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BETT Deep Dive

Seasonality and Battery Degradation

Cenex – Transport Team

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Document Control

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Project Overview

The Battery Electric truck Trial (BETT) is a research project funded by Innovate UK to trial 20 DAF Electric LF 19-tonne trucks. The trial is being run by DAF with support from Cenex for data collection, analysis and dissemination.

The truck has a range of up to 280 kilometres on each battery charge and can be rapid charged at 150 kW for quick turn-around between shifts. Further information can be found on the project website: https://bett.cenex.co.uk/

This deep dive report looks at how the vehicle efficiency is affected by ambient temperature across the year, and how the state of health of the battery has changed during the trial.

Introduction

Weather conditions, and in particular temperature, affects the performance of all vehicles, including both those powered by batteries and internal combustion engines.

This report investigates how the efficiency of both the propulsion and ancillary power usage of the BETT vehicles varies as the ambient temperature changes throughout the year.

Over their lifetime the propulsion batteries will degrade. This report also looks at how this degradation has progressed during the trial and whether there is any relationship between degradation and usage.

Key Conclusions

- The overall efficiency of the vehicles is strongly correlated with ambient temperature, with around 30% drop in range in winter conditions compared to summer.

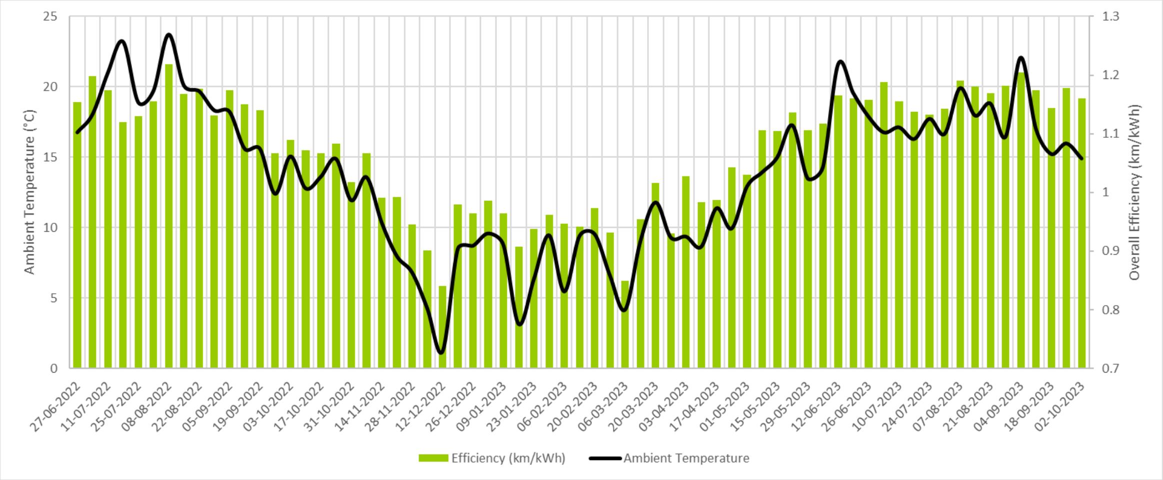
- The efficiency of vehicles with a temperature control unit (TCU) is lower across the year compared to vehicles with normal bodies, even in summer where the cargo is not heated. This is mostly due to the higher vehicle weight and higher payload carried by these vehicles, with a small reduction due to the TCU itself which consumes around 4% of the energy in vehicles where one is fitted.

- The battery state of health has dropped by between 2% and 5% in all vehicles, but there is no correlation with usage. The duration of the trial has been too short to draw clear conclusions about battery degradation, but the current rate of degradation is well below the manufacturer's warranty.

Overall Efficiency

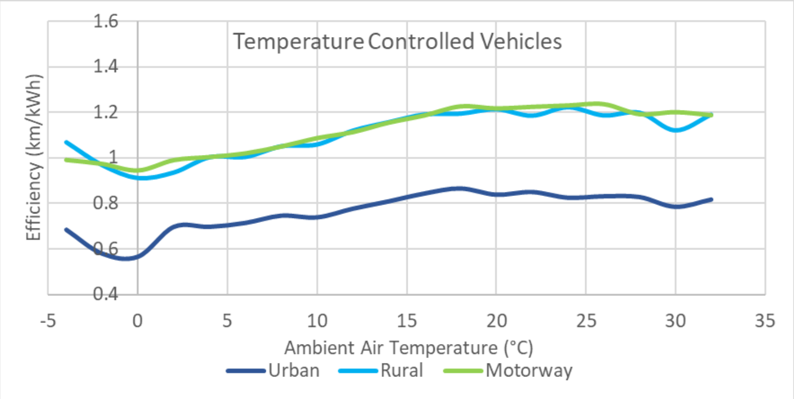
This graph shows both the ambient temperature and average overall efficiency of all vehicles for each week of the trial.

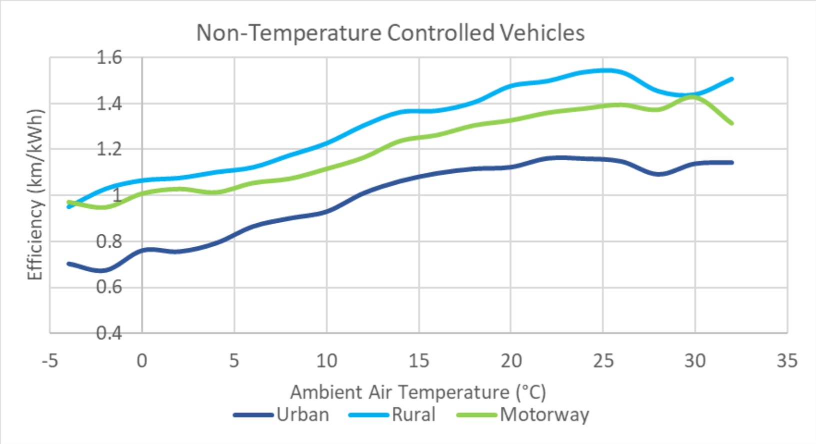
There is a clear correlation showing that temperature has a strong impact on efficiency, which varies from around 0.8 to 1.2 km for every kWh used. This is a drop of around 30% between summer and winter.



This graph includes all vehicles and ancillary consumption across all types of driving. The following pages dig down to see how the efficiency varies by drive cycle and ancillary consumption.

Efficiency by Temperature



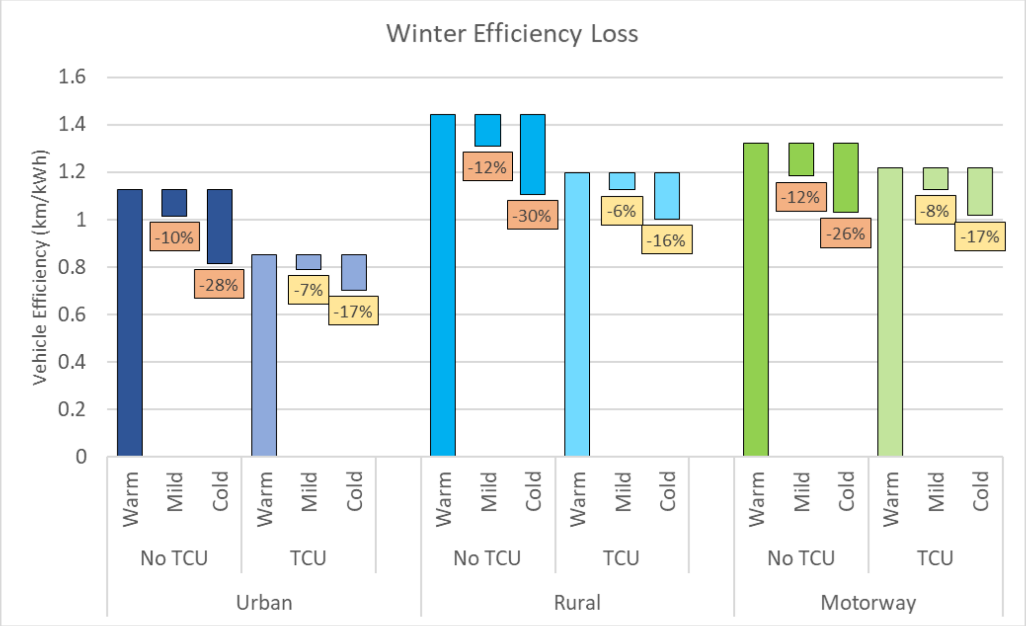


These graphs show the overall efficiency, including all ancillaries, split by drive cycle. The left graph shows vehicles with a temperature control unit (TCU), and on the right those with normal cargo areas. The correlation with temperature is clear, but there are other interesting features: the vehicles with a TCU have lower efficiency than normal vehicles overall, but especially in warmer conditions and urban driving. Also, vehicles with a TCU have almost identical efficiency for both the rural and motorway drive cycles.

Note on temperature ranges: cold is <8 °C, mild is 8 to 16 °C, warm is >16 °C

Winter Efficiency Loss

This graph is an alternative representation of those on the previous page, highlighting the drop in efficiency, and therefore range, seen during colder weather compared to the warm weather efficiency, for each of the three drive cycles. The comparison with the addition of the TCU is also included.



Across all drive cycles, the vehicles without a TCU see a roughly 12% loss in efficiency in mild (8 to 16 °C) conditions, and 28% loss in the cold (<8 °C), compared to the same vehicles in warm weather (>16 °C), as shown in the orange boxes.

The vehicles with a TCU see a smaller 7% and 17% reduction across all drive cycles in mild and cold conditions respectively, compared to TCU vehicles in warm weather, as shown in the yellow boxes.

BETT Seasonality and Battery Degradation

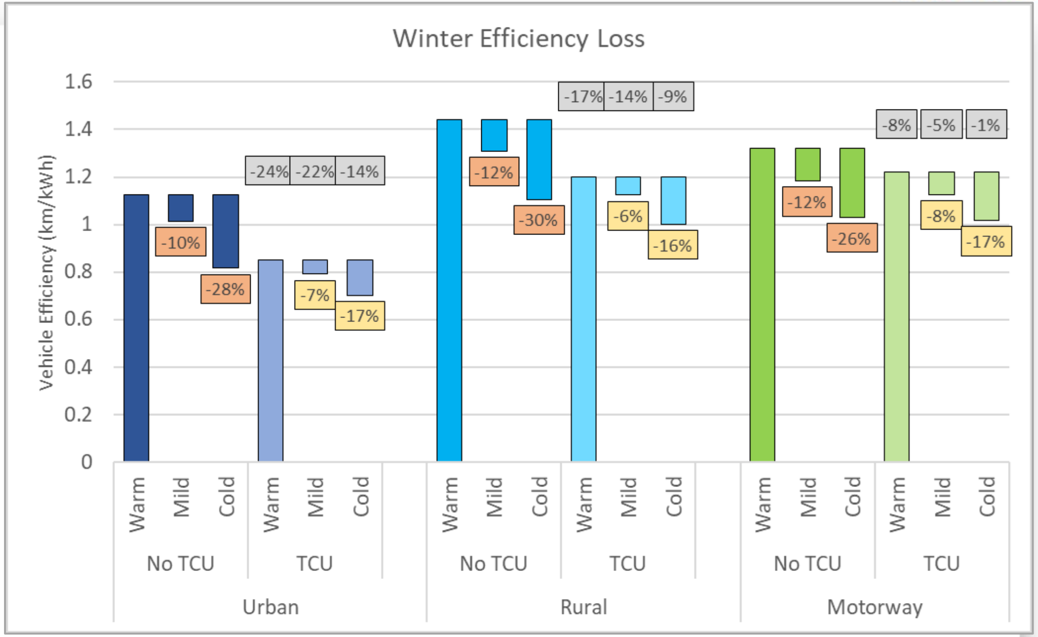
Note on temperature ranges: cold is <8 °C, mild is 8 to 16 °C, warm is >16 °C

Winter Efficiency Loss

The grey boxes show the reduction in efficiency of the TCU vehicles compared to the *equivalent temperature* non-TCU vehicles. It demonstrates that the drop is much more pronounced in the urban and rural drive cycles, with the warm weather efficiency dropping by 24% and 17% respectively, compared to only 8% in the motorway drive cycle.

This pattern is repeated at lower temperatures, although the loss in efficiency is smaller as the temperature decreases.

This indicates that much of the reduction in efficiency of the vehicles with a TCU is caused by non-seasonal factors.

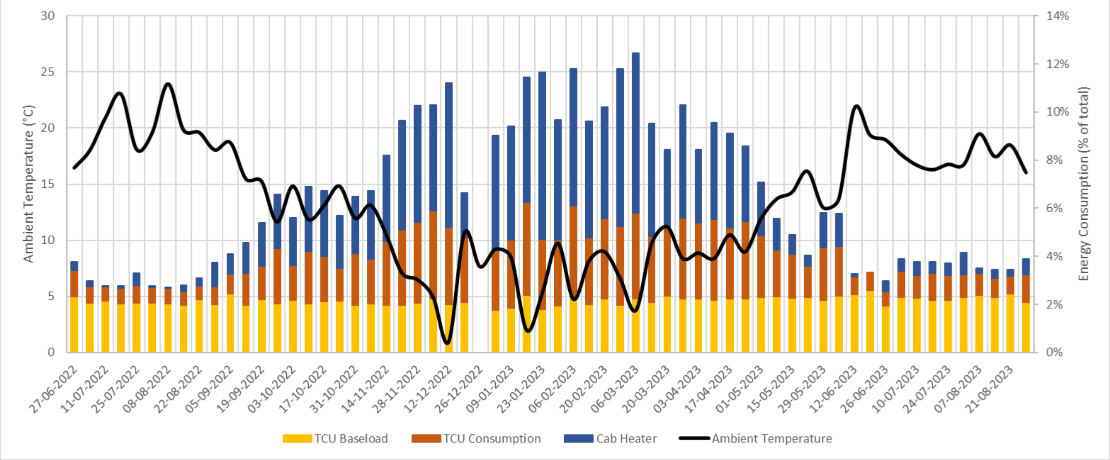


The apparent lesser impact of cold weather on vehicles with a TCU is mostly due to the summer efficiency of TCU vehicles being especially lower than that of non-TCU vehicles. As explained in subsequent slides, this is due to the TCU vehicles having an inherently lower efficiency overall due to their greater weight.

Energy Consumption of Ancillaries

This graph shows the energy consumption of the main ancillaries: the cab heater and TCU, for just the 8 temperature-controlled vehicles. Because the cargo is actually heated in winter, the peak TCU consumption is during cold weather, which matches cab heater consumption.

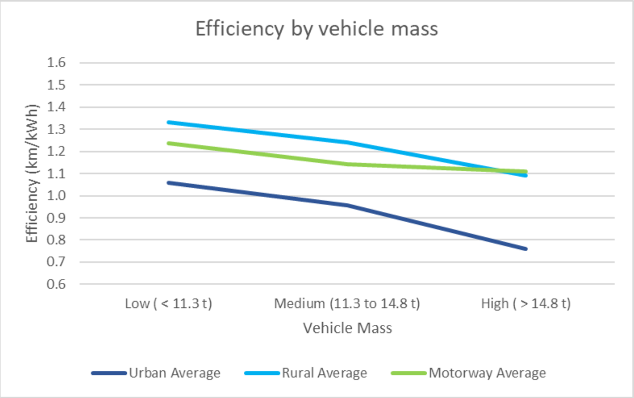
Note that the gap in December is due to very low usage of the vehicles over the Christmas week.

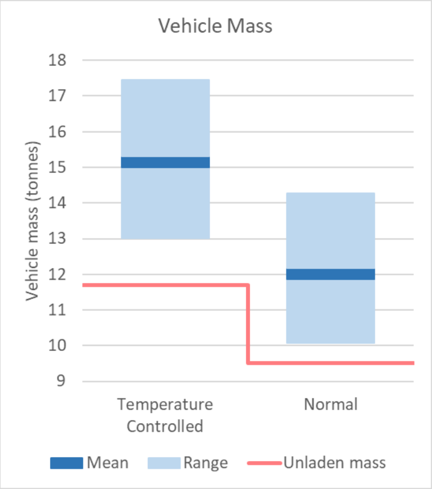


This raises the question: why is the efficiency of temperature-controlled vehicles especially lower in warmer summer weather compared to normal vehicles, as shown by the grey boxes on the previous slide? This seems counter-intuitive when the majority of ancillary consumption is in the winter.

Energy Consumption by Payload

These graphs are summaries of data presented in the “Energy by Usage” deep dive report. The graph on the right shows that the unladen weight of temperature-controlled vehicles is around two tonnes heavier than the normal vehicles, and that they tend to carry around one tonne more payload, making them three tonnes heavier on average.





The left-hand graph shows that across all vehicles, at high payloads the efficiency of the rural drive cycle is lower than motorway. This is because more energy is required to accelerate this greater mass.

Due to including lots of start-stop activity, the efficiency of the urban drive cycle is especially lower for heavier vehicles.

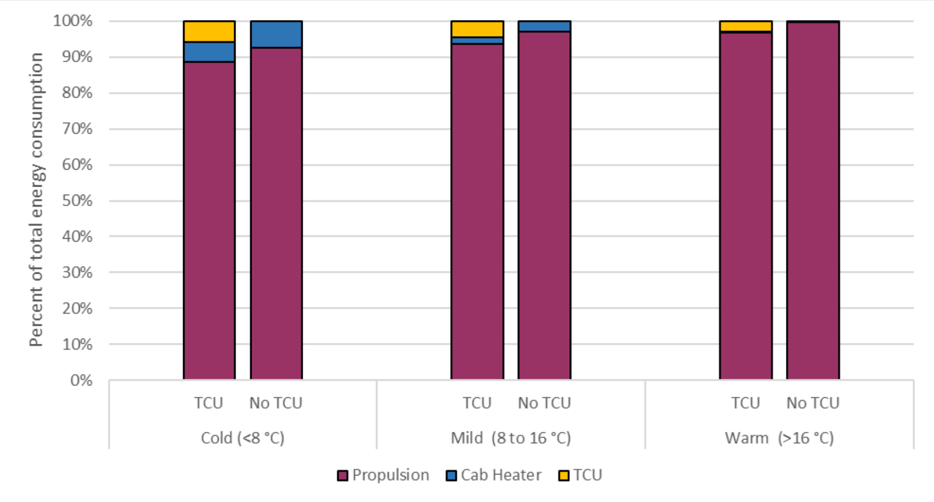
This explains the grey box results as it indicates that the efficiency difference between the temperature-controlled and normal vehicles is driven predominantly by the difference in vehicle weight and payload, not the energy consumption of the refrigeration unit.

Propulsion and Ancillaries

This graph shows the proportion of energy used by propulsion and the main ancillaries, split by the vehicles with and without a TCU across a range of temperatures.

In warm conditions, the TCU consumes just 3% of the energy of the vehicles with one fitted. In cold conditions, the TCU consumption increases to around 6%, with total ancillaries consuming 11% for vehicles with a TCU, and 7% for those without.

The energy consumption of the ancillaries is much lower than the roughly 20% reduction in efficiency seen between the TCU and non-TCU vehicles, further reinforcing that payload and temperature play a much larger part in the overall efficiency than the ancillary consumption.

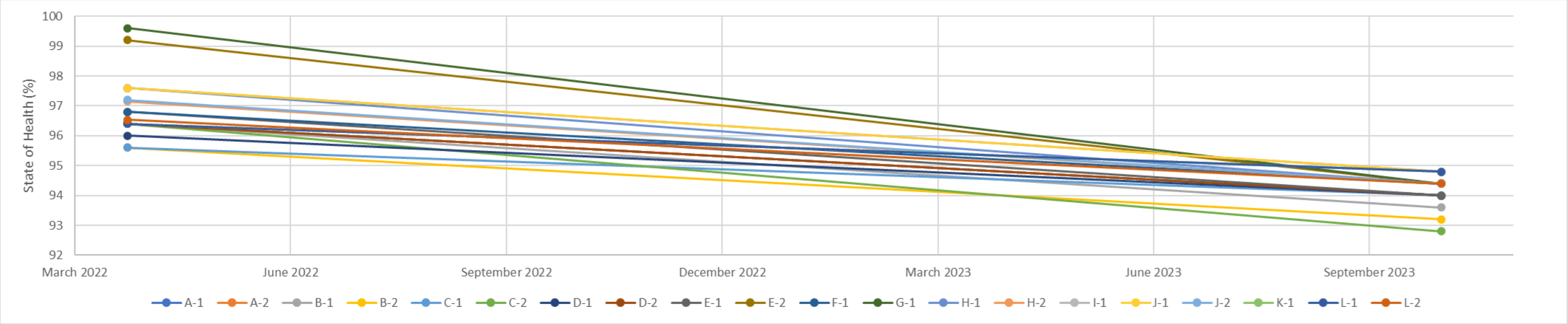


Higher payload increases the energy required to accelerate and climb hills. Winter conditions reduces the efficiency of the powertrain and mechanical components due to lower temperature, while more wind and rain increases air and rolling resistance.

Battery Degradation

The vehicles report the propulsion battery's state of health (SOH) which is a measure of how degraded the battery has become due to age or usage. The exact meaning of this and how it is calculated varies by battery manufacturer, but it's generally a rough indicator of how much of the original energy capacity the battery can still hold.

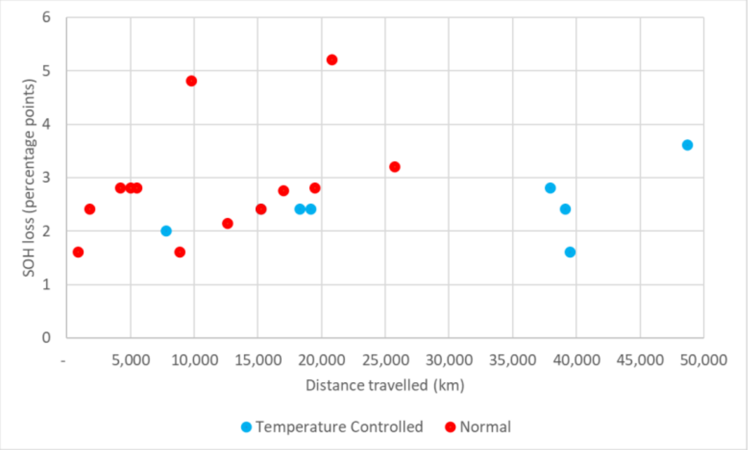
All of the batteries started at below 100% SOH, which likely shows discrepancies with how the SOH is measured rather than any issue with those batteries. However, all vehicles showed a small SOH drop during the trial.



Battery Degradation

There is, however, little correlation with the usage of the vehicles. Most vehicles lost about 2% to 3% SOH during the trial, regardless of the distance travelled or use of ancillary consumption. Two vehicles lost 5% SOH, however both had a starting SOH around 2 percentage points higher than the rest, so this may well simply be uncertainties in measuring the SOH rather than higher degradation.

DAF provides a warranty that the SOH will be greater than 70% after 6 years, and even a 5% loss after 18 months is well within this.



Due to battery degradation being a slow process, the BETT trial has not been long enough to draw definitive conclusions of the long-term battery health.

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To keep up to date with the trial, visit bett.cenex.co.uk

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