Powered Light Vehicles:
Challenges and Opportunities for Low Carbon L-Category Vehicles in the UK

Whole Life Cycle Energy Requirements

Final Report
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Powered Light Vehicles: Whole Life Cycle Energy Requirements

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Project Brief:

The L-Category vehicle sector has been identified as offering economic, environmental and societal benefits. However, the UK currently lags behind other countries in exploiting the advantages of this transport sector. Following a LowCVP seminar and workshop on the subject, it was agreed that further work would be worthwhile, to explore L-Category vehicles' potential in greater detail. The primary focus was to be around the larger three and four-wheeled L-Category vehicles, dubbed **Powered Light Vehicles**, as Powered Two-Wheelers (PTWs), such as motorbikes and mopeds, are already established markets in the UK.

A consortium of specialists from seven UK universities have come together to produce a series of reports, pro bono, in conjunction with the LowCVP's Innovation Working Group and including input from stakeholders to ensure relevance.

These reports are not intended as an end in themselves, but instead to act as a spur to action: to build the UK's capability in ultra-light automotive engineering and to provide conditions which support the market for micro vehicle uptake.

For more information about the LowCVP and the Partnership's work on Powered Light Vehicles visit:

LowCVP.org.uk/PLV

Whole Life Cycle Energy of Powered Light Vehicles

The upper end of L-Category Powered Light Vehicles (PLVs) can be described as lower powered and lighter equivalents of the everyday M-category vehicles. The reduced size, reduced load-carrying abilities and lower max power has meant that the category has been side-lined in the UK because it simply cannot compete with larger, more powerful, vehicles. This also means that L-category PLVs are not generally regarded as being versatile use vehicles.

However, over the last ten years the automotive focus has shifted towards energy-efficient and lower material cost cars. The largest change has been the strong push to reduce tailpipe emissions which has taken effect across the world and forced automotive manufacturers to reconsider drivetrain choices and focus on light-weighting. In addition, long term sustainability of travel and transport, and congestion in cities, have become serious concerns. Fortunately, the low mass and relatively low-powered PLVs offer solutions, albeit with the additional costs of innovation, experimentation and the risks that accompanies any new venture. A combination of regulation and incentivisation in the UK could elevate the recognition of PLVs. Indeed, L-category powered light vehicles could become a beacon for electric vehicle adoption.

PLVs are not currently a dominant feature in any country’s transport sector, with production consisting mostly of small, independent companies. However, the markets for these smaller lighter class of vehicles have been developed strongly in China as well as in France, Germany and Italy. This module covers the whole life cycle consideration of these vehicles.

2.1. Whole Life Energy

The whole life of vehicles is the best way to compare the environmental impact that their usage will have, because it considers not only the use phase of the vehicle but also the impact from the production of the components and the end life of these components. While there are few details available regarding the exact materials used, processes used in the components' manufacture and the exact amount of materials recycled, the numbers can be estimated to provide a reasonable comparison of L-category and M-category vehicles. (The assumptions are presented in Table A2.1 in the Appendix of this report.)

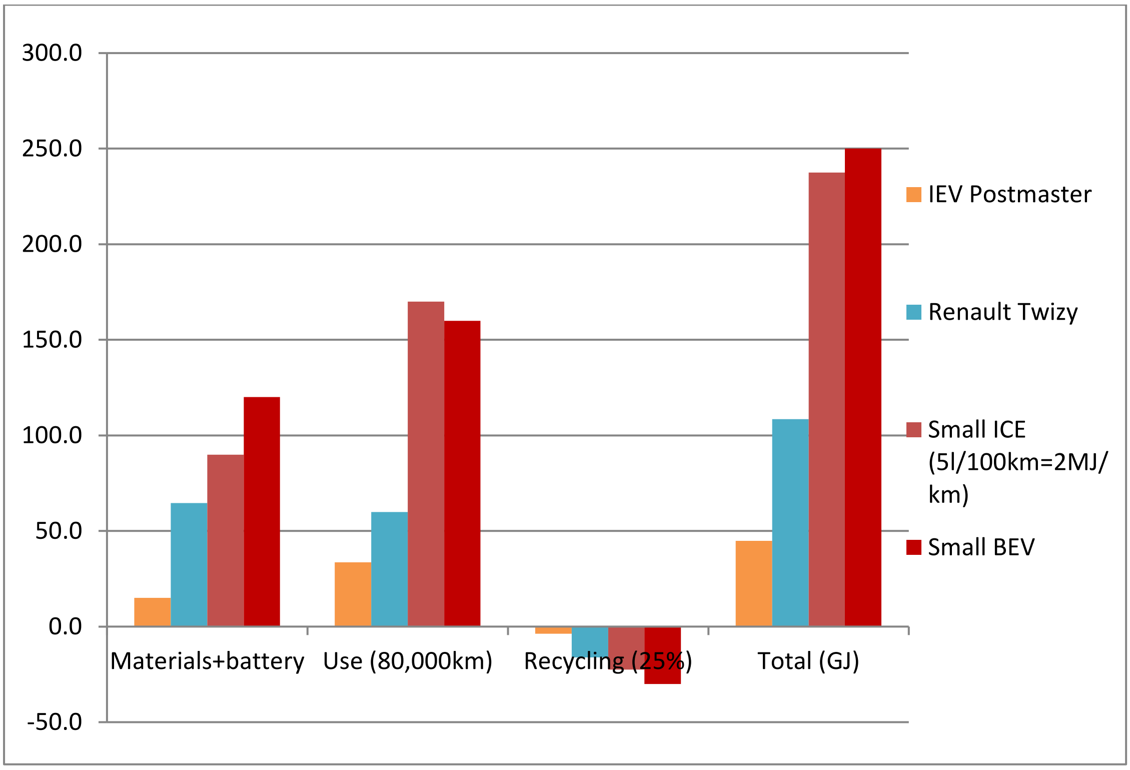

FIGURE 2.1. WHOLE LIFE ENERGY COMPARISON OF AN IEV POSTMASTER (L2E), RENAULT TWIZY (L7E), A SMALL ICE VEHICLE (M1) AND A SMALL BEV (M1).

PLVs require much less energy in the use phase, largely because of their lower overall masses. Even ignoring the "in-use phase", the materials generally offer a much lower embodied energy, too. The Twizy for example uses an aluminium chassis and so has a relatively large embodied energy due to the high embodied energy content of aluminium.

There is little overall difference between the smallest M-category vehicles, irrespective of powertrain type.

2.2. Manufacturing

Manufacturing of the vehicles encompasses important aspects in a vehicles life such as the materials used, and the processes used in manufacturing.

Due to the low weight limit of L-category powered light vehicles, manufacturers need to use lighter components in order meet these limits while also satisfying customer expectations. There is also a moral imperative to consider the recyclability of vehicles although L-category vehicles are excluded currently from EU regulations. Together, these two factors are pushing the manufacture of PLVs to using lighter, recyclable materials. The Mega Van, for example, consists of a lightweight aluminium chassis and ABS panelling which can be recycled and also be constructed from recycled materials.

As well as a change in materials used in the manufacture of vehicles, the processes used to produce them also change with the main direction being towards the simplification of the processes. This simplification may be due to a few factors:

- L-category manufacturing is largely dominated by small, young companies
- The new materials allow for different production methods
- The recycling imperative requires disassembly of vehicles to be simplified and so impacts the processes used in construction.

2.3 In-Use Phase

The in-use phase of a vehicle has impacts in terms of the energy expenditure as well as the emissions generated over the whole life of the vehicle. As shown in figure 2.1, the use phase for typical vehicles that cover modest distances contributes the largest amount of whole life energy consumption.

TABLE 2.1. COMPARISON OF VARIOUS VEHICLES AND RELEVANT SPECIFICATIONS.

Vehicle	Category	Cost/ 100km (£)	CO_2 Emissions (g/km)	Payload (kg)	L/ 100km	kWh/ 100km
Smarta GT 8 (pedelec) [1]	Similar to L1e	£0.06	0	-	-	0.6
IEV Postmaster [2]	L2e	£0.39	0	260	-	4.2
Inazuma 260 (motorcycle) [3]	L3e	£3.13	64	-	2.7	-
Ape 60 [4]	L6e	£3.36		200	2.9	-
Mega Van Electric [5]	L7e	£1.23	0	630	-	13.4
Mega Van Diesel [6]	L7e	£3.76	-	630	3.1	-
Renault Twizy [7]	L7e	£0.69	0	-	-	7.6
Opel RAK e [8]	L7e	£0.46	-	-	-	6.0
Ford Transit Van [9]	N1	£4.41	97	677	3.8	-
BMW 6 Series Saloon [10]	M1	£4.99	114	-	4.3	-
Renault Clio [11]	M1	£4.06	86	-	3.6	-
BMW i3	M1	£1.60	0		-	18

[1] www.electricbikesales.co.uk
[2] www.ieve.dk
[3] www.suzuki-gb.co.uk
[4] www.piaggioape.co.uk
[5] www.megavan.org
[6] www.megavan.org
[7] www.renault.co.uk
[8] www.vauxhall.co.uk/vehicles/future-models-and-concepts/rak-e/overview.html
[9] www.ford.co.uk/CommercialVehicles
[10] www.bmw.co.uk
[11] www.renault.co.uk

Table 2.1 demonstrates the potential of L-category vehicles and how they measure up against typical M-category vehicles. The Mega Van shows multiple benefits when compared to a competing light commercial vehicle, the Ford Transit van. Both vehicles have similar payload yet the Mega Van (electric) offers zero emissions and costs less than a third of the Transit vans' "fuel" costs. This fuel saving is echoed in the diesel version of the van which has similar payload again and a slightly lower fuel cost.

Another interesting comparison is the passenger vehicles, namely the Renault Twizy and the Clio. The story is the same here, with the Twizy demonstrating zero emissions and a running cost of less than 26% of that of the Clio. The average distance travelled per year in a passenger car in the UK in 2017 is 7,800 miles, which results in the Twizy saving £428 annually in fuelling costs. The use of an electric vehicle also opens the possibility of alternative energy sources which would make the entire operation of the Twizy emission free.

The L-category sector contains many electric vehicles but there is still a fairly large range of typical ICE based vehicles which produce point-of-use emissions. Euro emissions standards were implemented in 1993 and the regulations are regularly tightened to carefully control vehicle emissions within a reasonable limit.

One general issue is that PLVs are lighter and have smaller engines than M-category vehicles. As such, the pressure to innovate and develop the technology is not as high on these niche vehicles compared to larger cars. However, the benefit of this is that there is much more flexibility in the manufacture of PLVs.

A main area of commercial activities that PLVs can benefit from is the idea of last mile delivery which would typically be undertaken by a petrol or diesel van. TNT, a delivery company, created a mobile depot system in Brussels which will be filled with parcels and dropped off at strategic points in the city. From there, a fleet of electric covered tricycles will deliver the parcels all around the city (Figure 2.2). This mobile depot will result in 900 km of van movement being removed from the city per week and so reduce the emissions and noise pollution in the city. If all delivery services were to be replaced with such measures, significant improvements in air quality, noise pollution and congestion could be made in cities.

FIGURE 2.2. TNT MOBILE DEPOT (WITH PEDELEC TRIKE IN THIS EXAMPLE)
Source: www.tnt.com (Corporate News on Mobile Depot)

Finally, it should be noted that the relatively low power requirement of vehicles in the L-category lends itself to some form of renewable energy source such as solar. Typically, the much heavier M-category vehicles require large amounts of energy that cannot be realistically supplied by solar charging alone.

2.4 End of life vehicle legislation

The EU passed the End of Life Vehicles (ELV) Directive in September 2000 (European Union, 2000). It is an EU producer responsibility Directive targeted at making vehicles in general much more environmentally friendly at the end of their service lives, by forcing vehicle manufacturers to adopt new practices and core principles. A more specific Directive concerning type approval of vehicles was introduced in 2006 (European Union, 2006); this extended the concept of ELV to the design stage of vehicle production, thus influencing more directly materials and assembly methods. These Directives do not apply currently to L-category vehicles. However, it is inevitable, especially with greater numbers of PLVs, that they will apply at some time in the future.

The main ELV Directive can be broken down into four sections: limit waste production, organise waste collection and treatment, prioritise recovery and reuse of waste, and facilitate dismantling of vehicles. Prioritisation of re-use and recovery of waste is the most important section regarding the vehicles because it sets strict goals for manufacturers regarding the recycling of their vehicles. The aims in this Directive should have been met in two stages already (2006 and 2016) for M- and N-category vehicles and can be summarised for 2016 as “96% of a vehicle’s average weight shall be recovered or reused, including 86% which must be recycled or reused” (European Union, 2000).

2.5. Summary

The markets for L-category powered light vehicles are dominated by small vehicle manufacturers with limited money for development. However, as evidenced by the Renault Twizy, Opel 'RAK e' and various 3- and 4-wheel products from Toyota, larger automotive manufacturers have ventured into the market and are likely to push the boundaries of what can be extracted from vehicles in this category. The Toyota i-Road represents an innovation from a large automotive company where an original concept for an L2e vehicle has been developed. Kei cars have been a dominant vehicle in Japan for almost a century, with similar specifications to an L-category vehicle. This shows that L-category vehicles do have useful applications in personal mobility and light commercial use, provided the correct incentives are offered and barriers to the adoption of the vehicles are dealt with effectively.

Whilst the focus of this report is on quadricycles and enclosed tricycles, the L1e (moped) category includes vehicles such as e-bikes which could be utilised in many interesting ways. Their low power consumption means that they could be powered solely by renewable sources and could be implemented on a large scale to displace city cars.

There appears to be a significant growth in electric versions of L-category vehicles in some key markets outside the UK. PLVs could accelerate the adoption of electric vehicles (EV) in the UK dramatically with appropriate incentives and regulations. Powered light vehicles can offset the traditional EV barriers of battery cost and vehicle range, and they can better exploit the opportunity to use renewable energy sources such as solar to provide their power requirements. Thus PLVs could provide a unique opportunity to provide EVs as efficient solutions for the movement of people and goods.

Key applications/markets for L-category powered light vehicles may be summarised as:

- Freight distribution and last mile delivery in cities and congested urban areas
- On-line and home delivery of goods and services in cities and urban areas
- Personal mobility in cities and congested urban areas through car share, taxi and private hire
- Movement of people and goods within large organisations (government departments, universities, hospitals, airports, etc)
- Leisure solutions for rural areas and parks
- Mobile sales points for food and refreshments
- Home delivery of goods, services and food in the developing health care sector for older generations.

The whole life energy assessment has demonstrated that there are significant advantages associated with PLVs, potentially reducing lifetime energy consumption by well over 60%. The motivation to promote electric PLVs is therefore very compelling for appropriate markets.

Appendix

Several assumptions were made in the simplified LCA in Section 4, leading to the development of Figure 2.1. This appendix shows the assumptions made for each section. It should be noted that the energy used in manufacturing processes was largely omitted due to the lack of available information on the processes used in several of the vehicles. In the whole life scope, this is a small omission.

Materials: Limited published information was found for the L-category vehicles, the IEV Postmaster and Renault Twizy. Thus, estimates were made based on the vehicle mass and what can be seen on the vehicle. Fortunately, the simple nature of L-category vehicles makes the estimation of materials fairly straightforward. The M-Category assumptions were based on much general and specific published data (*Ashby, 2013; Raugei et al., 2016*).

All of the data are summarised in Table A2.1.

Assumptions:

Embodied energy of 1kWh of electricity = 10MJ

Total embodied energy of petrol = 68MJ/kg = 46MJ/l = 2MJ/km for an economical 60mpg (4.7l/100km) car

Embodied energy of typical Li-ion traction battery pack = 110MJ/kg

Al = 194MJ/kg

Cu = 36MJ/kg

Steel = 31MJ/kg

Electronics = 1,000MJ/kg

Body panels/seats = say 100 MJ/kg

In-Use phase

	kWh/100km	**Energy/fuel for 80,000km**	**GJ**
IEV Postmaster	4.2	3360kWh	33.6
Renault Twizy	7.6	6000kWh	60
Small ICE	4.7(l/100km)	3760l	170
Small BEV	20	16000kWh	160

Materials

IEV Postmaster	187kg (total)	**MJ**
Steel chassis + tubing	100kg	3,100
Body panels + seat	10kg	1,000
Motor + drivetrain (40cu/60steel)	64kg	2,086
Wheels (al/rubber)	17kg	2,360
Electronics	1kg	1,000
Total		**9,636**

Renault Twizy	347kg (total)	**MJ**
Al chassis	207kg	40,168
Body/interior/seats	46kg	4,600
Motor + drivetrain (40cu/60steel)	64kg	2,086
Wheels (al/rubber)	28kg	3,880
Electronics	3kg	3,000
Total		**63,624**

	Battery Mass	**Energy (MJ)**
IEV Postmaster	60kg	6,600
Renault Twizy	100kg	11,000
Small BEV	290kg	32,000

Assume 110MJ/kg

In use: A modest annual distance covered was assumed, based upon city use. This was 80,000km total, based potentially on 8,000km pa for 10 years.

Recycling: Recycling is the simplest of the phases analysed and assumes that an average of 26% of all materials used in the construction of the vehicle will be retrieved and be in a useful, re-useable state.

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