Sunderland City Council
Electric Vehicle Analysis Report

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Cenex

Centre of excellence for low carbon and fuel cell technologies

Executive summary

- Sunderland City Council has made a commitment to reduce the city's greenhouse gas emissions by 80% by 2050 as well as becoming a national hub of the low carbon economy by using the opportunities offered by new low carbon technologies to stimulate economic activity in Sunderland.
- These aims emphasise the need to showcase electric vehicle projects.
- The Cenex FCRT is a simulation tool that can calculate the fuel usage, carbon dioxide emissions generated and operating costs incurred by the operation of a fleet of vehicles over representative driving cycles.
- Existing simulation models were used as the results would be representative of small passenger cars and 3.5 tonne van performance within the Sunderland fleet operation.
- Cenex were requested to match SCC's typical drive cycle profiles to an existing drive cycle in the FCRT.
- Two drive cycles were selected for analysis; the FTP72 cycle was the most representative of the SCC vehicle usage. The Artemis urban cycle was selected for additional analysis to show how heavy urban usage impacts on environmental and cost of ownership performance.
- The Ownership Cost analysis included electricity prices, residual values, mileage scenarios and maintenance costs.
- Electric car use make economic sense in a heavy urban usage; especially when combined with increased mileage and increased off peak charging.
- Purchasing and using electric cars has potential for significant cost savings of up to £914 per annum.
- There is potential for parity in electric van ownership costs when the new Plugged in Van Grant is accounted for as well as linear rising energy prices (diesel and electricity), especially when increased mileage and off peak charging scenarios are included.
- The potential ranges of the selected EVs are more than sufficient to cover the required duty pattern.
- In the case of the electric van, there is the potential to 'right size' the battery and therefore reduce purchase price.
- For electric car use, the well to wheel carbon dioxide emission savings range from 9% to 15% depending on operation., with a potential annual carbon dioxide saving of 2.5 tonnes per annum.
- For electric van use, the well to wheel carbon dioxide emissions range from 10% to 19% depending on operation, with a potential annual carbon dioxide saving of 7 tonnes per annum.
- New and emerging electric vehicle technology (e.g. Nissan EV200) have potential to fit SCC fleet operations.

Contents

Introduction

- Sunderland City Council (SCC) has made a commitment to reduce the city's greenhouse gas emissions by 80% by 2050, along with an action plan to manage and reduce the city's greenhouse gas emissions over the coming years.

- The Sunderland Strategy 2008-2025 details a commitment to reducing the city's transport carbon emissions by developing more sustainable modes of transport through the Sunderland Partnership.

- Sunderland's Economic Masterplan (EMP) was produced in 2010. Aim 2 of the EMP is that Sunderland will be a national hub of the low-carbon economy by using the opportunities offered by new low-carbon technologies to stimulate economic activity in Sunderland. This Aim emphasises the city's national potential and the need to showcase projects such as electric vehicles.

- Driven by the desire to reduce fleet carbon dioxide (CO_2) emissions and stimulate economic activity, SCC approached Cenex to undertake the following activity:
  - An initial top level electric vehicle replacement analysis with the aim of showing the potential ownership cost and environmental benefits of operating electric vehicles within the Council's fleet operations.

- Cenex, through their leading edge low carbon expertise, have developed a Fleet Carbon Reduction Tool (FCRT) which allows the accurate estimation of the carbon reduction performance of different transport fuels and technology options in real-world fleet applications. This tool would be used to identify the potential ownership cost and environmental benefits of operating electric powered cars and 3.5 tonne vans within the Council's operation.

Key points

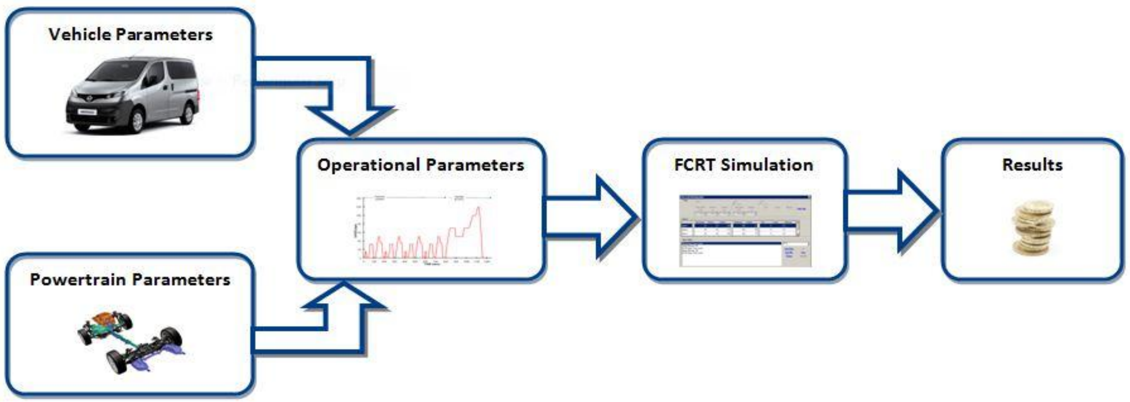
Sunderland City Council has made a commitment to reduce the city's greenhouse gas emissions by 80% by 2050 as well as becoming a national hub of the low carbon economy by using the opportunities offered by new low carbon technologies to stimulate economic activity in Sunderland. These aims emphasise the need to showcase electric vehicle projects.

Fleet Carbon Reduction Tool: Overview

- The Cenex FCRT is a simulation tool that can calculate the fuel usage, carbon dioxide emissions generated and operating costs incurred by the operation of a fleet of vehicles over representative driving cycles. Additionally the FCRT will highlight current operating conditions which may not be met by alternative vehicle technologies (such as range or payload restrictions).

- The tools is able to support a wide number of different powertrain technologies and vehicle categories, ranging from car derived vans through to full sized commercial vehicles; and to allow for customisation to more accurately reflect the actual mix of vehicles used by any given fleet operator.

- The operation of the tool is depicted below:



- The tool therefore yields quantitative information to feed into the decision making process for choosing low carbon technology options which can reduce and/or eliminate the need for trialling some technology options in the field.

Key points

The Cenex FCRT is a simulation tool that can calculate the fuel usage, carbon dioxide emissions generated and operating costs incurred by the operation of a fleet of vehicles over representative driving cycles.

The selected vehicles

- The analysis undertaken compared the performance of the following vehicles:
- City cars
    - Smart diesel & smart ED
    - Cenex have existing simulation models
    - Considered suitable, as it is similar in driving style to a Nissan Leaf

Smart ED	
Gross vehicle weight	1020 kg
Motor power	28 kW
Battery capacity	16.5 kWh
Max speed	100 kph

- Panel vans
    - Peugeot Boxer and Allied Boxer ED
    - Allied – converted Peugeot; retro-fitted with electric motor
    - Cenex have existing simulation models
    - Most suitable comparison as used by many Local Authorities and other public sector organisations

Allied ED	
Gross vehicle weight	3500 kg
Motor power	60 kW
Battery capacity	54 kWh
Max speed	90 kph

- Results generated by using these simulation models will be representative of small passenger cars and 3.5 tonne van performance within the Sunderland fleet operation.

Key points

Existing simulation models were used and the results will be representative of small passenger cars and 3.5 tonne van performance within the Sunderland fleet operation.

Drive cycle creation

- A drive cycle is a robust method of analysing the comparative performance of vehicles for the following reasons:
  - It allows different vehicles to be directly compared over identical driving conditions with external sources of variation (such as traffic conditions and driving style) removed.
  - Repeatable tests allow new technologies to be evaluated over real-world derived drive cycles and compared to existing fleet vehicles in very short times at a relatively low cost (when compared to a vehicle trial).

- To create bespoke SCC drive cycles Cenex would normally require second by second time-speed data from the Council's telematics provider (ctrack).
  - SCC are in the process of upgrading and improving their fleet management software and vehicle tracking systems.

- Following dialogue with SCC officers, it was considered that based upon the suitability of the data available the best approach would be to agree appropriate journeys for analysis. Two most appropriate uses are a car derived van used for inspections and visits to sites and a 3.5 tonne panel style van used for typical loading and unloading operations

Sunderland drive cycle key stats		
Distance	38	miles
Avg speed	20	mph
Town driving	96	%
A/B road driving	0	%
Motorway driving	5	%

- Therefore Cenex were requested to match the Council's typical drive cycle profile to an existing drive cycle contained in the FCRT.

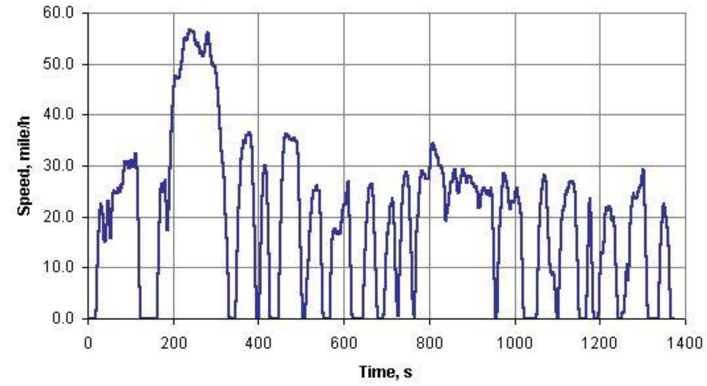
Key points

A drive cycle is a robust method of analysing the comparative performance of vehicles.
Cenex were requested to match SCC's typical drive cycle profile to an existing drive cycle in the FCRT.

Selected drive cycles

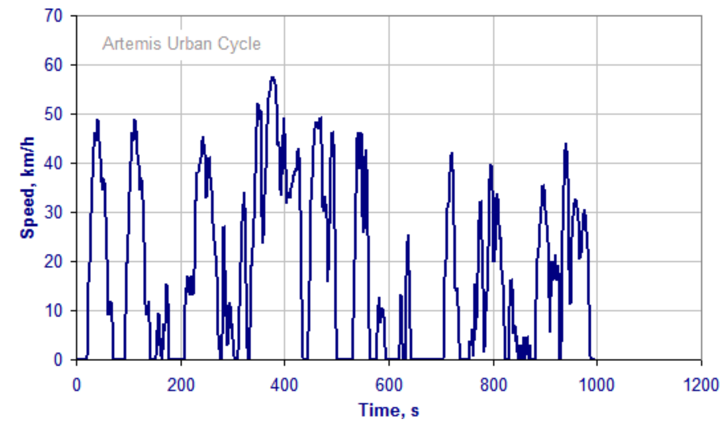
- The drive cycles selected for analysis were:
  - FTP72: a US test cycle for cars and vans which simulates a urban route with frequent stops.
  - Representative of typical Council van usage

FTP72 drive cycle key stats		
Distance	17.5	miles
Avg speed	19	mph
Town driving	90	%
A/B road driving	0	%
Motorway driving	10	%



  - Artemis Urban: a reference drive cycle from real world European fleet data.
  - Representative of ‘heavy’ urban vehicle usage

Artemis urban drive cycle key stats		
Distance	3	miles
Avg speed	10	mph
Town driving	100	%
A/B road driving	0	%
Motorway driving	0	%



Key points

Two drive cycles were selected for analysis; the FTP72 cycle was the most representative of the SCC vehicle usage. The Artemis urban cycle was selected for additional analysis to show how heavy urban usage impacts on environmental and cost of ownership performance.

Economics

➢ The economic and total cost of ownership data used for the EV analysis are detailed below:

Energy scenarios

- **Fixed energy cost model (current energy costs)**
  - 111.4 ppl diesel
  - 9.4 p/kWh peak electricity
  - 5.7 p/kWh off-peak electricity
- **Linear rising energy cost scenarios**
  - 111.4 rising to 200.4 ppl in year 7
  - 9.4 rising to 15.1 p/kWh peak in year 7
  - 5.7 rising to 11.4 p/kWh off-peak in year 7
- **Charging time scenarios**
  - 90% peak / 10% off-peak
  - 10% peak / 90% off-peak
- **Fuel consumption modelled using the Cenex FCRT**

Vehicle purchase and residual values

- £8,392 for diesel smart (40 kW Cdi) and £15,833 for smart ed (based on insurance value, including PiCG). smart residual value 40%, 32% and 22 % in yrs 3, 5 and 7 (not including PiCG)
- £23,416 for diesel Peogeot Boxer (L2H2 120HP 2.2l HDi) and £64,000 for an EV van. Residual value 25%, 18% and 9% in yrs 3, 5 and 7 (not including PiVG)
- Residual values adjusted to incorporate annual mileage

Annual mileage scenarios

- **Base mileage case (10,000 miles)**
  - Average daily mileage extrapolated to 260 days per annum.
- **Increased mileage case**
  - Daily mileage increased by 40%.

Maintenance

- Scheduled maintenance costs included
- Unscheduled maintenance costs excluded

Other

- No insurance cost differential
- EVs and the diesel smart fortwo pay £0 rate UK road tax. The Peugeot Boxer pays £210 PA UK road tax.
- No soft incentives included (e.g. exemption from parking charges, road pricing fees etc.)
- No allowance was included for the installation and maintenance of recharging infrastructure

Key points

A thorough TCO analysis included electricity prices, residual values, mileage scenarios and maintenance costs.

Analysis Results: economics

- Smart CDI vs. smart ED
- Over analysed operations at current mileage (using 90% peak charging) the average annual premium is £326.
  - This decreases to £236 when charging scenario changed to 90% off peak
- Over analysed operations at increased mileage (using 90% peak charging) the average annual premium is £157.
  - This decreases to £32when charging scenario changed to 90% off peak
- When linear rising energy prices (diesel and electricity) are taken into account significant ownership cost savings can be achieved; especially when increased mileage and off peak charging scenarios are included.
  - Up to £914 saving per annum.

		Smart fortwo ED											
		Current Energy Prices						Linear Rising Energy Prices					
Mileage Scenario	Drive Cycle	90% Peak			90% Off Peak			90% Peak			90% Off Peak		
		Year 3	Year 5	Year 7	Year 3	Year 5	Year 7	Year 3	Year 5	Year 7	Year 3	Year 5	Year 7
Base mileage	SCC - FTP72	525	369	330	446	289	250	392	146	18	312	67	-61
	SCC - Artemis Urban	361	204	165	262	105	66	167	-119	-287	68	-218	-386
Increase mileage	SCC - FTP72	389	233	194	278	122	83	155	-134	-307	36	-253	-426
	SCC - Artemis Urban	159	3	-36	21	-136	-175	-182	-532	-765	-331	-681	-914

Key points

Electric car use make economic sense in a heavy urban usage; especially when combined with increased mileage and increased off peak charging.

Purchasing and using electric cars has potential for significant cost savings of up to £914 per annum.

Analysis Results: economics

- Boxer CDI vs. Allied ED

- Over analysed operations at current mileage (using 90% peak charging) the average annual premium is £5,810.
  - This decreases to £5,602 when charging scenario changed to 90% off peak.

- Over analysed operations and at increased mileage (using 90% peak charging) the average annual premium is £5,390.
  - This decreases to £5,100 when charging scenario changed to 90% off peak.

- When linear rising energy prices (diesel and electricity) are taken into account, even when increased mileage and off peak charging scenarios are included the lowest potential annual premium is £1,367.

		Electric Panel Van (no PIVG)											
		Current Energy Prices						Linear Rising Energy Prices					
Mileage Scenario	Drive Cycle	90% Peak			90% Off Peak			90% Peak			90% Off Peak		
		Year 3	Year 5	Year 7	Year 3	Year 5	Year 7	Year 3	Year 5	Year 7	Year 3	Year 5	Year 7
Base mileage	SCC - FTP72	8569	5329	4071	8381	5140	3882	8231	4765	3280	8042	4576	3092
	SCC - Artemis Urban	8209	4969	3711	7983	4743	3485	7739	4186	2614	7513	3960	2388
Increase mileage	SCC - FTP72	8221	4981	3723	7957	4717	3458	7747	4191	2616	7483	3927	2352
	SCC - Artemis Urban	7718	4477	3219	7401	4161	2902	7059	3381	1684	6743	3065	1367

Key points

At the current purchase price (£64,000), the Allied ED does not make economic sense for the Council.

Analysis Results: economics

- Boxer CDI vs. Allied ED
- When new Plugged in Van Grant taken into account, the results of the economic analysis indicate that it remains difficult to justify purchase of Allied electric vehicles.
- However, potential for parity in ownership costs is achievable when linear rising energy prices (diesel and electricity) are taken into account, especially when increased mileage and off peak charging scenarios are included.
  - The lowest potential annual premium using these scenarios is £224

		Electric Panel Van (with PIVG)											
		Current Energy Prices						Linear Rising Energy Prices					
Mileage Scenario	Drive Cycle	90% Peak			90% Off Peak			90% Peak			90% Off Peak		
		Year 3	Year 5	Year 7	Year 3	Year 5	Year 7	Year 3	Year 5	Year 7	Year 3	Year 5	Year 7
Base mileage	SCC - FTP72	5903	3729	2928	5714	3540	2739	5564	3165	2137	5375	2976	1949
	SCC - Artemis Urban	5543	3369	2568	5317	3143	2342	5073	2586	1471	4847	2360	1245
Increase mileage	SCC - FTP72	5555	3381	2580	5291	3117	2316	5081	2591	1473	4816	2327	1209
	SCC - Artemis Urban	5051	2877	2076	4734	2561	1759	4393	1781	541	4076	1465	224

Key points

There is potential for parity in ownership costs when the new Plugged in Van Grant is accounted for as well as linear rising energy prices (diesel and electricity), especially when increased mileage and off peak charging scenarios are included.

Drive cycle vehicle efficiency & range

- The potential ranges of the Smart and Allied electric vehicle were analysed over the FTP72 and Artemis urban drive cycles to gain an understanding of whether they could undertake the anticipated daily working pattern, without requiring recharging.

- The current daily working pattern for SCC is 38 miles.

- As can be seen from the tables, both the Smart and Allied electric vehicle have the potential range to cover the expected duty:
  - On the SCC representative drive cycle (FTP72) the smart car could achieve 61 miles; while the van could achieve 83 miles.
  - On a more urban drive cycle (Artemis urban) the smart car could achieve 48 miles; while the van could achieve 69 miles.

- In the case of the Allied, there is the potential to 'right size' the battery; which may reduce the initial price of the vehicle.
  - Right sizing involved reducing the size of the battery pack (and therefore capacity) to a size appropriate to the expected operation.

battery capacity (kWh)	
Smart	16.5
Allied	54

	Energy Consumption (kWh/100km)		Range (miles)	
	FTP72	Artemis Urban	FTP72	Artemis Urban
Smart ED	16.9	21.09	61	48
Allied ED	40.21	48.15	83	69

Key points

The potential ranges of the selected EVs are more than sufficient to cover the required duty pattern.
In the case of the Allied, there is the potential to 'right size' the battery.

Introduction to vehicle CO_2 emissions

Well-to-wheel (WTW) emissions methodology was used to quantify the carbon footprint of the transport fuels. This assessed the carbon impact of the total energy chain used to produce and use the fuel and the source of the carbon embodied within the fuel i.e. whether it is from a fossil or renewable source. For the purpose of carbon accounting relevant to this project CO_2 emissions are quantified using three formats as described below.

- **WTW emissions –** WTW greenhouse gas emissions consisted of well-to-tank (WTT) and tank-to-wheel (TTW) emissions segments. The WTT portion quantified the emissions produced during the extraction, processing, delivery and dispensing of the fuel. Whilst the TTW portion quantified the CO_2 emitted directly from a vehicle that was additional to normal atmospheric CO_2 levels and hence contributed to global warming.

- **TTW emissions** – TTW emissions were introduced above. These are a measure of the CO_2 emitted directly from a fuel that is outside the planets natural carbon cycle and increases atmospheric CO_2 levels. Hence for the combustion of a renewable fuel the direct TTW emissions are typically very close to zero. Under UK emissions reporting guidance the direct TTW emissions only are the responsibility of the transport operator.

- **Tailpipe emissions** – These represents the absolute amount of CO_2 emitted directly from a vehicles exhaust pipe regardless of the fuels origin and sustainability. Manufacturers are legally bound to test and declare the tailpipe emissions of their vehicle over the regulated test cycle. However, tailpipe emissions are not relevant when assessing the CO_2 performance of a renewable fuel.

Key points

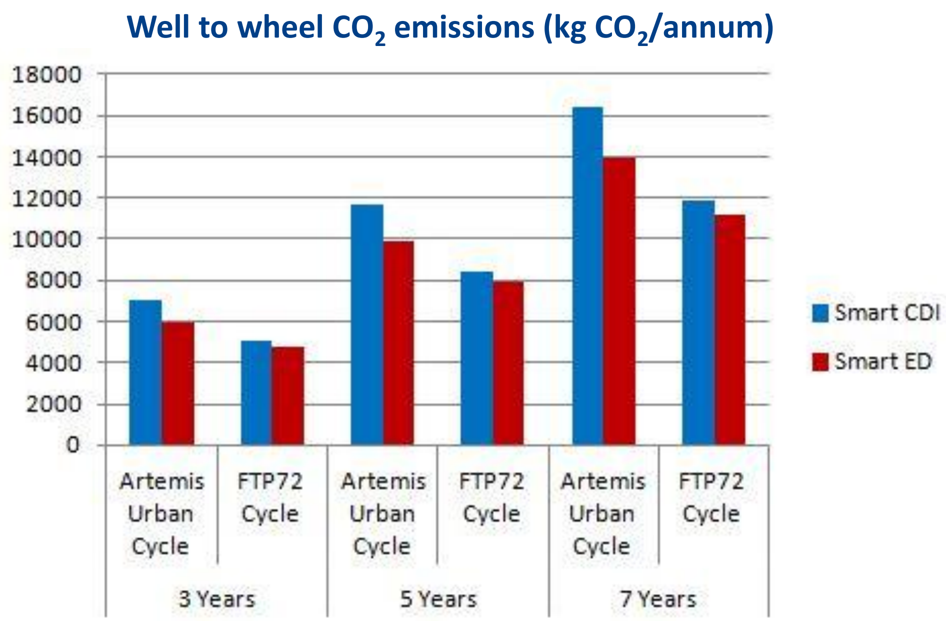
WTW emissions quantify the total carbon footprint of a transport fuel.
Tailpipe emissions are an absolute measure of CO_2 emitted from a vehicles exhaust pipe regardless of the fuels origin.
As SCC are not using a renewable fuel, this report does not provide figures for TTW emissions.

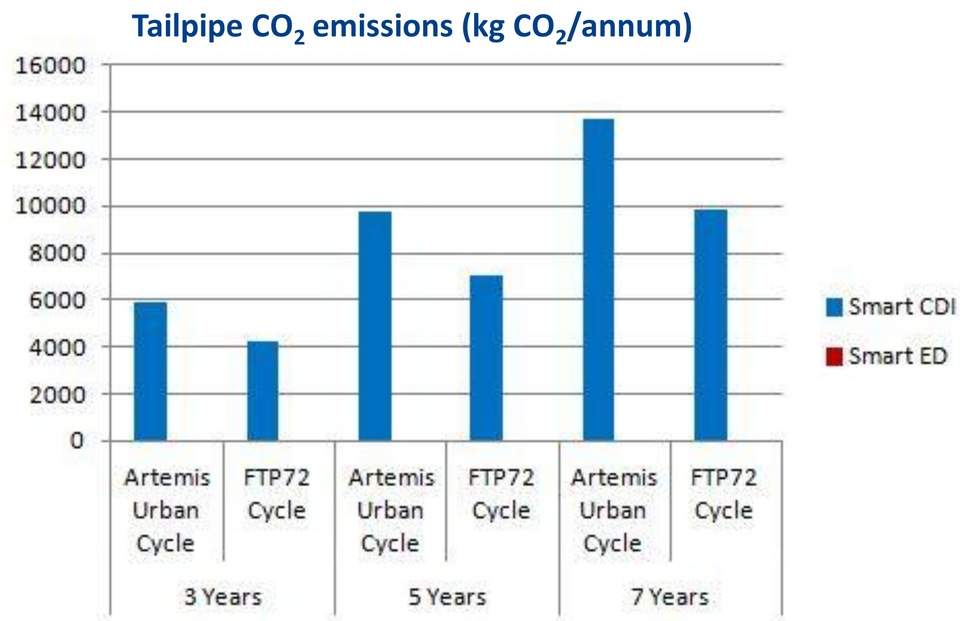
Analysis Results: carbon emissions

- Smart CDI vs. Smart ED
  - Over each drive cycle
  - Over each replacement cycle

- WTW CO_2 savings
  - 15% on Artemis urban
  - 9% on FTP72

- Tailpipe CO_2 savings
  - 100% on both





Key points

Carbon dioxide emission savings are more pronounced in fully urban environments.
Well to wheel carbon dioxide emission savings range from 9% to 15% depending on operation.
Potential for annual carbon dioxide saving of 2.5 tonnes per annum

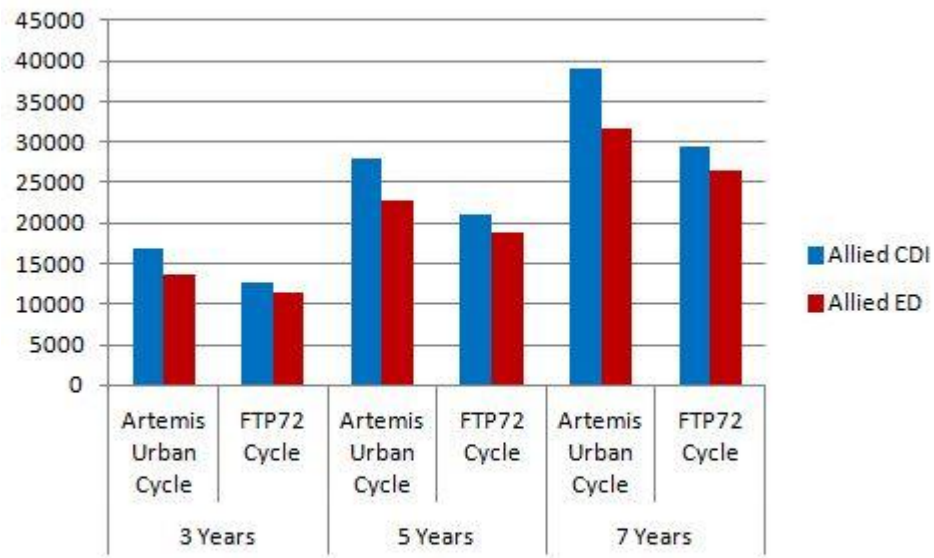
Analysis Results: carbon emissions

- Boxer CDI vs. Allied ED
  - Over each drive cycle
  - Over each replacement cycle

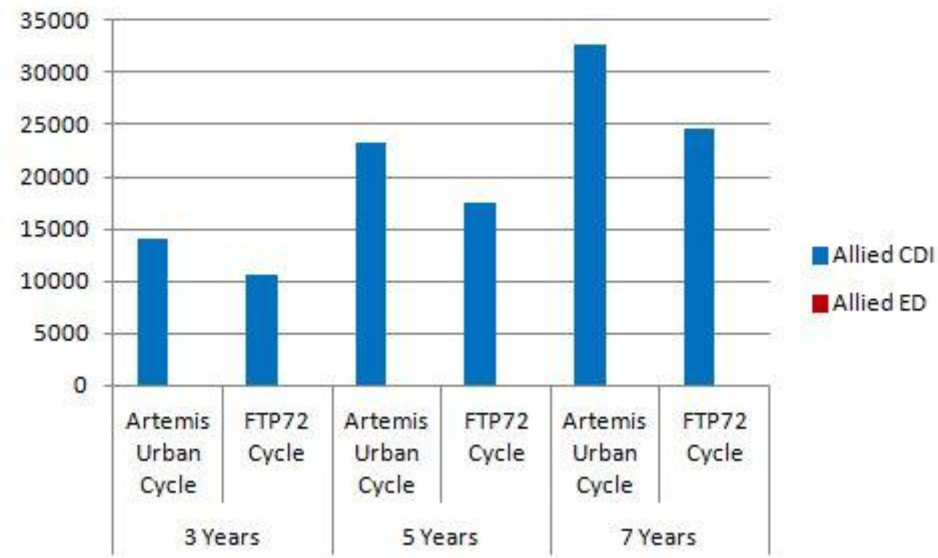
- WTW CO_2 savings
  - 19% on Artemis urban
  - 10% on FTP72

- Tailpipe CO_2 savings
  - 100% on both

Well to wheel CO_2 emissions (kg CO_2/annum)



Tailpipe CO_2 emissions (kg CO_2/annum)



Key points

Carbon dioxide emission savings are more pronounced in fully urban environments.
Well to wheel carbon dioxide emissions range from 10% to 19% depending on operation.
Potential for annual carbon dioxide saving of 7 tonnes per annum.

FTP72 drive cycle summary

Sunderland City Council
FTP72 drive cycle summary

Vehicle type	Fuel consumption (l/100km)	Diesel vehicle emissions ($g\ CO_2$ / km)		Energy efficiency (kWh/100 km)	Vehicle range (km)	Electric vehicle emissions ($g\ CO_2$ / km)		Emission reduction from diesel to electric (%)	
		Tailpipe emission	WTW emission			Tailpipe emission	WTW emission	Tailpipe emission	WTW emission
Smart	3.29	88.95	106.53	16.90	98	0.00	100.36	100	6
Boxer/Allied	8.18	221.21	264.94	40.21	134	0.00	238.74	100	10

Key points

Artemis urban drive cycle summary

Sunderland City Council

Artemis urban drive cycle emissions summary

Vehicle type	Fuel consumption (l/100km)	Diesel vehicle emissions (g CO_2 / km)		Energy efficiency (kWh/100 km)	Vehicle range (km)	Electric vehicle emissions (g CO_2 / km)		Emission reduction from diesel to electric (%)	
		Tailpipe emission	WTW emission			Tailpipe emission	WTW emission	Tailpipe emission	WTW emission
Smart	4.56	123.23	147.59	21.09	78	0.00	125.21	100	15
Boxer/Allied	10.86	293.69	351.75	48.15	112	0.00	285.83	100	19

Key points

Concluding statements (1)

- Due to the limited range of an electric vehicle, drive cycle based TCO modelling is essential if sweet spots of economic operation are to be accurately identified in fleets.
- This document presents a performance evaluation of two comparable groups of vehicles, the Smart CDI and Smart ED and the Peugeot Boxer CDI and Allied Boxer ED. The vehicles selected were deemed most appropriate for this analysis as they are directly comparable.
- The drive cycles selected were chosen as they best reflected the operation of the SCC fleet.
  - Additional drive cycles may be created to further assess chosen vehicle specifications using data obtained from the Council's fleet management information.
- Challenges in terms of total cost of ownership need to be overcome. The total cost of ownership will clearly vary dependent on a fleets duty cycle, energy usage levels and the vehicle technology used.
  - The variation in economic performance shown in the tables above demonstrates the influence of energy costs and more critically energy consumption on the analysis results. Essentially, the driving duty and daily mileage must allow the savings in fuel costs to recover the additional purchase cost of the EV.
- Extending vehicle ownership periods and utilising cheaper off-peak electricity can be used to fine tune the economic case.

Key points

Electric cars provided the best potential for cost and environmental savings within the analysed drive cycles.
Emissions of WTW CO_2 were significantly improved for both vehicle groups when running in a more urban drive cycle.

Concluding statements (2)

- Fixing energy costs at today's prices for the duration of the analysis is both pessimistic and unrealistic and estimating future energy costs is fraught with uncertainty. The tables above show the results using both energy cost scenarios. The linear costs analysis is a more likely scenario and incorporates a cautious linear rise in energy prices based on historical trends.

- The electric passenger car analysis showed that marginal ownership cost reductions can be achieved when fixing today's energy prices.
    - Significant cost savings can be achieved when increased mileage and off peak charging are taken into account, up to £914 saving per annum.

- The electric panel van analysis showed that cost beneficial operation was not currently achievable; mainly due to the high purchase price of the Allied Boxer ED.

- Emissions of WTW CO_2 were significantly improved for both vehicle groups when running in a more urban drive cycle.

- Electric car use provided the best potential for cost and environmental savings within both the FTP72 and Artemis urban drive cycles.

- The analysis results show that there is potential to 'right size' the battery in the electric van, which may help to reduce the purchase price.

- Use of current panel van electric vehicles within the analysed scenarios would require fundamental shift in use and ownership strategy for the Council.

- New and emerging electric vehicle technology (e.g. Nissan EV200) have potential to fit SCC fleet operations.
    - Cenex in communication with Nissan regarding creating a Nissan EV200 simulation model

Key points

Electric cars provided the best potential for cost and environmental savings within the analysed drive cycles.
Emissions of WTW CO_2 were significantly improved for both vehicle groups when running in a more urban drive cycle.

Next steps

- A more detailed analysis is needed to better understand the potential for deploying electric powered cars and vans within the SCC fleet operation. This will require:

  - Additional drive cycles may be created to further assess chosen vehicle specifications using data obtained from the Council's fleet management information.

  - The selection or development of more appropriate vehicle simulation models.
    - Cenex are in the process of developing improved car and light van EV simulation models.

  - Review of SCC operations with regards vehicle fit to job to understand whether any vehicles can be 'down-sized' due to under used load capacity.
    - This may allow for wider selection of electric vans to be chosen (e.g. Nissan EV200)

Key points

A more detailed analysis is needed to fully understand the potential for deploying a range of appropriate electric vehicles within the SCC fleet operation.

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