 'Partly Cloudy (Night)', 'Tampines': 'Partly Cloudy (Night)'}

Fuel Limit if raining: $38.75692
Fuel Limit if not raining: $34.42
Locations are not raining, allowance not applied.

Final Fuel Limit: $34.42
```

Calculating Dynamic Fuel Limit using Baseline and Real-time Weather of Delivery Locations

Dynamic Fuel Limit

- Since the weather at the delivery locations were cloudy but not raining, the additional allowance of 12.6% was not applied to the baseline value.
- Fuel limit is simply the baseline value of $34.42.

Appendix: Annual Cost Projection for FCMS

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Cost	Amount
Fuel Card Issuance Cost	$25 (issuance fee per card) * 10167(Number of Drivers/Riders) = $254,175
Software Development/Integration with V3 Smart Technologies	$20,000 (One TIme Cost)
Training Costs (to use the technology)	2 Sessions * $2000 (cost per session) = $4,000
Maintenance Cost	$5,000
First Year Annual Cost	**$283.175**
Subsequent Year Annual Cost (Excluding Fuel Card Issuance Cost and Software Development Cost)	**$9,000**

First Year Annual Cost

- Fuel Card Issuance Cost + Software Development Cost + Training Cost + Maintenance Cost

Subsequent Year Cost

- Training Cost + Maintenance Cost

Appendix: Cost of Owning vs Cost of Leasing

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Cost of Ownership of 1 3-Tonne Truck		
Vehicle Price	$ 200,000	
Registration Fee	$ 350	
Additional Registration Fee	$ 10,000	*(5% of Open Market Value)*
COE	$ 70,112	*(Cat C assumed)*
Road Tax (1 Year)	$ 656	*($328 semi-annually)*
Maintenance Costs (1 Year)	$ 353	*(Assume Insurance is covered in Maintenance costs)*
Resale Cost After 1 Year	$ (256,606)	*(includes COE)*
Grants	$ -	
Total	$ 24,865	
Cost of Lease of 1 3-Tonne Truck		
Lease Price (1 Year)	$ 21,600	
Total	$ 21,600	
Cost Savings	$ 3,265	

Assumptions

- Resale cost is depreciated by 20 years at a flatline rate
- Price of old truck was derived by accounting for inflation and eventual depreciation

Appendix: Derivation of Resale Prices

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Inflation-adjusted Old ICE Truck Salvage Value in 2026			
Purchase Year	Quantity	Age (Years)	Salvage Value ($P)
2000	1	26	$ -
2001	1	25	$ -
2002	6	24	$ -
2003	2	23	$ -
2004	1	22	$ -
2005	3	21	$ -
2006	3	20	$ 3,020
2007	1	19	$ 9,147
2008	1	18	$ 15,567
2009	4	17	$ 23,237
2010	2	16	$ 30,055
2011	20	15	$ 37,770
2012	88	14	$ 46,981
2013	34	13	$ 56,689
2014	71	12	$ 65,763
2015	12	11	$ 74,253
2016	11	10	$ 81,641
2017	70	9	$ 88,939

Assumptions

- Assumption that the only factor affecting price is inflation
- Inflation rates were derived from Singapore's inflation rates
- Assumed that vehicle manufacturing year is the purchase year
- Resale cost is depreciated by the Modified Accelerated Cost Recovery System (MACRS)
- Depreciated against 20 years, the lifespan of heavy-duty commercial vehicles as from Onemotoring

Inflation-adjusted Old ICE Vehicle Prices				
Purchase	Inflation Rate	Vans	lotorcycle	Trucks
1990	3.46%	80,135.42	3,205.42	106,847.23
1991	3.43%	82,908.75	3,316.35	110,545.00
1992	2.26%	85,748.95	3,429.96	114,331.94
1993	2.29%	87,689.54	3,507.58	116,919.38
1994	3.10%	89,697.01	3,587.88	119,596.02
1995	1.72%	92,477.71	3,699.11	123,303.61
1996	1.38%	94,068.79	3,762.75	125,425.05
1997	2.00%	95,369.95	3,814.80	127,159.93
1998	-0.27%	97,280.78	3,891.23	129,707.71
1999	0.02%	97,020.56	3,880.82	129,360.74
2000	1.36%	97,036.76	3,881.47	129,382.34
2001	1.00%	98,358.01	3,934.32	131,144.01
2002	-0.39%	99,338.84	3,973.55	132,451.78
2003	0.51%	98,949.73	3,957.99	131,932.97
2004	1.66%	99,452.29	3,978.09	132,603.06
2005	0.43%	101,105.89	4,044.24	134,807.85
2006	0.96%	101,535.69	4,061.43	135,380.92
2007	2.10%	102,513.37	4,100.53	136,684.50
2008	6.63%	104,671.18	4,186.85	139,561.57
2009	0.60%	111,608.57	4,464.34	148,811.43
2010	2.82%	112,274.54	4,490.98	149,699.39
2011	5.25%	115,444.84	4,617.79	153,926.45
2012	4.58%	121,503.15	4,860.13	162,004.20
2013	2.36%	127,062.65	5,082.51	169,416.87
2014	1.03%	130,059.55	5,202.38	173,412.73
2015	-0.52%	131,392.79	5,255.71	175,190.39
2016	-0.53%	130,706.13	5,228.25	174,274.84
2017	0.58%	130,010.38	5,200.42	173,347.18
2018	0.44%	130,759.63	5,230.39	174,346.18
2019	0.57%	131,333.15	5,253.33	175,110.86
2020	-0.18%	132,075.57	5,283.02	176,100.76
2021	2.30%	131,835.33	5,273.41	175,780.43
2022	6.12%	134,874.00	5,394.96	179,832.00
2023	4.80%	143,129.77	5,725.19	190,839.69
2024		**150,000**	**6,000**	**200,000**

Appendix: Suitable substitute for vehicles identified

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3-Tonne Truck

Models	Load Capacity	Fuel Efficiency
Canter FECX1	3,785kg	9.5km/l
Current Fleet	3,000kg	5.78km/l

Panel Van

Models	Load Capacity	Fuel Efficiency
Nissan NV200	860kg	19.2km/l
Current Fleet	800kg	13.2 km/l

Motorcycle

Models	Load Capacity	Fuel Efficiency
Yamaha YBR125	190kg	35km/l
Current Fleet	146kg	19.0 km/l

Appendix: Why choose motorcycles to phase out?

6,628 MOTORCYCLES

57% OF OPTIMUS PRIME'S MILEAGE

- Biggest fleet with the highest mileage, **due to be phased out** in phase 3
- Doing so in phase 2 increases **logistical ease** in phase 3
- Also enables more time for **cash accumulation**
- Costs can also be **covered by sale of old motorcycles**

G1			Non-Fuel Cost Savings	Per Unit Gain from Sale of Old Vehicle		Total Cost Savings
Panel Van	$P	$	8,780	55621.68	$	46,842.09
3-tonne Truck	$P	$	3,265	84,393	$	81,128.36
Motorcycle	$P	$	(1,141)	2,532	$	3,672.69
Pick-up truck	$P	$	3,737	82,265	$	78,528.55
Window Van	$P	$	1,706	39,115	$	37,409.85
7-seater Van	$P	$	1,551	76,341	$	74,790.34
Patrol Vans	$P	$	1,581	47,179	$	45,597.92
8-tonne Truck	$P	$	519	101,789	$	101,269.85

* average age of vehicle is assumed for calculation of resale value

Appendix: Why not just lease EVs directly?

Considering the financial constraints of Optimus Prime,

- Average EV lease prices are **50% higher** than ICE vehicles, not considering **high charging rates**
- To work towards our long term goal of ***sustainable electrification of our fleet***, it is more cost-efficient in the long run to first lease old ICE vehicles
  - *Accumulate cash for ownership of electric vehicles*
  - *Accumulate cash for implementation of infrastructure*
- Transitioning directly to EVs carries inherent risks, including uncertainties related to technology, infrastructure, and market acceptance.
  - Leasing ICE vehicles for the first 7 years provides a gradual transition period, allowing Optimus Prime to mitigate risks and address potential challenges before committing fully to EVs.

Appendix: Potential leasing partners

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3-Tonne Truck

GOLDBELL

PAN PACIFIC LEASING GROUP
LEASING REDEFINED

FCY ENTERPRISE

Canter FECX1

- **Headquartered in Singapore**
- $1,750+/month

Panel Van

A & L GROUP

AUTODEALZ
DRIVEN BY DEDICATION

CAR CHOICE
SINGAPORE

Honda N Van

- **Big commercial vehicle leasing companies**
- $1,000+/month

Motorcycle

AloRide RENTAL

Ban Hock Hin Co Pte Ltd

VROOM

Yamaha YBR125

- **Trusted local brands**
- $300+/month

Appendix: Cost of Replacing Optimus Prime’s Entire Fleet with EVs

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```python
# Calculate the purchase cost for these vehicles
# Map the purchase costs to the vehicles in the DataFrame
older_vehicles['Purchase Cost'] = older_vehicles['Category'].map(purchase_costs)

# Show the updated DataFrame with the 'Purchase Cost' column
print(older_vehicles.head())

# Show the Total Cost of switching the current old vehicles to EVs
total_purchase_cost = older_vehicles['Purchase Cost'].sum()
total_number_of_vehicles = older_vehicles.shape[0]  # number of rows
print("\nTotal Cost of Switching old vehicles to EVs:")
print(f"Total Purchase Cost: ${total_purchase_cost:,.2f}")
print(f"Number of Vehicles to be replaced: {total_number_of_vehicles}")


# Also calculate what is the Total Cost of switching the entire fleet
fleet_data['Purchase Cost'] = fleet_data['Category'].map(purchase_costs)
total_fleet_purchase_cost = fleet_data['Purchase Cost'].sum()
total_number_of_fleet_vehicles = fleet_data.shape[0]  # number of rows
print("\nTotal Cost of Switching the entire fleet to EVs:")
print(f"Total Purchase Cost: ${total_fleet_purchase_cost:,.2f}")
print(f"Number of Vehicles to be replaced: {total_number_of_fleet_vehicles}")
```

```
            District    Category        Type     Business Unit Vehicle Brand  \
0  Heritage Highlands  Motorcycle  Motorcycle  Domestic Parcels         HONDA
1  Heritage Highlands  Motorcycle  Motorcycle  Domestic Parcels         HONDA
2  Heritage Highlands  Motorcycle  Motorcycle  Domestic Parcels         HONDA
3  Heritage Highlands  Motorcycle  Motorcycle  Domestic Parcels         HONDA
4  Heritage Highlands  Motorcycle  Motorcycle  Domestic Parcels         HONDA

  Vehicle Model  Vehicle Manufactured Year  Purchase Cost
0     C1004-MA                       2008           8000
1     C1004-MA                       2008           8000
2     C1004-MA                       2008           8000
3     C1004-MA                       2008           8000
4     C1004-MA                       2008           8000

Total Cost of Switching old vehicles to EVs:
Total Purchase Cost: $335,040,000.00
Number of Vehicles to be replaced: 4650

Total Cost of Switching the entire fleet to EVs:
Total Purchase Cost: $753,534,000.00
Number of Vehicles to be replaced: 10167
```

Appendix: Fuel Cost-savings of Replacing Optimus Prime's Entire Fleet with EVs

```python
EV_energy_efficiency = {
    'Motorcycle': 0.09,
    'Panel Van': 0.26,
    '3-tonne Truck': 1.5,
    'Window Van': 0.26,
    'Patrol Vans': 0.26,
    '7-seater Van': 0.26,
    '8-tonne Truck': 1.5,
    'Pick-up truck': 1.5
}
# Calculate total fuel cost for each vehicle category
fleet_log['Total Fuel Cost'] = (fleet_log['Fuel Amount2020 ($P)'] + fleet_log['Fuel Amount2021 ($P)']) / 2

# Calculate total electricity cost for each vehicle category
fleet_log['Total Electricity Cost'] = (fleet_log['Average Total Distance'] * fleet_log['Category'].apply(lambda x: EV_energy_efficiency.get(x, 0)) * 0.4)

# Sum up total fuel and electricity costs for the entire fleet
total_fuel_cost = fleet_log['Total Fuel Cost'].sum()
total_electricity_cost = fleet_log['Total Electricity Cost'].sum()

# Calculate change in fuel cost
change_in_fuel_cost = total_fuel_cost - total_electricity_cost

# Calculate percentage change in fuel cost and round to the nearest integer
percentage_change_in_fuel_cost = round((change_in_fuel_cost / total_fuel_cost) * 100)

print("Percentage Change in fuel cost if switching whole fleet to EVs:", percentage_change_in_fuel_cost, "%")
```

```
Percentage Change in fuel cost if switching whole fleet to EVs: -61 %
```

```python
# Calculate the percentage change in fuel cost for each vehicle type
fleet_log['Percentage Change in Fuel Cost'] = ((fleet_log['Total Fuel Cost'] - fleet_log['Total Electricity Cost']) / fleet_log['Total Fuel Cost']) * 100

# Now you have the percentage change in fuel cost for each vehicle category in the 'Percentage Change in Fuel Cost' column
print(fleet_log[['Category', 'Percentage Change in Fuel Cost']])
```

```
        Category  Percentage Change in Fuel Cost
0      Panel Van                       29.126363
1  3-tonne Truck                      -70.024656
2     Motorcycle                      -84.064948
3  Pick-up truck                     -584.882748
4     Window Van                       13.835656
5   7-seater Van                       40.959053
6    Patrol Vans                       29.429916
7  8-tonne Truck                      -64.046862
<ipython-input-67-ebb6f365f74f>:2: SettingWithCopyWarning:


A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
```

Appendix: Maintenance Cost-savings of Replacing Optimus Prime's Entire Fleet with EVs

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(b) Look at the long term savings when we convert their entire fleet into EVs.

```python
# Analyse the long-term maintenance cost for entire fleet

# Get the a dictionary for the total avg distance travelled per vehicle type
avg_total_distances = fleet_log.groupby('Category')['Average Total Distance'].mean().to_dict()
avg_total_distances.pop('TOTAL', None)


# Calculate the total current and potential maintenance costs for the entire fleet
total_current_maintenance_cost = sum(
    (avg_total_distances[cat] / 1000) * ICEmaintenance_cost_per_1000km[cat] for cat in avg_total_distances
)
total_potential_maintenance_cost = sum(
    (avg_total_distances[cat] / 1000) * EVmaintenance_cost_per_1000km[cat] for cat in avg_total_distances
)

# Calculate the total savings from switching to EVs
total_savings = total_current_maintenance_cost - total_potential_maintenance_cost

print(f"Total Current Maintenance Cost: ${total_current_maintenance_cost:,.2f}")
print(f"Total Potential Maintenance Cost after Switching to EVs: ${total_potential_maintenance_cost:,.2f}")
print(f"Total Savings from complete switch to EVs per year: ${total_savings:,.2f}")
```

```
Total Current Maintenance Cost: $5,545,948.49
Total Potential Maintenance Cost after Switching to EVs: $4,262,354.45
Total Savings from complete switch to EVs per year: $1,283,594.04
```

Appendix: Change in CO2 Emissions when replace Optimus Prime's Entire Fleet with EVs

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```python
total_electricity_emissions_motorcycle = (124063672 * EV_energy_efficiency['Motorcycle'] * 0.55)
total_electricity_emissions_panel_van = (49819434 * EV_energy_efficiency['Panel Van'] * 0.55)
total_electricity_emissions_3tonne_truck = (14750403 * EV_energy_efficiency['3-tonne Truck'] * 0.55)
total_electricity_emissions_pickup_truck = (12960361 * EV_energy_efficiency['Pick-up truck'] * 0.55)
total_electricity_emissions_window_van = (1699607 * EV_energy_efficiency['Window Van'] * 0.55)
total_electricity_emissions_7seater_van = (708474 * EV_energy_efficiency['7-seater Van'] * 0.55)
total_electricity_emissions_patrol_vans = (661600 * EV_energy_efficiency['Patrol Vans'] * 0.55)
total_electricity_emissions_8tonne_truck = (52286 * EV_energy_efficiency['8-tonne Truck'] * 0.55)

total_electricity_emissions = (total_electricity_emissions_panel_van +
                               total_electricity_emissions_3tonne_truck +
                               total_electricity_emissions_motorcycle +
                               total_electricity_emissions_pickup_truck +
                               total_electricity_emissions_window_van +
                               total_electricity_emissions_7seater_van +
                               total_electricity_emissions_patrol_vans +
                               total_electricity_emissions_8tonne_truck)

total_petrol_emissions_panel_van = (fleet_log[fleet_log['Category'] == 'Panel Van']['Fuel Amount2020 ($P)'] + fleet_log[fleet_log['Category'] == 'Panel Van']['Fuel Amount2021
total_diesel_emissions_3_tonne_truck = (fleet_log[fleet_log['Category'] == '3-tonne Truck']['Fuel Amount2020 ($P)'] + fleet_log[fleet_log['Category'] == '3-tonne Truck']['Fue
total_petrol_emissions_motorcycle = (fleet_log[fleet_log['Category'] == 'Motorcycle']['Fuel Amount2020 ($P)'] + fleet_log[fleet_log['Category'] == 'Motorcycle']['Fuel Amount2
total_petrol_emissions_pickup_truck = (fleet_log[fleet_log['Category'] == 'Pick-up truck']['Fuel Amount2020 ($P)'] + fleet_log[fleet_log['Category'] == 'Pick-up truck']['Fuel
total_petrol_emissions_window_van = (fleet_log[fleet_log['Category'] == 'Window Van']['Fuel Amount2020 ($P)'] + fleet_log[fleet_log['Category'] == 'Window Van']['Fuel Amount2
total_petrol_emissions_7_seater_van = (fleet_log[fleet_log['Category'] == '7-seater Van']['Fuel Amount2020 ($P)'] + fleet_log[fleet_log['Category'] == '7-seater Van']['Fuel A
total_petrol_emissions_patrol_vans = (fleet_log[fleet_log['Category'] == 'Patrol Vans']['Fuel Amount2020 ($P)'] + fleet_log[fleet_log['Category'] == 'Patrol Vans']['Fuel Amou
total_diesel_emissions_8_tonne_truck = (fleet_log[fleet_log['Category'] == '8-tonne Truck']['Fuel Amount2020 ($P)'] + fleet_log[fleet_log['Category'] == '8-tonne Truck']['Fue

total_petrol_emissions_panel_van /= 2
total_diesel_emissions_3_tonne_truck /= 2
total_petrol_emissions_motorcycle /= 2
total_petrol_emissions_pickup_truck /= 2
total_petrol_emissions_window_van /= 2
total_petrol_emissions_7_seater_van /= 2
total_petrol_emissions_patrol_vans /= 2
total_diesel_emissions_8_tonne_truck /= 2
```

```python
total_internal_combustion_emissions = (
    total_petrol_emissions_panel_van +
    total_diesel_emissions_3_tonne_truck +
    total_petrol_emissions_motorcycle +
    total_petrol_emissions_pickup_truck +
    total_petrol_emissions_window_van +
    total_petrol_emissions_7_seater_van +
    total_petrol_emissions_patrol_vans +
    total_diesel_emissions_8_tonne_truck
)

# Calculate change in carbon emissions
change_in_carbon_emissions = total_internal_combustion_emissions -  total_electricity_emissions
print("Change in carbon emissions if switching to EVs:", change_in_carbon_emissions, "kgCO2")

# Calculate percentage change in carbon emissions
percentage_change_in_carbon_emissions = (change_in_carbon_emissions / total_internal_combustion_emissions) * 100
print("Percentage Change in carbon emissions if switching to EVs:", percentage_change_in_carbon_emissions, "%")
```

```
Change in carbon emissions if switching to EVs: 10052614.788848862 kgCO2
Percentage Change in carbon emissions if switching to EVs: 21.54373665188234 %
```

Appendix: Cost of Replacing High Carbon Emissions Vehicles

```
Total purchase cost for high carbon emissions EVs: $579,654,000.00
Number of Motorcycles: 6628
Purchase Cost for Motorcycles: $53,024,000.00

Number of 3-tonne Trucks: 331
Purchase Cost for 3-tonne Trucks: $82,750,000.00

Number of Panel Vans: 2466
Purchase Cost for Panel Vans: $443,880,000.00
```

Appendix: Fuel Cost-savings of Replacing High Carbon Emissions Vehicles


```python
# Filter fleet_log for specific categories
selected_categories = ['Motorcycle', 'Panel Van', '3-tonne Truck']
filtered_fleet_log = fleet_log[fleet_log['Category'].isin(selected_categories)]

# Calculate total fuel cost for each vehicle category
filtered_fleet_log['Total Fuel Cost'] = (filtered_fleet_log['Fuel Amount2020 ($P)'] + filtered_fleet_log['Fuel Amount2021 ($P)']) / 2

# Calculate total electricity cost for each vehicle category
filtered_fleet_log['Total Electricity Cost'] = (filtered_fleet_log['Average Total Distance'] * filtered_fleet_log['Category'].apply(lambda x: EV_energy_efficiency.get(x, 0)) *

# Sum up total fuel and electricity costs for the selected categories
total_fuel_cost_selected = filtered_fleet_log['Total Fuel Cost'].sum()
total_electricity_cost_selected = filtered_fleet_log['Total Electricity Cost'].sum()

# Calculate change in fuel cost
change_in_fuel_cost_selected = total_fuel_cost_selected - total_electricity_cost_selected

# Calculate percentage change in fuel cost and round to the nearest integer
percentage_change_in_fuel_cost_selected = round((change_in_fuel_cost_selected / total_fuel_cost_selected) * 100)

print("Percentage Change in fuel cost if switching selected categories to EVs:", percentage_change_in_fuel_cost_selected, "%")
```

```
Percentage Change in fuel cost if switching selected categories to EVs: -24 %
```

Appendix: Maintenance Cost-savings of Replacing High Carbon Emissions Vehicles

```python
# Cost-savings in Maintenance
total_average_distance_motorcycles = 124063672.0

# Calculate maintenance costs for current ICE motorcycles and future EV motorcycles
total_current_maintenance_cost = (total_average_distance_motorcycles / 1000) * ICEmaintenance_cost_per_1000km['Motorcycle']
total_new_maintenance_cost = (total_average_distance_motorcycles / 1000) * EVmaintenance_cost_per_1000km['Motorcycle']

# Calculate savings in dollars
total_savings = total_current_maintenance_cost - total_new_maintenance_cost

# Calculate the percentage of cost-savings
percentage_of_savings = (total_savings / total_current_maintenance_cost) * 100

# Print the maintenance cost-savings and percentage of cost-savings
print(f"The short-term maintenance cost-savings in 1 year from replacing ICE motorcycles with EVs is: ${total_savings:,.2f}")
print(f"Percentage of maintenance cost-savings: {percentage_of_savings:.2f}%")

fleet_data[fleet_data['Category'] == 'Motorcycle'].count()
```

```
The short-term maintenance cost-savings in 1 year from replacing ICE motorcycles with EVs is: $124,063.67
Percentage of maintenance cost-savings: 12.50%
```

Appendix: Change in CO2 Emissions from replacing High Carbon Emissions Vehicles

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```
# Calculate total carbon emissions for electric motorcycles
total_electricity_emissions = (total_electricity_emissions_panel_van +
                               total_electricity_emissions_3tonne_truck +
                               total_electricity_emissions_motorcycle) *

# Calculate total electricity needed for all vehicle categories
total_carbon_emissions_all_categories = (
    total_petrol_emissions_pickup_truck +
    total_petrol_emissions_window_van +
    total_petrol_emissions_7_seater_van +
    total_petrol_emissions_patrol_vans +
    total_diesel_emissions_8_tonne_truck
)

# Calculate change in carbon emissions for the selected categories
change_in_carbon_emissions_selected = total_internal_combustion_emissions - (total_carbon_emissions_all_categories + total_electricity_emissions)
print("Change in carbon emissions for selected categories if switching to EVs:", change_in_carbon_emissions_selected, "kgCO2")

# Calculate percentage change in carbon emissions
percentage_change_in_carbon_emissions_selected = (change_in_carbon_emissions_selected / total_internal_combustion_emissions) * 100
print("Percentage Change in carbon emissions for selected categories if switching to EVs:", percentage_change_in_carbon_emissions_selected, "%")
```

```
Change in carbon emissions for selected categories if switching to EVs: 6759219.566848867 kgCO2
Percentage Change in carbon emissions for selected categories if switching to EVs: 14.48566859261074 %
```

Appendix: Cost of Replacing Old and High Carbon Emissions Vehicles

```python
# Map the purchase costs to the vehicles in the DataFrame
replacement_vehicles['Purchase Cost'] = replacement_vehicles['Category'].map(purchase_costs)

# Show the updated DataFrame with the 'Purchase Cost' column
print(replacement_vehicles.head())

# Show the Total Cost of switching the current old vehicles to EVs
total_purchase_cost = replacement_vehicles['Purchase Cost'].sum()
total_number_of_vehicles = replacement_vehicles.shape[0]  # number of rows
print("\nTotal Cost of switching old and high Carbon Emissions vehicles to EVs:")
print(f"Total Purchase Cost: ${total_purchase_cost:,.2f}")
print(f"Number of Vehicles to be replaced: {total_number_of_vehicles}")
```

```
             District    Category        Type     Business Unit Vehicle Brand  \
0  Heritage Highlands  Motorcycle  Motorcycle  Domestic Parcels         HONDA
1  Heritage Highlands  Motorcycle  Motorcycle  Domestic Parcels         HONDA
2  Heritage Highlands  Motorcycle  Motorcycle  Domestic Parcels         HONDA
3  Heritage Highlands  Motorcycle  Motorcycle  Domestic Parcels         HONDA
4  Heritage Highlands  Motorcycle  Motorcycle  Domestic Parcels         HONDA

  Vehicle Model  Vehicle Manufactured Year  Purchase Cost
0      C1004-MA                       2008           8000
1      C1004-MA                       2008           8000
2      C1004-MA                       2008           8000
3      C1004-MA                       2008           8000
4      C1004-MA                       2008           8000

Total Cost of switching old and high Carbon Emissions vehicles to EVs:
Total Purchase Cost: $23,920,000.00
Number of Vehicles to be replaced: 2990
```

Appendix: Fuel Cost-savings of Replacing Old and High Carbon Emissions Vehicles

```
# Filter fleet_log for the 'Motorcycle' category
motorcycle_data = fleet_log[fleet_log['Category'] == 'Motorcycle']

# Calculate total fuel cost for motorcycles
total_fuel_cost_motorcycles = (motorcycle_data['Fuel Amount2020 ($P)'] + motorcycle_data['Fuel Amount2021 ($P)']).mean()

# Calculate total electricity cost for motorcycles
total_electricity_cost_motorcycles = (motorcycle_data['Average Total Distance'] * EV_energy_efficiency['Motorcycle'] * electricity_cost_per_kWh).sum()

# Calculate change in fuel cost
change_in_fuel_cost_motorcycles = total_fuel_cost_motorcycles - total_electricity_cost_motorcycles

# Calculate percentage change in fuel cost and round to the nearest integer
percentage_change_in_fuel_cost_motorcycles = round((change_in_fuel_cost_motorcycles / total_fuel_cost_motorcycles) * 100)

print("Percentage Change in fuel cost for switching old and high carbon emissions vehicles to EVs:", percentage_change_in_fuel_cost_motorcycles, "%")
```

```
Percentage Change in fuel cost for switching old and high carbon emissions vehicles to EVs: 8 %
```

Appendix: Maintenance Cost-savings of Replacing Old and High Carbon Emissions Vehicles

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```
[1349] # Analyse the short-term maintenance cost for switching old & high carbon emissions fleet
replacement_count = replacement_vehicles['Category'].value_counts()
# Go look at the 7-seater Van and calculate the distance
total_average_distance_motorcycle = 124063672
curr_no_of_motorcycle = 6628
replace_no_of_motorcycle = 2990
EV_total_average_distance_motorcycle = (total_average_distance_motorcycle/curr_no_of_motorcycle) * replace_no_of_motorcycle

# Calculate maintenance costs
total_current_maintenance_cost = (total_average_distance_motorcycle / 1000) * ICEmaintenance_cost_per_1000km['Motorcycle']
total_new_maintenance_cost = ((total_average_distance_motorcycle-EV_total_average_distance_motorcycle) / 1000) * ICEmaintenance_cost_per_1000km['Motorcycle'] + ((EV_total_ave

# Calculate savings
total_savings = total_current_maintenance_cost - total_new_maintenance_cost
print(f"The short-term maintenance cost-savings in 1 year of replacing old + carbon inefficient ICE vehicles with EVs: ${total_savings:,.2f}")

# Calculate percentage cost savings
percentage_savings = (total_savings / total_current_maintenance_cost) * 100
print(f"The percentage short-term maintenance cost-savings in 1 year of replacing old + carbon inefficient ICE vehicles with EVs: {percentage_savings:.2f}%")
```

```
The short-term maintenance cost-savings in 1 year of replacing old + carbon inefficient ICE vehicles with EVs: $55,967.17
The percentage short-term maintenance cost-savings in 1 year of replacing old + carbon inefficient ICE vehicles with EVs: 5.64%
```

Appendix: Change in CO2 Emissions from Replacing Old and High Carbon Emissions Vehicles

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```
# Calculate total carbon emissions for electric motorcycles
total_electricity_emissions_motorcycle = (((2990/6628)* 124063672.0 )* EV_energy_efficiency['Motorcycle'] * 0.55)

# Calculate total electricity needed for all vehicle categories
total_carbon_emissions_all_categories = (
    total_petrol_emissions_panel_van +
    total_diesel_emissions_3_tonne_truck +
    total_petrol_emissions_pickup_truck +
    total_petrol_emissions_window_van +
    total_petrol_emissions_7_seater_van +
    total_petrol_emissions_patrol_vans +
    total_diesel_emissions_8_tonne_truck
)

# Calculate change in carbon emissions for motorcycles
change_in_carbon_emissions_motorcycle = total_internal_combustion_emissions - total_carbon_emissions_all_categories - total_electricity_emissions_motorcycle

print("Change in carbon emissions for 2990 motorcycles if switching to EVs:", change_in_carbon_emissions_motorcycle, "kgCO2")

# Calculate percentage change in carbon emissions for motorcycles
if total_internal_combustion_emissions != 0:
    percentage_change_in_carbon_emissions_motorcycle = (change_in_carbon_emissions_motorcycle / total_internal_combustion_emissions) * 100
    print("Percentage Change in carbon emissions for 2990 motorcycles if switching to EVs:", percentage_change_in_carbon_emissions_motorcycle, "%")
else:
    print("Cannot calculate percentage change: Total internal combustion emissions for 2990 motorcycles are zero.")

total_electricity_emissions_motorcycle
```

```
Change in carbon emissions for 2990 motorcycles if switching to EVs: 3805375.803005588 kgCO2
Percentage Change in carbon emissions for 2990 motorcycles if switching to EVs: 8.15529251676275 %
2770374.7396439346
```

Appendix: Calculating Short-term EV Infrastructure

```python
# Short term
# Constants
charger_costs = {'22 kW DC': 8000, '60 kW DC': 100000, '120 kW DC': 220000} #($P)
charger_support_ratios = {'Motorcycle': 10, 'Van': 5, 'Truck': 2}
charging_power = {'Motorcycle': 22, 'Van': 60, 'Truck': 120}
public_charging_rate = {'22 kW DC': 0.3,'60 kW DC':0.3, '120 kW DC': 2.2}  # Assuming same rate for 60 kW and 120 kW for simplicity #($P/min)
total_chargers_needed = {'22 kW DC': 0, '60 kW DC': 0, '120 kW DC': 0}


# EV Energy Efficiencies (kWh/km)
EV_energy_efficiency = {
    'Motorcycle': 0.09,
    'Van': 0.26,
    'Truck': 1.5
}

for category, num_vehicles in replacement_old_vehicles.items():
    # Map the specific vehicle category to its general category for calculations
    general_category = category_map[category]

    # Determine charger type based on general category
    charger_type = '22 kW DC' if general_category == 'Motorcycle' else ('120 kW DC' if general_category == 'Truck' else '60 kW DC')

    # Calculate chargers needed using the general category
    chargers_needed = math.ceil(num_vehicles / charger_support_ratios[general_category])
    infrastructure_cost = chargers_needed * charger_costs[charger_type]

    # Calculate kWh needed and annual charging cost
    total_distance = total_average_distance[category]
    kWh_needed = total_distance * EV_energy_efficiency[general_category]
    charging_power_kw = charging_power[general_category]  # Use general_category to fetch charging power
    charging_hours = kWh_needed / charging_power_kw
    charging_minutes = charging_hours * 60
    annual_charging_cost = charging_minutes * public_charging_rate[charger_type]
    total_chargers_needed[charger_type] += chargers_needed

    print(f"Category: {category}")
    print(f"Number of Chargers needed: {chargers_needed}")
    print(f"  Infrastructure Cost: ${infrastructure_cost:,.2f}")
    print(f"  Annual Charging Cost: ${annual_charging_cost:,.2f}\n")


print("Total number of each type of charger needed:")
for charger_type, total_needed in total_chargers_needed.items():
    print(f"{charger_type}: {total_needed}")
```

```
Category: Motorcycle
Type of Charger needed: 22 kW DC
Number of Chargers needed: 663
  Infrastructure Cost: $5,304,000.00
  Annual Charging Cost: $9,135,597.67

Category: Panel Van
Type of Charger needed: 60 kW DC
Number of Chargers needed: 494
  Infrastructure Cost: $49,400,000.00
  Annual Charging Cost: $3,885,915.85

Category: 3-tonne truck
Type of Charger needed: 120 kW DC
Number of Chargers needed: 166
  Infrastructure Cost: $36,520,000.00
  Annual Charging Cost: $24,338,164.95
```

Assumption:
One charging station has to capacity to charge 10 motorcycles or 5 vans or 2 trucks at any point in time.

Appendix: Calculating Long-term EV Infrastructure

```python
# Long term

total_chargers_needed = {'22 kW DC': 0, '60 kW DC': 0, '120 kW DC': 0}


for category, num_vehicles in older_vehicles_to_replace.items():
    # Map the specific vehicle category to its general category for calculations
    general_category = category_map[category]

    # Determine charger type based on general category
    charger_type = '22 kW DC' if general_category == 'Motorcycle' else ('120 kW DC' if general_category == 'Truck' else '60 kW DC')


    # Calculate chargers needed using the general category
    chargers_needed = math.ceil(num_vehicles / charger_support_ratios[general_category])
    infrastructure_cost = chargers_needed * charger_costs[charger_type]

    # Calculate kWh needed and annual charging cost
    total_distance = total_average_distance[category]
    kWh_needed = total_distance * EV_energy_efficiency[general_category]
    charging_power_kw = charging_power[general_category]  # Use general_category to fetch charging power
    charging_hours = kWh_needed / charging_power_kw
    charging_minutes = charging_hours * 60
    annual_charging_cost = charging_minutes * public_charging_rate[charger_type]
    total_chargers_needed[charger_type] += chargers_needed

    print(f"Category: {category}")
    print(f"Type of Charger needed: {charger_type}")
    print(f"Number of Chargers needed: {chargers_needed}")
    print(f"  Infrastructure Cost: ${infrastructure_cost:,.2f}")
    print(f"  Annual Charging Cost: ${annual_charging_cost:,.2f}\n")

print("Total number of each type of charger needed:")
for charger_type, total_needed in total_chargers_needed.items():
    print(f"{charger_type}: {total_needed}")
```

```
Category: Motorcycle
Type of Charger needed: 22 kW DC
Number of Chargers needed: 663
  Infrastructure Cost: $5,304,000.00
  Annual Charging Cost: $9,135,597.67

Category: Panel Van
Type of Charger needed: 60 kW DC
Number of Chargers needed: 494
  Infrastructure Cost: $49,400,000.00
  Annual Charging Cost: $3,885,915.85

Category: 3-tonne truck
Type of Charger needed: 120 kW DC
Number of Chargers needed: 166
  Infrastructure Cost: $36,520,000.00
  Annual Charging Cost: $24,338,164.95

Category: Window Van
Type of Charger needed: 60 kW DC
Number of Chargers needed: 10
  Infrastructure Cost: $1,000,000.00
  Annual Charging Cost: $132,569.39

Category: Patrol Vans
Type of Charger needed: 60 kW DC
Number of Chargers needed: 10
  Infrastructure Cost: $1,000,000.00
  Annual Charging Cost: $51,604.80

Category: 7-seater Van
Type of Charger needed: 60 kW DC
Number of Chargers needed: 14
  Infrastructure Cost: $1,400,000.00
  Annual Charging Cost: $55,261.01

Category: 8-tonne truck
Type of Charger needed: 120 kW DC
Number of Chargers needed: 12
  Infrastructure Cost: $2,640,000.00
  Annual Charging Cost: $86,271.90

Category: Pick-up truck
Type of Charger needed: 120 kW DC
Number of Chargers needed: 276
  Infrastructure Cost: $60,720,000.00
  Annual Charging Cost: $21,384,596.48

Total number of each type of charger needed:
22 kW DC: 663
60 kW DC: 528
120 kW DC: 454
```

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