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KINETIC ENERGY RECOVERY

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Alternative Propulsion Systems

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Chapter 1 – Introduction

This study focuses on a Tesla Cybertruck, which has been chosen for an investigation into the application of a Kinetic Energy Recovery System (KERS). Analysis will be conducted to evaluate the potential for energy recovery during vehicle operation while under the Worldwide Harmonised Light Vehicle Test Procedure (WLTP). Furthermore, the vehicle's key dynamic characteristics; including test mass, frontal area, rolling resistance coefficient and aerodynamic drag coefficient are identified and applied.

A spreadsheet is created with the intention of plotting the cumulative tractive and braking energies required at the wheel throughout the WLTP cycle. Additionally, the analysis identifies the periods of maximum potential KERS power input and corresponding energy storage requirements. Based on the results, a suitable KERS configuration is identified, with component sizing and efficiency values determined.

Finally, the recovered kinetic energy is plotted, followed by an analysis of the system's operational principles, and the potential impact on driver experience relative to conventional ICE and friction braking systems.

Chapter 2 – Tesla Cybertruck Dynamic Characteristics

Table 1 – Test Mass Calculation

<i>Parameter</i>	<i>Description / Formula</i>	<i>Value (kg)</i>	<i>Notes</i>	<i>Reference</i>
Vehicle Category	Category 1 (Passenger Vehicle)	—	15% load factor (0.15)	(Find Your EV, 2025) (Addendum 15: Global technical regulation No. 15 – Global technical regulation on Worldwide harmonized Light vehicles Test Procedures (WLTP): Amendment 3, 2018)
Vehicle Mass	—	3,104	Excludes Driver + Test Equipment	
Driver Assumed Mass	(WLTP §3.2.6)	+ 75	Added to vehicle mass	
Standard Allowance	(WLTP §3.2.25)	+ 25	Fixed Addition	
Actual Vehicle Mass	$3,104 + 75 + 25$	3,204	Base Mass	
Vehicle Payload	Maximum Payload	1,055	—	
Mass Representative	$0.15 \times 1,055$	158.25	15% Load Factor	
Test Mass	$3,204 + 158.25$	$\approx 3,362 \text{ kg}$	Final WLTP Test Mass	

Table 2 – Vehicle Parameters

<i>Parameter</i>	<i>Value</i>	<i>Reference</i>
Drag Coefficient (Cd)	0.34	(Find Your EV, 2025)
Frontal Area (A)	3.19	
Rolling Resistance Coefficient (Crr)	≈ 0.0126	(Bower, 2019)

Chapter 3 – Worldwide harmonised Light vehicle Test Procedure (WLTP)

Table 3 – WLTP Test Class

<i>Parameter</i>	<i>Symbol</i>	<i>Value</i>	<i>Unit</i>	<i>Notes</i>
Rated Power	(P)	630,000	W (630 kW)	Peak Power
Kerb Mass	(m)	3,104	kg	Approximate curb weight
Power-to-Mass Ratio	P / m	$630,000 / 3,104 = 202.96 \approx \mathbf{203}$	W/kg	$630,000 / 3,104$
WLTP Class 1 Limit	—	≤ 22	W/kg	Low-power vehicles
WLTP Class 2 Range	—	$> 22 \text{ and } \leq 34$	W/kg	Medium-power vehicles
WLTP Class 3 Threshold	—	> 34	W/kg	High-performance vehicles
Resulting Class	—	Class 3	—	($203 > 34$)

Figure 1, Excel Spreadsheet, Explanation, 2025

This file contains the WLTC cycles for validation 2, based on the following preliminary vehicle classification:									
Class 1	ratio of rated power in W / kerb mass in kg ≤ 22								
(version 1)	The table with the speed trace is named "WLTC_class_1" and contains a low and a medium speed part.								
	If $v_{max} \geq 70$ km/h, phase low is repeated after phase medium.								
	If $v_{max} < 70$ km/h, phase medium is replaced by a repetition of phase low.								
	If a vehicle has a ratio of rated power in W divided by kerb mass in kg close to the borderline, any additional tests with the WLTC, class 2, version 1.4 cycle are highly welcomed.								
Class 2	ratio of rated power in W / kerb mass in kg > 22 but ≤ 34								
(version 1)	The table with the speed trace is named "WLTC_class_2" and contains a low, a medium and a high speed part.								
	If $v_{max} < 90$ km/h, phase high is replaced by a repetition of phase low.								
	If a vehicle with a ratio of rated power in W divided by kerb mass in kg between 22 and 34, but close to the lower borderline cannot follow the WLTC class 2, version 1.4 speed trace it shall proceed at full throttle until the reference speed profile is reached again. This test shall be repeated at least 3 times. Additionally, the same vehicle can be tested with the WLTC, class 1, version 1.4 driving cycle (3 tests), provided that all the other provisions of the WLTP are the same as before.								
	If a vehicle has a ratio of rated power in W divided by kerb mass in kg between 22 and 34, but close to the upper borderline, any additional tests with the WLTC, class 3, version 5 cycle are highly welcomed.								
Class 3	ratio of rated power in W / kerb mass in kg > 34								
(version 5)	The table with the speed trace is named "WLTC_class_3" and contains a low, a medium, a high and an extra high speed part.								
	If $v_{max} < 135$ km/h, phase high is replaced by a repetition of phase low.								
	If a vehicle with a ratio of rated power in W divided by kerb mass in kg > 34 , but close to this borderline cannot follow the WLTC class 3, version 5 speed trace it shall proceed at full throttle until the reference speed profile is reached again. This test shall be repeated at least 3 times. Additionally, the same vehicle can be tested with the WLTC, class 2, version 1.4 driving cycle (3 tests), provided that all the other provisions of the WLTP are the same as before.								
	kerb mass means the "unladen mass" as defined in ECE R83.								
	v_{max} is the maximum speed of the vehicle as declared by the manufacturer (ECE R 68) and not any use restriction or safety based limitation.								

The Tesla Cybertruck is able to achieve a power-to-weight ratio of around 203 watts per kilogram (W/kg), this figure is far above the 34 W/kg threshold for WLTP Class 3.

Furthermore, this classification means that the vehicle must be tested under the WLTC Class 3 cycle, which includes low, medium, high, and extra high-speed phases. To add, the WLTP procedure, conveys that; if a vehicle's maximum speed (v_{max}) is below 135 km/h, the high-speed phase is replaced by a repetition of the low-speed phase to ensure the test remains representative of the vehicle's real-world capabilities.

However, the Cybertruck has a maximum speed exceeding 209 km/h, meaning it easily qualifies to complete all four WLTC Class 3 phases. This ensures that its test cycle accurately reflects the performance and operational range of a high-power, highway-capable electric vehicle.

Chapter 4 – Spreadsheet

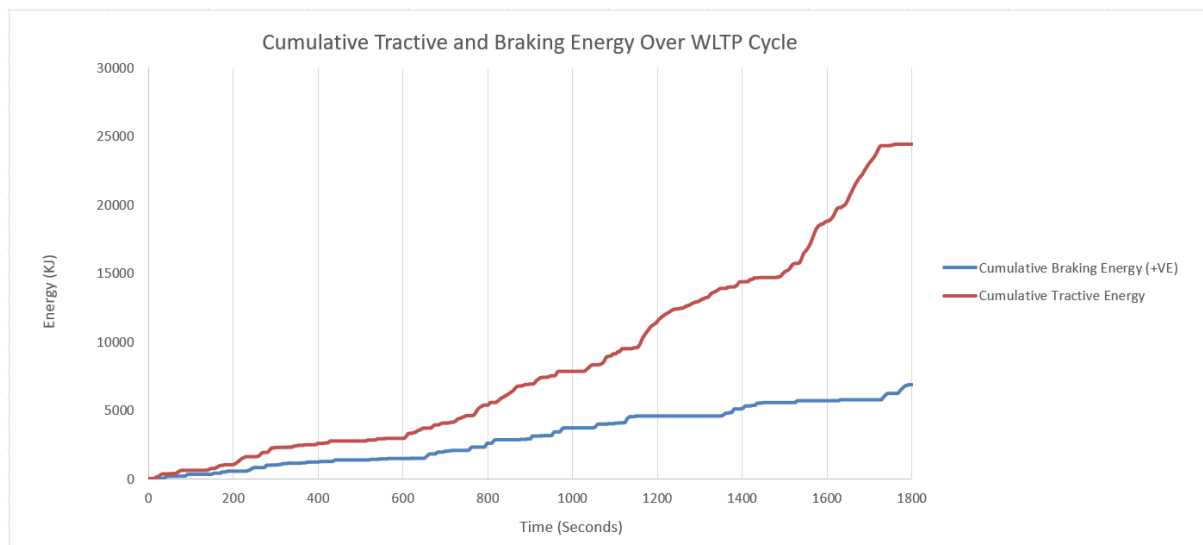
Figure 2, Excel Spreadsheet, Robbie Sandford - WLTC_class_3, 2025

14.5/255		Rolling Drag		Drag Coefficient		Frontal Area (A _f)		Rolling Resistance Coefficient		Vehicle Test Weight		Gravity		Air Density		Initial KE		Maximum KE Encountered		
14.5/255		1.34		2.73		0.1755		325		325		9.81		1.225		2229.5125		651.05575		
m		m ²		m ²		N		KJ		m/s ²		kg/m ³		kg		KJ		KJ		
Phase	Total elapsed time Seconds	Phase elapsed time Seconds	WLTC class 3 vehicle speed km/h	WLTC class 3 vehicle speed m/s	WLTC class 3 vehicle speed m/s	Acceleration m/s ²	Aerodynamic Resistance N	Rolling Resistance N	Resistor Force N	Torque At The Wheel Nm	Tractive Force N	Total Tractive Force N	Tractive Power W	Energy J	Cumulative Tractive Energy KJ	Cumulative Braking Energy KJ	Cumulative Braking Energy (-KE) KJ	Losses sustained During Cycle KJ	KE KJ	Potential KE Gains KJ
Low	0	0	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	1	1	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	2	2	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	3	3	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	4	4	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	5	5	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	6	6	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	7	7	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	8	8	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	9	9	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	10	10	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	11	11	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	12	12	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	13	13	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	14	14	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	15	15	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	16	16	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	17	17	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	18	18	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	19	19	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	20	20	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	21	21	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	22	22	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	23	23	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	24	24	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	25	25	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	26	26	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	27	27	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	28	28	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	29	29	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	30	30	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	31	31	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	32	32	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	33	33	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	34	34	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	35	35	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	36	36	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	37	37	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	38	38	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	39	39	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	40	40	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	41	41	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	42	42	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	43	43	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	44	44	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	45	45	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	46	46	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	47	47	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	48	48	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	49	49	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	50	50	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	51	51	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	52	52	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	53	53	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	54	54	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	55	55	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	56	56	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	57	57	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	58	58	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	59	59	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	60	60	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	61	61	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	62	62	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	63	63	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	64	64	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	65	65	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	66	66	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	67	67	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	68	68	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	69	69	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415.56	0	0	0	0	0	0	0	0	0
Low	70	70	0.0	0.00	0.00	0.00	415.56	415.56	0.00	415.56	415									

Figure 3, Graph Overview, Robbie Sandford - WLTC_class_3, 2025



Figure 4, Cumulative Tractive and braking energy, Robbie Sanford - WLTC_class_3, 2025



This graph illustrates how the total energy used for propulsion and the energy dissipated through braking accumulate over time during a Worldwide Harmonized Light Vehicles Test Procedure (WLTP) cycle.

The x-axis represents time in seconds, covering the full duration of the test, while the y-axis represents energy in kilojoules (kJ). The red line shows the cumulative tractive energy, which is the total energy required by the vehicle to overcome resistance and propel the vehicle forward.

The blue line represents the cumulative braking energy (+VE), which reflects the braking energy requirement, showing how much energy is needed to slow down the vehicle.

Over the course of the cycle, both curves rise in a Sequential pattern, reflecting alternating phases of acceleration and deceleration. The cumulative tractive energy increases at a faster pace and reaches a much higher total value $\approx 25,000$ kJ compared to the braking energy, which plateaus between 5,000 – 6,000 kJ.

This demonstrates that the vehicle consumes much more energy on propulsion than it can recover through braking.

Figure 5, Forces On The Vehicle, Robbie Sandford - WLTC_class_3, 2025



The graph shows forces acting on a vehicle over a time period of 30 minutes. The X-axis represents time 0 and 1800 seconds, and the Y-axis shows force in Newtons -6000 to 8000 N.

Four forces are highlighted: aerodynamic resistance (blue), acceleration resistance (red), total tractive force (green), and rolling resistance (purple).

Aerodynamic resistance is minimal and steady ranging from 0 to 400 N, representing drag.

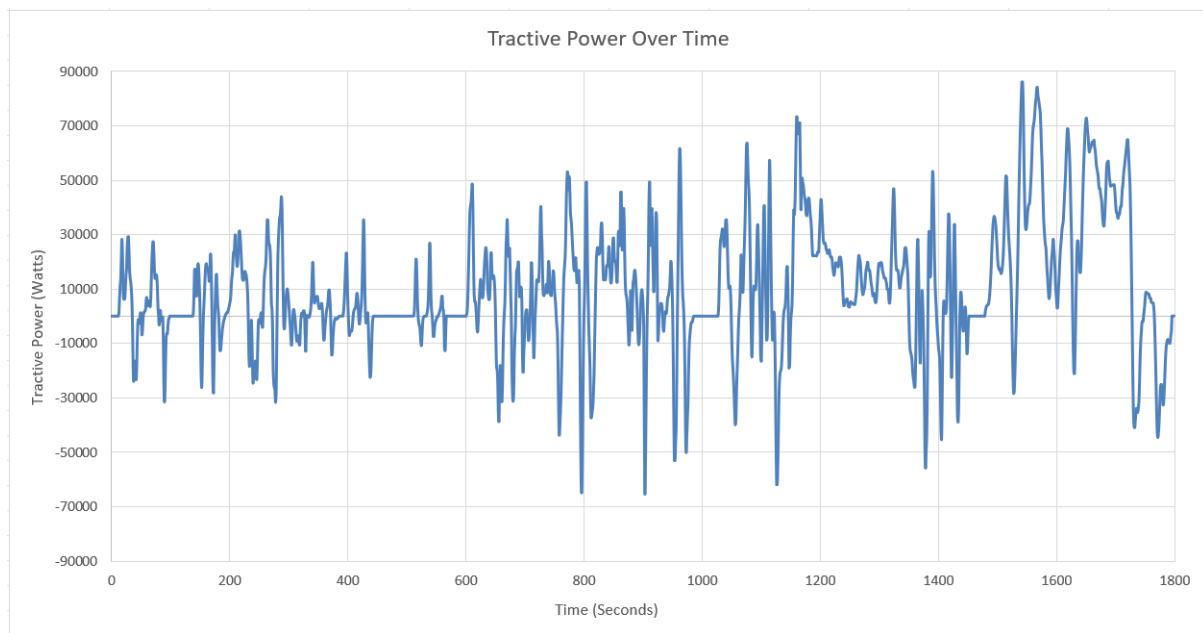
Rolling resistance is also minor, as a constant of around 400 N, which reflects the tire road friction.

Acceleration resistance fluctuates widely between -5000 N and 5000 N, with negative values indicating deceleration or braking.

Total tractive force shows large, spiky swings between the values of -5000 N and 6000 N, representing the forces pushing against the vehicle, resisting motion.

Aerodynamic and rolling resistances remain relatively constant, while acceleration resistance drives most fluctuations. Total tractive forces are the sum of all forces, meaning that when acceleration resistance drops, total tractive forces drop at the same rate because they are directly connected.

Figure 6, Tractive Power Over Time, Robbie Sandford - WLTC_class_3, 2025



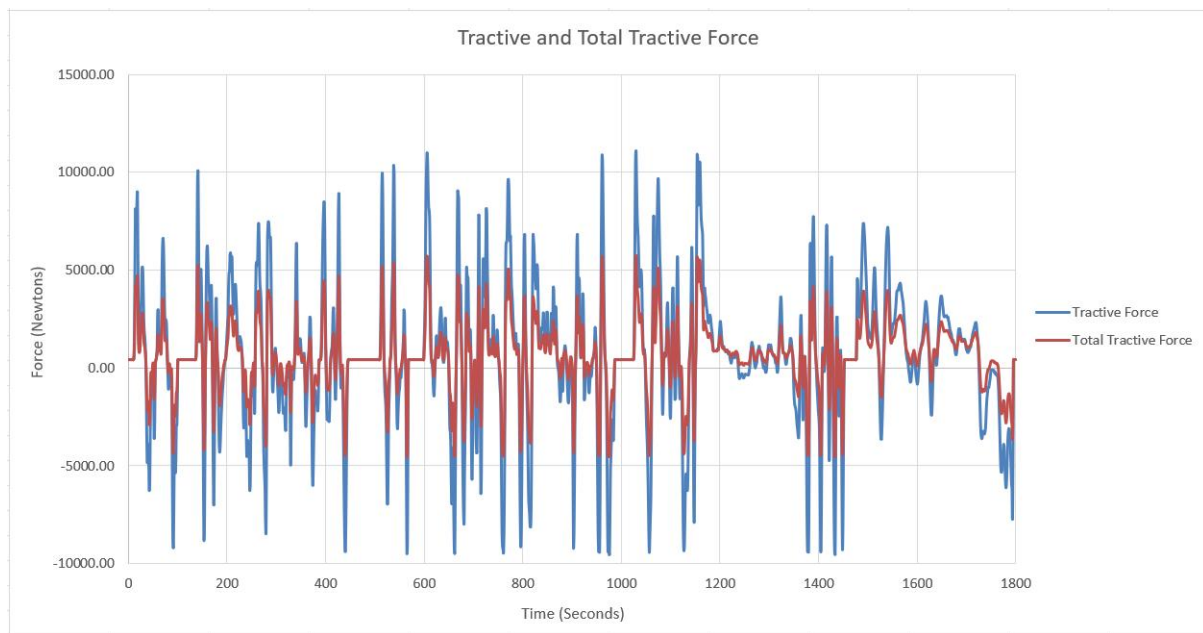
This graph conveys how a vehicle's power output changes over a 30-minute period. The X-axis represents time in seconds while the Y-axis represents tractive power in watts, ranging roughly from -90,000 W to +90,000 W.

Tractive power is the power used to move the vehicle. The positive values indicate propulsion, whereas the negative values convey braking or regenerative energy recovery. (Use, 2025)

Observing the graph, power fluctuates suggest variable acceleration and braking. Early in the timeline, values vary primarily between $\pm 30,000$ W, while after 1200 seconds, peaks reach $\pm 80,000$ – 90,000 W, indicating strong acceleration or braking events.

Sharp drops below zero correspond to regenerative braking. Positive spikes, such as +70,000 W, reflect strong forward acceleration, whereas negative spikes, like -70,000 W, represent strong braking. However, values near zero indicate constant-speed travel.

Figure 7, Tractive and Total Tractive Force, Robbie Sandford - WLTC_class_3, 2025



This graph shows tractive force and total tractive force acting on a vehicle over a driving cycle lasting 30 minutes.

The blue curve represents the force required at the wheels to meet the vehicle's acceleration and overcoming resistances such as aerodynamic drag and rolling resistance. (tractive force)

The tractive force is greater than the total tractive forces because the vehicle is in motion; It represents the sum of both components, as they have to overcome those forces to move.

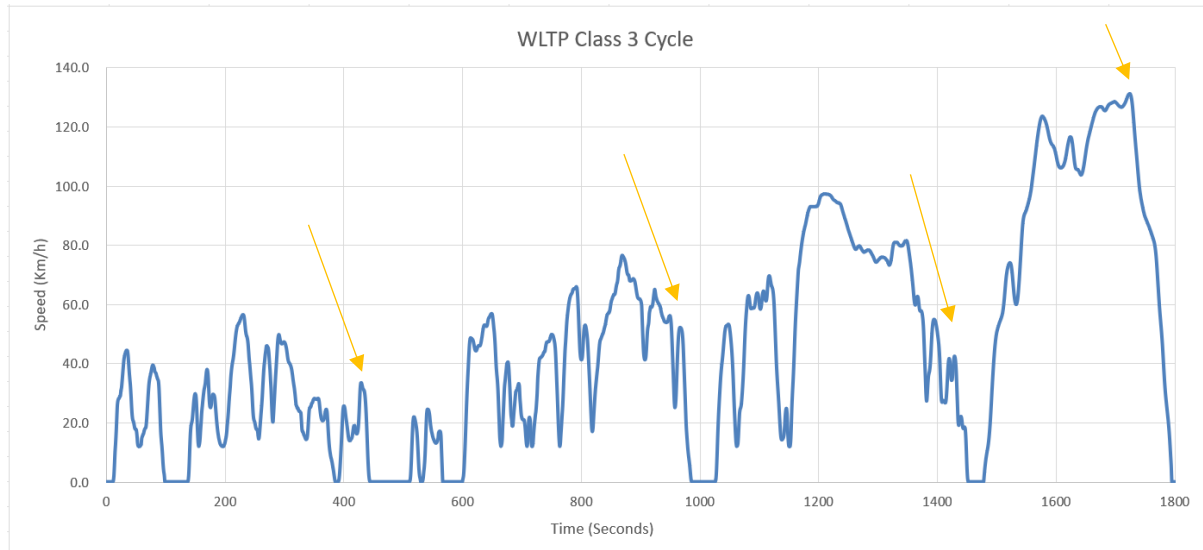
The values on the y-axis indicate whether the vehicle is applying positive force or negative force (regenerative braking or deceleration).

Large spikes represent rapid acceleration or braking events, while flatter regions show cruising or steady-state motion.

Overall, the plot suggests a highly dynamic drive cycle with frequent changes in demanded wheel force.

Chapter 5 – KERS Power Input and Energy Storage Requirements

Figure 8, WLTP Class 3 Cycle, Robbie Sandford - WLTC_class_3, 2025



This graph displays the WLTP Class 3 driving cycle, which acts as a controlled speed vs time schedule for testing fuel consumption, emissions, and energy use under conditions meant to reflect real everyday driving.

The cycle lasts 30 minutes and is divided into four phases: low, medium, high, and extra-high speed. In the first portion of the graph, the vehicle undergoes frequent acceleration and braking/stopping, this simulates dense urban traffic where speeds frequently drop to zero.

This next section captures the impact of idling, stop-start behaviour and low-speed efficiency. As the cycle progresses, the speed rises into the medium and high ranges with fewer stops, representing suburban and rural driving. (Anon, n.d.)

The final section features long stretches at high and extra-high speeds, reaching ≈ 130 km/h.

The deceleration points are represented by the declining slopes in the graph. The largest braking event occurs around 1750 seconds, where speed drops rapidly from ≈ 130 km/h to 0 km/h. Other smaller energy-recoverable points are at ≈ 1400 s, 1000 s, and 500 s. These are all downward trends where regenerative braking could occur and are shown in the graph, highlighted by yellow arrows.

Overall, the graph outlines constant fluctuations, rapid transitions, and wide speed variation, indicating that WLTP is designed to be more realistic and demanding than older testing methods.

Chapter 6 – Current KER System

I've been tasked with finding a suitable Kinetic Energy Recovery (KER) system for my vehicle. However, the Tesla Cybertruck already utilises a KER system through the use of regenerative braking. That said, it differs from conventional systems in how it operates.

When throttle input is eased in a Tesla, the vehicle is not limited to standard friction brakes alone. Furthermore, the electric motor operates in reverse and acts as a generator, by capturing the vehicle's motion and converts it into electrical energy for reuse. Unlike traditional KER systems; wasting the kinetic energy as thermal energy, Tesla's system channels energy it into the battery.

This process, known as regenerative braking, optimizes efficiency and extends the range of each battery charge. This is achieved by recovering energy that would otherwise be lost, Tesla's can achieve more miles per charge from the same battery capacity.

Additionally, this system reduces the workload on the mechanical brakes, as the vehicle is less reliant on conventional friction braking. A significant benefit of this is; brake pads and rotors are subjected to less stress and abrasion. As a result, the system demands less maintenance, ultimately extending component lifespan over time.

Overall, Tesla is able to integrate this energy-recovery process seamlessly, improving the driving experience. Beyond that, the power management system regulates deceleration, coordinates energy capture, and battery charging. Consequently, ensuring smooth and intuitive driving. (sustainablebusiness, 2025)

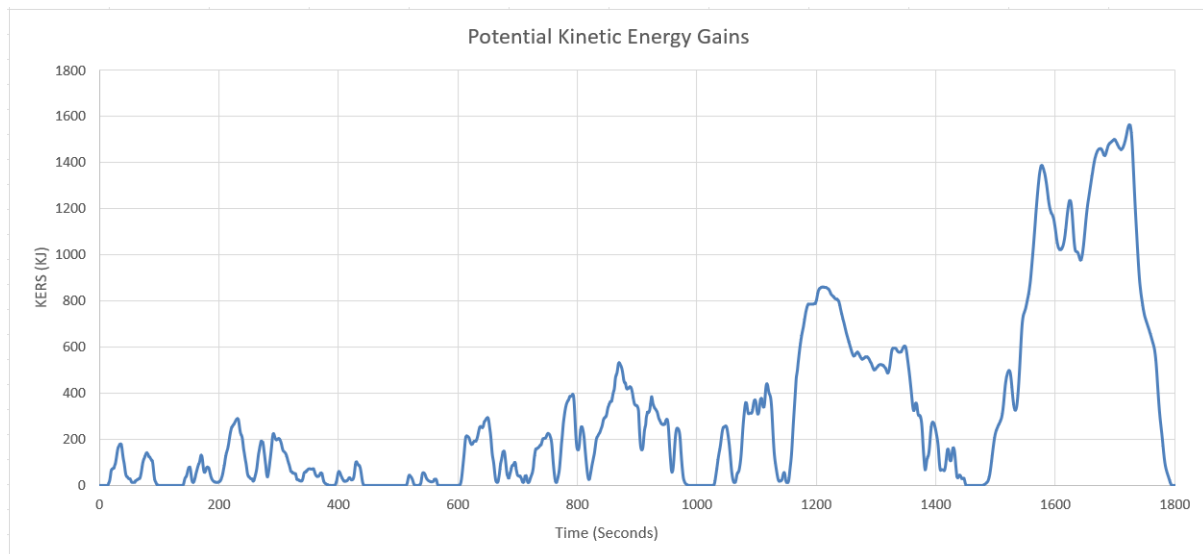
By conducting rigorous research, I was able to deduce that Tesla's are capable of reclaiming a substantial portion of energy that would otherwise be dissipated as thermal energy during braking. However, this is dependent on driving conditions, with factors such as; terrain and specific models. While there is not a specific value, studies suggest that approximately 60% to 70% of this energy can be recovered. The recovered energy plays a key role in the vehicle's overall efficiency, facilitating optimal use of the vehicle's stored power. To add, when applied to real-world driving and a practical standpoint the energy recovery can lead to an increase in driving range of approximately 10% to 15%, with maximum impact occurring in stop-start urban traffic. More in depth, frequent deceleration in city driving provide multiple opportunities for energy reclamation, enhancing the effectiveness of regenerative braking in this application. (Chris, 2025)

Chapter 6.1 – Suitable KER System

Based on a comprehensive study of Volvo's carbon-flywheel kinetic energy recovery system, I was able to deduce how effectively it captures and reuses energy that would otherwise be lost during braking. Developed by Flybrid and tested on the Volvo S60, this system mounts a lightweight flywheel on the rear axle, which spins at up to 60,000 rpm within a vacuum housing to minimize friction. It works by using the kinetic energy generated during braking before being transferred to the flywheel via a continuously-variable transmission, which permits the energy to be stored mechanically and released almost instantaneously during acceleration. As a result of its low-friction design, this flywheel system is capable of a round-trip efficiency of approximately 70%, meaning that a large quantity of energy can be returned to assist propulsion. (GreenCarGuide.co.uk, 2019)

Chapter 7 – Kinetic Energy Recovered

Figure 9, Potential Kinetic Energy Gains, Robbie Sandford - WLTC_class_3, 2025



The graph shows how much potential kinetic energy recovery (KERS) is available over a 30-minute period. The horizontal axis represents time in seconds, and the vertical axis represents KERS energy in kilojoules (kJ). Each point on the line indicates the amount of recoverable kinetic energy, typically from deceleration such as braking or speed reductions. Furthermore, it shows potential KE recovery, if the vehicle stops at any given time along the cycle, the corresponding KE can be recovered based on the vehicle speed.

Lower values 0–200 kJ represent small braking events or brief slowdowns, while higher values above 800–1500 kJ correspond to large, sustained deceleration opportunities.

The spikes toward the end of the graph suggest periods of intense braking or multiple high-energy slowdown events, meaning the system could recover significantly more kinetic energy during those moments.

The maximum recoverable kinetic energy is calculated to be 1567.658575 KJ

Overall, the graph indicates how much kinetic energy is available for recovery throughout a drive or cycle, highlighting when energy-recovery systems would be most effective.

Chapter 8 – System Operation

Pairing a carbon flywheel KERS with a Tesla Cybertruck regenerative braking system could form an integrated solution of energy recovery that enhances both performance and efficiency.

A carbon flywheel, is exceptionally lightweight, extremely strong, and capable of spinning at very high speeds, consequently they can absorb and release energy much faster than a lithium-ion battery pack.

During repeated or intense braking, when the vehicles main battery may reach its charging limits, the flywheel can accept sudden surges of kinetic energy almost instantly, meaning they are able to prevent energy loss through friction brakes and reducing heat buildup within the battery. Moving on, demanding situations such as towing, driving in dense stop-start traffic or accelerating heavy vehicles, the flywheel can return that stored energy to the drivetrain, easing strain on the battery and improving responsiveness.

Furthermore, the additional mechanical storage also reduces the number of deep charge and discharge cycles the battery must endure, which can help preserve long term health. By combining the rapid response characteristics of mechanical energy storage with the high-capacity electrical regeneration of the Cybertruck, the integrated system can capture a wider range of real-world kinetic energy events, improve practical driving range, deliver brief bursts of extra power when needed, and make the vehicle more capable and adaptable in demanding everyday use.

(GreenCarGuide.co.uk, 2019)

By Integrating a carbon flywheel KERS system with the Tesla Cybertruck, it would enhance the driving experience by improving responsiveness and agility. To add, braking would feel smoother and more controlled, this is achieved because the flywheel absorbs sudden kinetic energy almost instantly, reducing reliance on friction brakes and minimizing brake fade during repeated stops.

Furthermore, drivers would experience quicker acceleration bursts, especially when towing, carrying heavy loads, or navigating stop-and-go traffic, because the flywheel can return stored energy to the drivetrain on demand.

The vehicle would feel more consistent and stable, as the battery experiences less thermal stress and strain. Overall, the combination of mechanical and electrical energy recovery would make the Cybertruck feel agile, powerful, and confident, enhancing both everyday driving and more challenging scenarios.

Calculations

Rolling Resistance Calculation

285/65/20 Pirelli Scorpion ATR		(Tesla.com, 2025)
Parameter	Calculation	Value
Sidewall Height	$65 \div 100 \times 285$	185.25mm
Rim Radius	$20 \times 25.4 \div 2$	254mm
Rolling Radius	Rim Radius + Sidewall Height	439.25mm = (0.43925m)

Excel Calculations

Parameter	Reference
Acceleration Resistance	(Hall, 2022)
Aerodynamic Resistance	(Hall, 2022)
Rolling Resistance	(Engineering ToolBox, 2008)
Resistant Force	(Suyabodha, 2017)
Torque At The Wheel	(Quora, 2019)
Tractive Force	(www.engineeringtoolbox.com, n.d.)
Total Tractive Force	
Tractive Power	
Energy	(BBC Bitesize, 2021)
Cumulative Tractive Energy	(Analog.com, 2025)
Cumulative Braking Energy	
Cumulative Braking Energy (+VE)	
Losses sustained during Cycle	
Kinetic Energy	(BBC Bitesize, n.d.)
Potential Kinetic Energy Gains	(GreenCarGuide.co.uk, 2019)

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