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***Kinetic Energy Recovery***

***Alternative Propulsion System (ACHA5010)***

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## 1 Introduction

This report is about implementing a Kinetic Energy Recovery System on a chosen vehicle. Before doing so, research its technical specifications to analyse its characteristics using the Worldwide Light Vehicle Test Procedure. Plotting the cumulative tractive and braking energy at the wheel over the specific WLTP cycle and identifying the largest possible KERS power input and storage and proposing a suitable KERS for the vehicle. This is to reduce the fuel consumption and provide an assumption as to what the driver may feel compared to a conventional ICE and friction brake vehicle.

## 2 Vehicle Chosen and Dynamic Characteristics

For this research to apply a Kinetic Energy Recovery System, the technical information of a 1983-1987 Toyota Sprinter Trueno AE86 Hatchback is used. These are the dimensions and weight of the specified vehicle:

- Wheelbase: 2400mm
- Track Width: Front- 1355mm, Rear- 1345mm
- Length: 4285mm
- Width: 1625mm
- Height: 1335mm
- Kerb Mass: 970kg(Hatchback) (*AE86 specifications, 2025*)

To find the test mass of the vehicle, using the WLTP, 75kg is added for the driver and an additional 25kg for luggage. (Mock *et al.*, 2014) Therefore, the test mass of this vehicle is 1,070kg.

The frontal area of this vehicle is recorded as 1.84 m<sup>2</sup> under the 1985 Corolla AE86 Sprinter. (*Drag Coefficient Table for Cars, 2025*). It can also be approximately calculated by a grid-based counting method. Taking a picture of the front view of the vehicle and adding a grid to calculate the percentage of what the vehicle covers. Width multiplied by the height to get the bounding rectangle and then multiplied by the percentage to get the estimate. (*Frontal Area Of A Racing Car, 2025*).

The value for the rolling resistance coefficient of tyres on asphalt is 0.013. (Ehsani *et al.*, 2018).

The coefficient of aerodynamic drag of the vehicle is 0.35. (*AE86 specifications, 2025*).

### 3 Worldwide Harmonised Light Vehicle Test Procedure

This vehicle did not go through the Worldwide Harmonised Light Vehicle Test Procedure, as WLTP was introduced in 2017-2018, applying only to all new car registrations. (*What is WLTP? Worldwide test explained*, 2025). This vehicle went under JISHA 1983 10 mode cycle, an emissions certification of light-duty vehicles in Japan. (*Japanese 10 Mode*, 2025).

WLTP consists of 3 classes, known as Worldwide Harmonised Light-vehicle Test Cycles (WLTC). It is designed to represent what real-life uses the vehicles go through, such as city traffic, extra-urban traffic, on car roads and highways. These are the classes' classification:

- Class 1: Vehicles for which the ratio of rated power in W/kg  $\leq 22$
- Class 2 Vehicles for which the ratio of rated power in W/kg  $> 22$  but  $\leq 34$
- Class 3 Vehicles for which the ratio of rated power in W/kg  $> 34$  (Amry *et al.*, 2022)

To identify what class the AE86 falls into, its power-to-mass ratio needs to be calculated by using the formula:

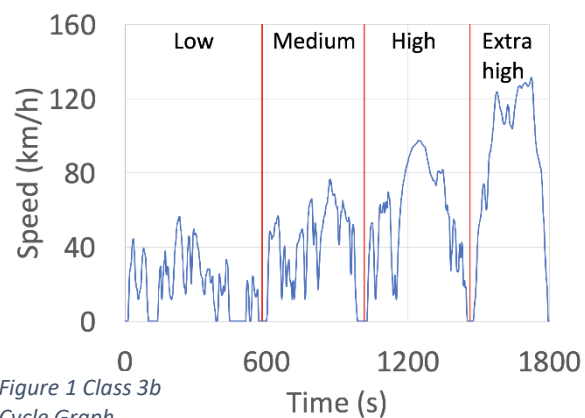
$$\frac{\text{Maximum engine power}}{\text{Vehicle's mass}} = \text{W/kg}$$

It's stated that the AE86 max power is 91kW @ 6600rpm. (*AE86 specifications*, 2025). Using this and the test mass of the vehicle, the value calculated is 85 W/kg. This indicates that the AE86 is classified as a Class 3 vehicle. Then there are 2 subclasses of class 3 cycle:

- 3a:  $v_{\text{max}} < 120\text{km/h}$
- 3b:  $v_{\text{max}} \geq 120\text{km/h}$

According to the same source, it states that the AE86 can reach a top speed of 200km/h. (*AE86 specifications*, 2025). While a different source declares that it can only go up to 180km/h. (*Toyota Sprinter Trueno AE86*, 2025). Regardless, they are still above 120km/h; therefore, the full classification is a Class 3b vehicle.

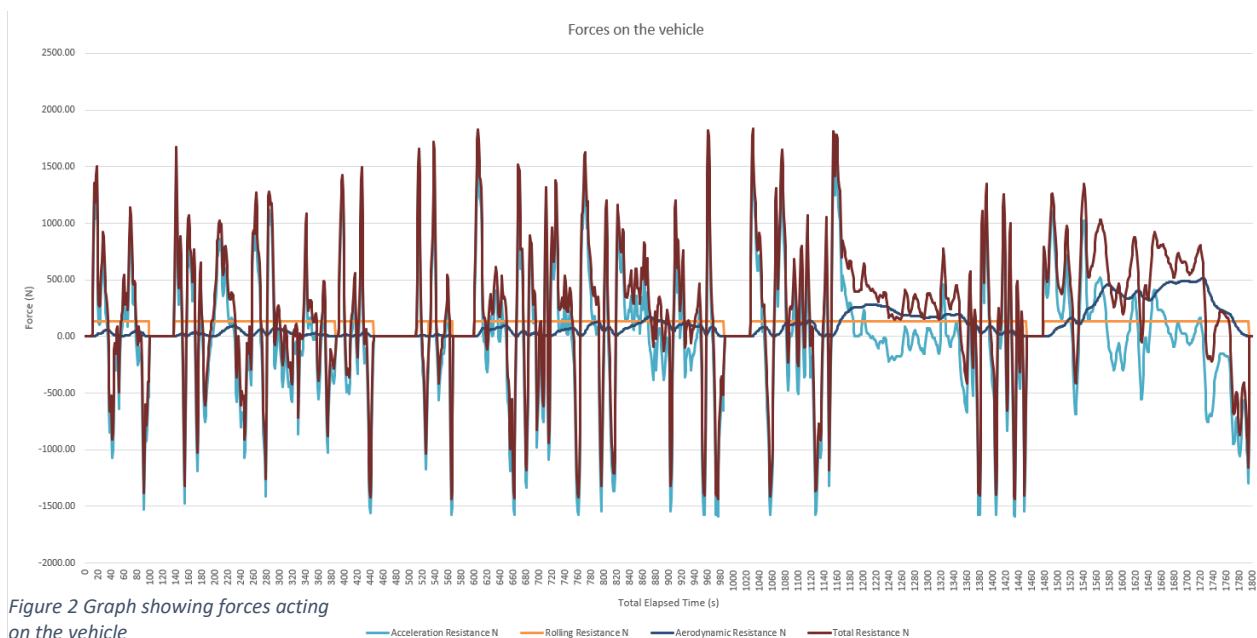
The graph shows the Class 3b cycle, including the low, medium, high and extra-high phases. (*International: Light-duty: Worldwide Harmonized Light Vehicles Test Procedure (WLTP)*, 2025).



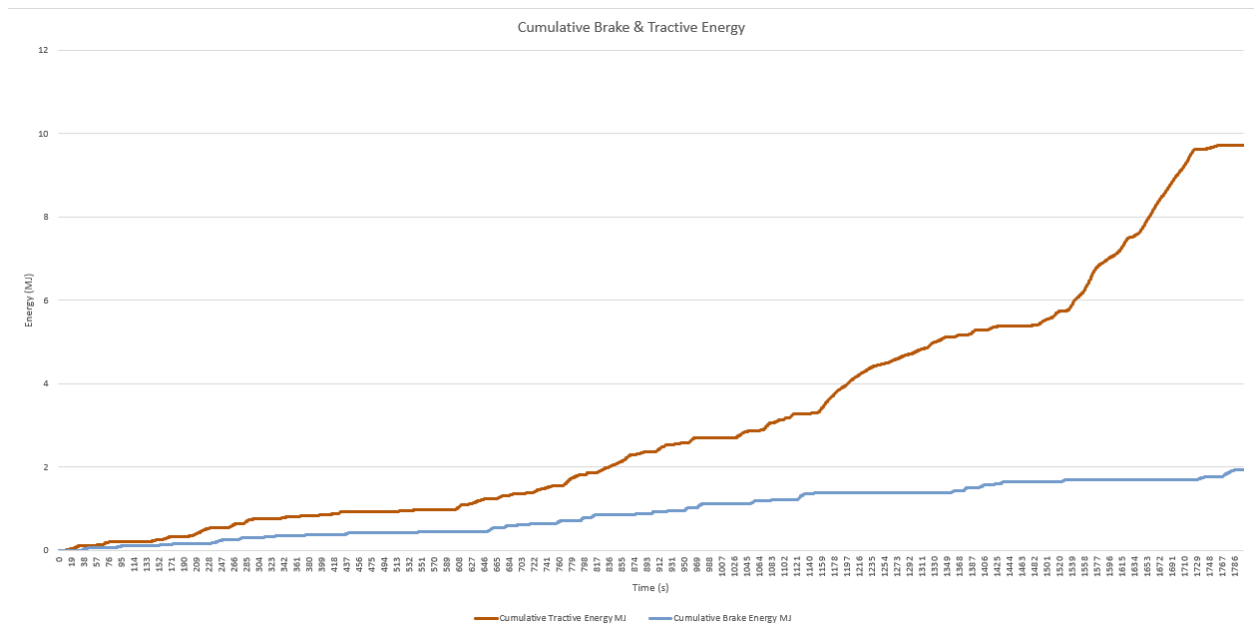
## 4 Cumulative Tractive and Braking Energy Spreadsheet

Using the Excel spreadsheet provided with the WLTP Class 3 cycle, it made it possible to calculate acceleration, rolling resistance, aerodynamic resistance and total resistance force acting on the vehicle. The graph below shows the positive and negative forces and the total force acting on the vehicle plotted against time. The spikes are the acceleration and deceleration of the vehicle during the cycle; therefore, they fluctuate rapidly while rolling resistance remains nearly constant, as it is primarily determined by the vehicle's weight and the tyre's rolling resistance coefficient.

Aerodynamic resistance increases with speed, becoming more significant during the extra-high phase in the cycle. Total resistance combines all forces acting on the vehicle and closely follows acceleration and deceleration.



The graph below shows the cumulative tractive and brake energy over the WLTP Class 3 cycle for the Toyota AE86. The cumulative tractive energy rises steadily during the acceleration, reaching almost 2MJ near the end of the cycle. The cumulative brake energy increases steadily during the low and medium phases of the cycle and rises sharply at the high and extra-high phases, nearly reaching 10MJ. This indicates that more kinetic energy is dissipated during the deceleration of the vehicle in the cycle.



## 5 KERS Power Input and Energy Storage

Based on the brake energy result obtained from the WLTP Class 3 driving cycle, the KER system for the Toyota AE86 would need to handle a peak regenerative brake energy of around 20kW. This value came from the recorded brake energy and represented the highest instantaneous brake energy during the cycle, indicating that this is the maximum rate at which energy is recovered and delivered to the energy storage. This means that the motor and electronics in the KER system are rated to absorb this amount of energy without overloading the system.

During the analysis, the data also show that the largest recorded brake energy during the braking period is 185.26kJ, representing the recoverable energy, assuming that the stored energy from each recovery period is fully utilised before the next period. This suggests that the KER system must have a capacity of 190kJ to store the energy recorded from the braking period. This ensures that the KER system can store the full amount of energy available from the braking periods without reaching the limit.

In short, the Kinetic Energy Recovery System performance value requirements are:

- Power Capability: 20kW
- Energy storage capacity: 190kJ

## 6 Kinetic Energy Recovery Systems

There are 3 different types of Kinetic Energy Recovery Systems:

- Electrical KERS
- Electro-Mechanical KERS
- Mechanical KERS (Batalha, 2025)

Each KERS stores their energy in different ways. Electrical KERS converts the kinetic energy into electrical energy using an Electric Motor-Generator unit (MGU) and uses a battery or supercapacitors to store the energy. The MGU also act as a motor to deliver the energy back to the drivetrain when accelerating. (Batalha, 2025)

Mechanical KERS stores the energy in a flywheel. This system doesn't convert kinetic energy to electrical energy; therefore, an MGU is not used. Instead, the kinetic energy produced during braking is transferred through a Continuously Variable Transmission, which connects to the flywheel. This causes it to spin at high rpm, and the CVT disconnects from the flywheel to prolong the energy. (Batalha, 2025)

Electro-mechanical KERS blends the systems together, where the flywheel itself is the generator. During braking, the kinetic energy is transferred to the flywheel that is encased in a vacuum housing with a stator. The flywheel is a magnetically loaded composite (MLC), allowing it to be magnetised as a permanent magnet. As the flywheel spins, it induces a current in the stator, producing electrical energy. This then powers an electric motor connected back to the drivetrain to accelerate. (*Williams F1 KERS explained*, 2009).

## 6.1 Suitable KER System for the Toyota AE86

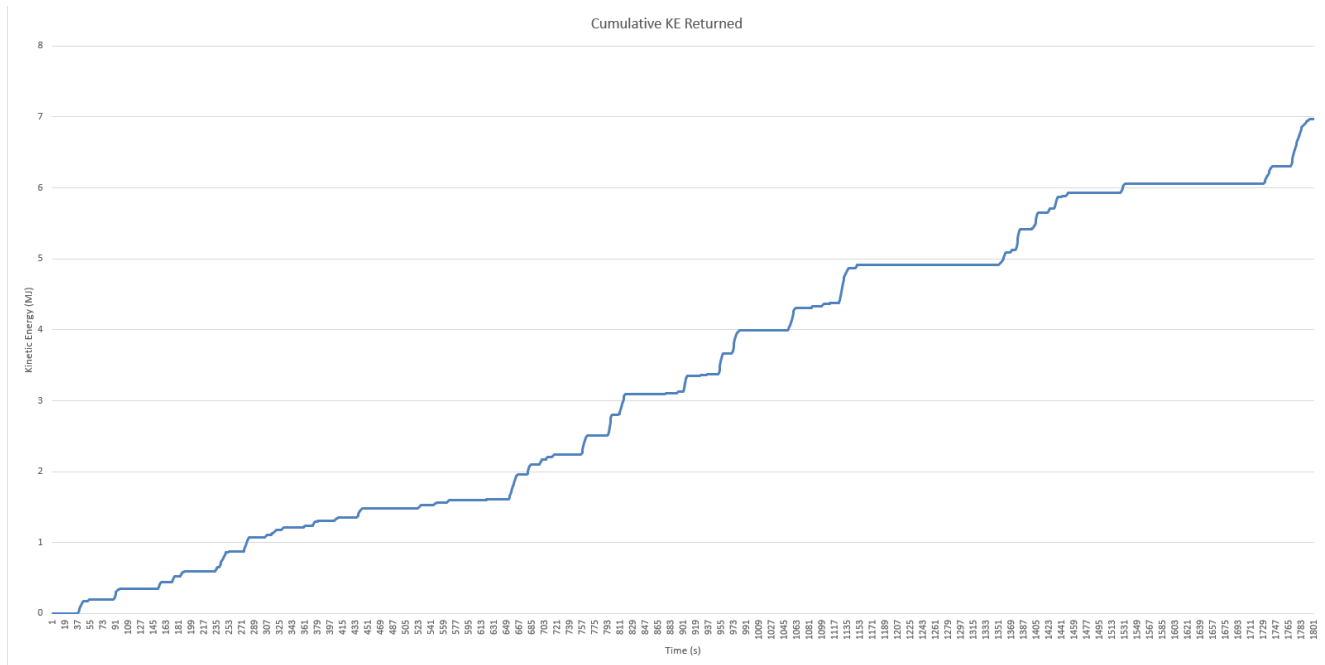
Since the criteria are to reduce fuel consumption, an electrical KER system is the most realistic and practical approach for the Toyota AE86. This system can store energy long-term, and this system is commercially proven and mass-produced in hybrids and EVs.

Therefore, in this KER system, the MGU must have a 25kW rating instead of 20kW to provide a safety margin to avoid overloading during the input and output of the energy. Assuming that energy is expended before the next recovery period, a usable capacity of 0.05kWh is required. Allowing margin and avoiding full cycling, a 0.1kWh capacity is greater. Though this may still be small, as it can overheat frequently due to reaching full charge often, which can lead to the battery degrading rapidly. A 1kWh capacity battery is used instead, which also provides more energy recoverable.

The efficiency of this system varies under different conditions, such as the vehicle size, driving conditions and positive or negative terrain elevation. Roughly around 60-70% of the kinetic energy is recaptured during braking back to the battery. (Shepherd, 2024).

## 7 Kinetic Energy Recovered

Since the electrical KER system recaptures 60-70% of the kinetic energy. The value 65% will be used for plotting the kinetic energy recovered.



The graph above shows the cumulative kinetic energy returned to the wheel during the WLTP Class 3 cycle. At every braking period, a portion of the vehicle's kinetic energy is recaptured and stored and later returned to the wheel with an assumed system efficiency of 65%. As the test progresses, the cumulative energy increases in steps. Periods of acceleration, constant velocity or idle appear in the flat section as no brake energy is recovered. So in each increase, braking occurs, recapturing energy. The curve rises steadily throughout the cycle from low, medium, high and extra high phases, indicating the repeated braking during the cycle. By the end of the cycle, the total kinetic energy recovered reaches nearly 7MJ, which highlights the potential of the KER system to reduce the energy demand on the vehicle and also how much energy can be recycled.

## 8 System Operation, Assumptions, Driver's Experience Compared to Conventional ICE & Frictional Brake Vehicle

A Kinetic Energy Recovery System recovers some of the vehicle's kinetic energy during braking and stores it to be utilised later. The chosen KER system for the Toyota AE86 is an electrical variant which consists of a Motor Generator Unit, a Power Control Unit and a compact high-power energy storage unit such as a battery or supercapacitor. (*Kinetic energy recovery system*, 2025)

During braking periods, the MGU operates as a generator, converting the kinetic energy from the wheel into electrical energy, though not all energy is recovered. The PCU then conditions the electrical energy and stores it in the battery. During acceleration or in need of extra torque, the MGU converts to a motor and uses the stored energy to apply torque back in the drivetrain, reducing the load on the engine.

For this system, an assumption is made that 60-70% of the kinetic energy is recovered due to energy losses from the MGU, PCU, battery and drivetrain. Another assumption is the specifications of the Toyota AE86, such as its frontal area, coefficient of drag and rolling resistance coefficient. Older vehicles like this are scarce and harder to find, so it is difficult to obtain the right value without testing. Therefore, having to rely on online information that is available.

To what a driver may feel with KERS installed, the driver may feel the vehicle is more responsive when accelerating due to the motor assisting and, in turn, reducing engine load. It may also provide a slight boost from static to motion.

The engine braking may feel stronger when the driver lifts off the accelerator; therefore, less wear on the brake pads. While beginning to brake, most braking torque is supplied by regenerative braking and then transitions to frictional braking. (*Understanding Regenerative Braking!*, 2023).

## 9 Conclusion

In conclusion, this investigated the performance and potential benefits of installing a Kinetic Energy Recovery System on a 1983-1987 Toyota AE86 over the WLTP Class 3b driving cycle. Calculating the technical dimensions of the vehicle, such as the frontal area and test mass, enabled the car to be tested on the WLTP. Analysing the characteristics of the vehicle during the cycle allowed an estimated value requirement for a KER system. The analysis displays the peak regenerative braking power of 20kW on the WLTP cycle during deceleration. For braking energy, the largest braking event contains 185kJ of recoverable energy. These values were used as a guide for the components when choosing a suitable KER system, and what it must handle.

After, an assumption was made that the electrical KER system recovers 60-70%. 65% value is used to calculate the cumulative kinetic energy returned during the WLTP Class 3 cycle. When the graph was produced, it showed the periods of acceleration, constant velocity or idle as a flat section and deceleration in each increase. This produces steps in the graph that steadily accumulate throughout the cycle from low, medium, high and extra-high phases. At the end of the cycle, the accumulated kinetic energy reaches nearly 7MJ, highlighting the potential of what the KER system contributes.

## 10 References

- AE86 specifications* (2025) *AEU86*. Available at: <https://www.aeu86.org/technical/ae86-specifications/> (Accessed: November 27, 2025).
- Amry, Y. *et al.* (2022) "Electric Vehicle Traction Drives and Charging Station Power Electronics: Current Status and Challenges," *Energies*, 15(16). Available at: <https://doi.org/10.3390/EN15166037>.
- Batalha, J. (2025) *Clemson Vehicular Electronics Laboratory: Kinetic Energy Recovery Systems, CVEL*. Available at: [https://cecas.clemson.edu/cvel/auto/AuE835\\_Projects\\_2009/batalha\\_project.html](https://cecas.clemson.edu/cvel/auto/AuE835_Projects_2009/batalha_project.html) (Accessed: November 30, 2025).
- Drag Coefficient Table for Cars* (2025) *AUTOMOTIVE GURU*. Available at: <https://automobil-guru.de/cw-werte-tabelle-stirnflaeche/> (Accessed: November 27, 2025).
- Ehsani, M. *et al.* (2018) *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*, Taylor & Francis Group. Available at: <https://ebookcentral.proquest.com/lib/trinity/reader.action?docID=5264494&c=RVBVQg&ppg=50> (Accessed: November 27, 2025).
- Frontal Area Of A Racing Car* (2025) *YourDataDriven*. Available at: <https://www.yourdatadriven.com/frontal-area-of-a-racing-car-easy-calculation/> (Accessed: November 27, 2025).
- International: Light-duty: Worldwide Harmonized Light Vehicles Test Procedure (WLTP)* (2025) *TransportPolicy.net*. Available at: <https://www.transportpolicy.net/standard/international-light-duty-worldwide-harmonized-light-vehicles-test-procedure-wltp/> (Accessed: November 28, 2025).
- Japanese 10 Mode* (2025) *DieselNet*. Available at: [https://dieselnet.com/standards/cycles/jp\\_10mode.php](https://dieselnet.com/standards/cycles/jp_10mode.php) (Accessed: November 26, 2025).
- Kinetic energy recovery system* (2025) *Energy Education*. Available at: [https://energyeducation.ca/encyclopedia/Kinetic\\_energy\\_recovery\\_system](https://energyeducation.ca/encyclopedia/Kinetic_energy_recovery_system) (Accessed: November 30, 2025).
- Mock, P. *et al.* (2014) "The WLTP: How a new test procedure for cars will affect fuel consumption values in the EU." Available at: <https://doi.org/10.1016/j.enpol.2013.12.013i>.
- Shepherd, J. (2024) *Understanding regenerative braking in electric vehicles (EVs) - EV Engineering & Infrastructure*, *EV Engineering Infrastructure*. Available at:

<https://www.evengineeringonline.com/how-are-the-efficiency-and-benefits-of-regenerative-braking-measured-in-evs/> (Accessed: November 30, 2025).

*Toyota Sprinter Trueno AE86* (2025) *CAR SPECS A-Z*. Available at: <https://www.carfolio.com/toyota-sprinter-trueno-37433> (Accessed: November 28, 2025).

*Understanding Regenerative Braking!* (2023) *Sabin Civil Engineering*. Available at: <https://www.youtube.com/watch?v=stq2E3sZYg0> (Accessed: November 30, 2025).

*What is WLTP? Worldwide test explained* (2025) *RAC*. Available at: <https://www.rac.co.uk/drive/advice/emissions/new-worldwide-fuel-consumption-test-explained/> (Accessed: November 26, 2025).

*Williams F1 KERS explained* (2009) *Racecar Engineering*. Available at: <https://www.racecar-engineering.com/articles/f1/williams-f1-kers-explained/> (Accessed: November 30, 2025).