Electric vehicles: Improving consumer information to encourage adoption

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Abstract

High purchase price, range anxiety, uncertainties associated with battery life and other factors relating to new and unfamiliar technology are known to be important in inhibiting electric vehicle uptake by consumers. A number of studies and demonstration projects have already taken place in the UK and elsewhere to identify the key factors inhibiting adoption.

This paper aims to synthesise the findings from existing studies and discuss opportunities for reducing the barriers resulting from insufficient or misleading information. The paper focuses, in particular, on efforts in the UK to integrate information about electric vehicles into the colour-coded Fuel Economy Label, an important mechanism to encourage car buyers to pay attention to the fuel economy and emissions of vehicles prior to and at the point of purchase.

This paper reports the findings of a UK study undertaken in 2012 using six deliberative workshops to ascertain the views and understanding of private car buyers when presented with alternative fuel economy label designs including comparative fuel cost and environmental information. Also reported are the results of an online survey (N=1,005) of UK car buyers which sought quantitative evidence to support or challenge focus group findings.

Results of the study reveal how information on the label is received and understood by consumers, including: the relative importance of fuel economy versus environmental information, the effectiveness of different energy metrics, and the potential of providing 'hard-links' (in the form of a QR code) for future information provision. The paper also makes suggestions for improvements in future labelling design.

Introduction

Electric vehicles[1] are considered a technologically effective means of reducing carbon emissions from the road transport sector and helping to meet the carbon reduction targets set to mitigate climate change. As road transport contributes about 20 % of overall UK CO_2 emissions, it is an important area of policy focus.

The UK was the first country in the world to introduce legally binding national targets for the reduction of greenhouse gas emissions through the Climate Change Act 2008 (DECC 2008), the targets being coordinated by the Carbon Plan (DECC 2011). The Plan sets out how the UK will achieve decarbonisation to meet the overall 2050 target (an 80 % cut as compared with 1990) based on the first four carbon budgets which run four-yearly to 2027. As part of its strategy, the Plan states that: "the emergence of ultra-low emission vehicles (ULEVs) and hybrid and electric cars will be crucial in preparing for progress in the 2020s" (DECC 2011; p. 48).

However, while expectations for the greenhouse gas reductions offered by electric vehicles were initially high (Element-Energy 2009), recent life cycle analyses are more modest in

1. The term 'electric vehicles' is used to refer to three types of technology: battery electric vehicles (BEVs) which use a fully electric drive-train; and plug-in hybrids (PHEVs) and range-extended electric vehicles (REEVs), which use a hybridised drive-train (internal combustion engine and battery) and can be recharged directly from an external electricity supply.

their assessments of the CO_2 emissions benefits which are highly location dependent (NTNU 2012). A recent report by Hawkins et al. (2012) finds that EVs powered by the present European electricity mix offer a 10–24 % reduction (depending on energy mix) in global warming potential relative to conventional vehicles.[2] These figures also reflect the fact that fuel cycle benefits are offset to a large extent by increased emissions associated with vehicle production, which for EVs can account for almost 50 % of life cycle emissions (Ricardo 2011).

Life cycle carbon reductions are nevertheless projected if grid decarbonisation continues, as is planned in the UK given the government's commitment to the legally binding emissions reduction targets set out in the Climate Change Act. The UK administration therefore considers vehicle electrification (allied with decarbonisation of the power supply sector) as a key component of its climate change mitigation strategy and has introduced a range of significant fiscal incentives to stimulate the uptake of electric and hybrid vehicle models (OLEV 2011; ACEA 2012; UK Government 2013). The European Union's proposals to amend the 'Cars and CO_2' regulations for 2020 also include 'super credits' for manufacturers introducing electric vehicles (EU DG Climate Action 2012).

Despite the widespread international focus on incentives for the introduction of plug-in electric vehicles and the increased availability of models for purchase, sales growth has been slow. Nissan, the producer of the leading battery electric car, the Leaf EV, is reported to have sold around 50,000 vehicles worldwide to date (Nissan 2013). Even in the United States, the world's largest vehicle market, sales of battery electrics and plug-in hybrids were below 50,000 in 2012, accounting for only around 0.04 % of total sales (ETDA 2012). In the UK, only around 2,200 battery and plug-in hybrid vehicles had been sold by the end of 2012 (approx. 0.1 % sales), with current forecasts of an additional 1,100 EV sales for 2013 (SMMT 2012).

Barriers to the adoption of electric vehicles

In parallel with the technological developments required to deliver market-ready EVs, a large amount of commercial, government and academic research has focused on the remaining barriers to consumer adoption of EVs.[3] Both policy makers and vehicle manufacturers have a powerful interest in understanding consumer motivation in this area in order to most effectively minimise barriers and increase vehicle uptake.

In general, previous studies have shown that (despite some variation according to region) the decision-making process for private conventional car purchases is predominantly driven by financial and performance considerations including purchase price, practicality, size and capability, comfort, running costs (including fuel consumption), styling, brand and reliability (IEEP 2006; Lane and Potter 2007).

However, Anable et al. (2011) point out that studies of car purchasing behaviour show that only a small set of vehicle characteristics are used to make car choices; that consumers engage in limited economic rationality and employ rules of thumb or heuristics to make decisions. They add that preferences are not stable and salient attributes often change considerably during the purchasing process. With reference to purchase decisions for alternative fuel vehicles (and EVs in particular) their recent study emphasizes the inadequacy of approaches which focus on rational choice theory and instrumental and functional motives of car choice.

While environmental issues are low down the list of considerations for conventional new car buyers (Lane and Banks 2010), recent literature suggests that this may be misleading in terms of early adoption of EVs. A number of studies show that the perceived compatibility of EVs with an individual's values plays a key role in stimulating an intention to purchase and use an EV (Graham-Rowe et al, 2011). Schuitema et al, (2013) find that the 'green' image of EVs may play an important role for some early adopters, especially if this aligns with their self-image. They comment that this is important knowledge for marketing strategies as consumers tend to align their self-identity with their purchase behaviours.

For electric vehicles, the key barriers to adoption cited in the literature (Skippon and Garwood, 2011; Tsang et al., 2012; UCLA Law 2012; Deloitte, 2011; Electrification Coalition 2009) include: increased purchase price; 'range anxiety' (linked to unavailability or inaccessibility of recharging infrastructure); recharge time; limited model availability; unfamiliarity of technology (lack of consumer information, experience and awareness); and other factors such as safety concerns and uncertainty about maintenance costs. Evidence gathered by Graham-Rowe et al. (2011) also suggests that the expectation that rapid technological and infrastructural developments will make current models obsolete acts as a further barrier to near-term uptake.

For most market segments and users, purchase price remains probably the main barrier to electric vehicle adoption. Despite subsidies and other incentives applied in many countries, the purchase price of EVs still significantly exceeds the cost of an equivalent conventional vehicle. The 'on-the-road' price of the battery electric Nissan Leaf EV in the UK, for example, is around £26,000 (€30,000) (end-2012) after the application of the £5,000 (€5,700) government grant. This compares with between £16,000–£20,000 (€18,000–€23,000) for an 'equivalent' conventional vehicle, such as the Volkswagen Golf BlueMotion (Next Green Car 2012).

Electric vehicles, however, offer significant running cost savings (in particular fuel costs), vehicle taxation and maintenance. While some studies have shown that these savings will not compensate most users for the higher purchase costs within a reasonable period (LowCVP 2011), these headline findings obscure the fact that for certain types of vehicle users (particularly those travelling a large annual mileage but requiring limited daily range) the total cost of ownership of an EV may be attractive. Skippon and Garwood (2011) suggest that premiums of up to four times the expected annual running cost savings – i.e. a four year payback on initial purchase premium – may be acceptable to many potential users.

2. A vehicle lifetime mileage of 150,000 km is assumed.

3. While this paper focuses on barriers to the adoption of EVs by private consumers, over 50 % of new cars are purchased for business use in the UK and business adoption has the capacity to drive new markets. Although many of the practical barriers are common to both categories, businesses generally take a more holistic view of costs, may have logistical needs more suited to EV use and are often in a better position to invest in recharging. Company car and business fleet users also benefit financially from reduced benefit-in-kind (BIK) tax rates and enhanced capital allowances for which electric vehicles are eligible which can significantly reduce total ownership costs (Energy Saving Trust 2012).

CONSUMER INFORMATION AND EV ACCEPTANCE

While vehicle price and the availability of refuelling infrastructure are influenced by government policy and industry (through the provision of subsidies and the setting of regulation and standards), the success or otherwise of the EV 'revolution' will largely depend on their acceptance by consumers and businesses. The provision of clear, relevant and timely information is a vital element in the market-building equation. A recent study in California, for example, described a lack of consumer awareness and information as the first in a list of three barriers to the mass adoption of electric vehicles in California (UCLA Law/Berkeley Law 2012).

Evidence shows that private car buyers – in common with most private buyers of energy using products – place a much greater priority on initial purchase costs than any running cost savings, even when the latter may offset the former in a modest period of time (Wallis 2005; Anable et al. 2009). Effectively targeted and clear consumer information can help to address this difficulty; evidence shows that some are willing to pay a premium for vehicle options or attributes that resonate with them (US DoE 2011). The prior discussion points to the fact that this is very likely to be the case for purchasers of EVs.

Correctly targeted information can also help to address other market barriers such as 'range anxiety' when connected with fears drivers may have in making particular journeys by providing comprehensive and up-to-date details about recharging facilities (House of Commons, Transport Committee, 2012). Effective communications can also provide reassurance/familiarity by enabling the sharing of experiences of early adopters with the wider, more conservative, community.

However, if information and other communications about electric vehicles are delivered inconsistently and by a variety of actors (government, industry, road users and other stakeholders) there is a clear danger that this can undermine the level of consumer trust in future information, however accurate and well-intentioned. Nissan's advertisement for the Leaf, for example, focuses on low whole-life costs citing "over 300 mpg equivalent", the calculation being based on the monetary equivalence of electricity and petrol fuels (Nissan 2012). Next Green Car, the UK's leading green car website, however, quotes an equivalent fuel economy of 169 mpg for the Leaf, the comparison with conventional fuels being conducted on an energy basis (Next Green Car 2012 (2)).

As recommended by the UCLA/Berkeley study (2012) in California, the provision of EV information and support must, therefore be highly coordinated, if it is to be effective. In the UK, the Low Carbon Vehicle Partnership (LowCVP) works to bring government, industry, road user groups and other stakeholders together to help ensure consistency in the messages delivered in relation to EVs, while also attempting to bring greater simplicity to the discussion, which can be fraught with complexity.

It is for these reasons, that this paper now focuses on one of the key information channels designed for new car buyers across the European Union; namely, the 'Fuel Economy Label' and, in particular, how this is being adapted to accommodate the introduction of electric vehicles.[4]

4. Research for the LowCVP found that more than half of new car buyers were then aware of the existence of the UK version of the fuel economy label and a large majority (71 %) considered it to be important (LowCVP, 2009).

European Fuel Economy Label

In 1999, the EU issued a Labelling Directive [1999/94/EC] requiring standardised fuel economy and CO_2 emissions information to be made available to buyers of new passenger cars in all EU Member States – effective from January 2001. One of the key information sources covered by the Directive is a Fuel Economy Label for all new passenger cars displayed at the point of sale.

Under the Directive, EU Member States are required to ensure that all car labels contain the numerical value of the official fuel consumption (expressed in litres per 100 kilometres or kilometres per litre) and emissions of CO_2 (in grams per kilometre). The value for fuel economy can be expressed in different units (gallons and miles) to the extent compatible with the provisions of Directive 80/181/EEC (European Commission 1979).

The fuel consumption and CO_2 figures which must appear on the label are taken from a larger dataset which is produced as part of the type-approval process and reported on the EC vehicle type-approval certificate (the figures also appearing on the 'Certificate of Conformity' or 'CoC' which accompanies each vehicle). The type-approval certificate also includes environmental information related to noise levels, Euro emissions standard and exhaust emissions for the so-called 'regulated pollutants': CO, NO_x, HC and PM_{10}.

The details of which fuel economy and emissions must be measured and communicated on the type-approval certificate are detailed in ECE Regulation No. 101 (UNECE 2005) – see Table 1.

In the UK, the EU Labelling Directive is implemented by the *Passenger Car (Fuel Consumption and CO_2 Emissions Information) Regulations 2001*, which came into force in November 2001 (HM Government 2001). The Passenger Car Regulations adhere to the Labelling Directive with minor additions such as the provision of fuel economy in units of 'miles-per-gallon' or 'mpg'.[5]

To meet the requirements of the Directive, in 2005, the LowCVP brokered the design and rollout of a UK Fuel Economy Label which included an energy-efficiency style colour coded fuel economy scale linking CO_2 emissions to Vehicle Excise Duty (commonly known as 'VED'; an annual UK vehicle circulation tax).[6] On the current UK label, the VED bands are colour-coded using a scale similar to the energy-efficiency rating system used for 'white goods' ranging from green for cars with the lowest CO_2 emissions through the colours of the spectrum to red for the most highly polluting vehicles.

Other information on the label includes: annual fuel cost which is estimated assuming a distance of 12,000 miles and based on the 'combined' fuel economy figure and a UK average fuel price for petrol, diesel and liquefied petroleum gas (LPG); and a 12-month Vehicle Excise Duty rate (now extended to include both first year and standard VED Rates). Fuel economy information is also displayed in the lower half of the label measured over three cycles: 'urban', 'extra-urban' and 'combined' and is presented in 'mpg' (miles per gallon) and 'litres/100 km'.

5. While the 2001 regulations only included vehicle powered by an internal combustion engine, they were amended in February 2013 to include EVs.

6. An example of the current UK label for new cars in available at: http://www.lowcvp.org.uk/fuel-economy/.

Table 1. Type approval data requirements according to ECE R101 (M_1 and N_1 vehicles only).

Power-train	**CO_2 mass emissions (g/km)**	**Fuel consumption[a]** (litre/100km)	**Electricity consumption** (Wh/km) and range (km)
Internal combustion engine; and non-externally chargeable (NOVC) hybrid electric	Urban[b] Extra-urban[b] Combined[b]	Urban[b] Extra-urban[b] Combined[b]	
Pure electric vehicles			Combined: Wh/km[b] Electric range (km)
Externally chargeable (OVC) hybrid electric	Condition A[c], combined[b] Condition B[c], combined[b] Weighted[d], combined[b]	Condition A[c], combined[b] Condition B[c], combined[b] Weighted[d], combined[b]	Condition A[c], combined[b] Condition B[c], combined[b] Weighted[d], combined[b] Electric range (km)

[a] *Repeat for petrol and gaseous fuel in the case of a vehicle that can run either on petrol or on a gaseous fuel. For vehicles fuelled with natural gas, the unit l/100 km is replaced by m^3/km.*

[b] *Urban, Extra-urban, and Combined cycle (urban/extra-urban driving) as defined by the New European Drive Cycle.*

[c] *Condition A test carried out with a fully charged electrical energy/power storage device. Condition B: test carried out with an electrical energy/power storage device in minimum state of charge.*

[d] *The weighted CO_2/fuel consumption/electricity consumption are calculated using $X = (De \cdot X_A + Dav \cdot X_B)/(De + Dav)$, where: X = CO_2/fuel consumption/electricity consumption (in g/km or l/100 km or Wh/km), X_A = CO_2/fuel consumption/electricity consumption over Condition A, X_B = CO_2/fuel consumption/electricity consumption over Condition B, De = vehicle's electric range, Dav = 25 km (assumed average distance between two battery recharges).*

LowCVP labelling research study

Since the UK label's introduction, the LowCVP has commissioned and conducted a series of research studies to assess the effectiveness of the label with regard to its influence on car purchasing decisions (Anable et al. 2009; Lane and Banks 2010). As part of this ongoing assessment programme, the LowCVP commissioned Ecolane and the Centre for Sustainable Energy (CSE) supported by the University of Aberdeen to test a series of alternative fuel economy label designs to explore private car buyers' attitudes regarding the information presented (Lane and Banks 2012). [7] The project (conducted in 2012) was also designed to explore how a future fuel economy label could accommodate new vehicle types including electric and plug-in hybrid vehicles. A designer was recruited to create a series of alternative label designs, working with LowCVP members to create example graphics, layout and information to be displayed on the labels.

METHODOLOGY

The methodology adopted by the study included a series of six focus groups and a web-based quantitative survey (N=1,005). The study was divided into two stages; 'Round 1' which included the three initial focus groups, and 'Round 2' which included the three remaining groups and an online survey. The target population was the private motorist with recent experience of buying a new or used car (within the previous two years). Buyers of new cars were over-represented in the survey to reflect the fact that labels must be displayed for new cars, whereas their use for used car sales in the UK is voluntary.

7. The publication was lodged with the client in July 2012. While the document is currently unpublished, the LowCVP intends to publish a version of the final report in 2013.

For the focus groups, the number of male and female participants was approximately equal (male 30, female 28). For the web-based survey, the number of male participants exceeded the number of female participants by a ratio of approximately 2:1. Participants who had recently bought a new car or a used car were both well represented within both samples – with at least half of those in the focus groups and two-thirds of the online sample buying new. Compared with the national age profile of new and used car owning households, the 25–64 age categories were well represented in the focus group and online samples, with the exception of the 17–24, 65+ age groups which were under-represented.

In the online sample, participants who had recently bought a new car had paid substantially more (median in £16–20 k range) than those who had purchased used vehicles (median £6–10 k). The focus group sample showed a similar but less pronounced variation (modal prices in £11–15 k versus £6–10 k categories). The difference in prices paid for new/used car between the two samples is thought to reflect the higher household income of the online sample.

Regarding fuel type of the current cars used by the web-survey sample, petrol cars accounted for 49 % (new: 43 %, used: 58 %) and diesel 50 % (new: 55 %, used: 40 %). Alternative fuels and vehicle types only accounted for around 2 % of the total sample (comprising 16 hybrids and 1 unknown car type). Within the focus groups, petrol cars accounted for 57 % (new: 52 %, used: 61 %) and diesel 43 % (new: 48 %, used: 39 %) with no participants reporting the purchase of an alternative type.

The study developed a series of prototype test labels and stimulus materials for use by the focus groups and online survey participants. Two rounds of fieldwork were conducted, each with its own set of test materials: in Round 1, an initial series of alternative labels created on the basis of existing research; and in Round 2, a revised set of alternative labels was created on the basis of findings from Round 1.

The six deliberative workshops, each with 8–10 participants, were conducted in six major UK cities/towns, each lasting two and a half hours in length. In all cases, group discussions were recorded and transcribed in full for later analysis. In return for taking part in the project, each survey participant received a cash reward of £50 or £60 (depending on venue). Using a discussion guide, which included extensive visual stimuli, the groups were invited to discuss their attitudes regarding: the most important factors during car purchase; useful information for car buyers; metrics included on the current label and their presentation; alternative ways to present information; the demand for comparative vehicle data; how best to present information for new plug-in vehicles; and the potential for using web-based tools for vehicle comparison.During the focus group discussions, electric vehicles were introduced to the participants for consideration. First a short presentation was made to the groups to explain (and discuss) the basic capabilities of the latest commercially available EVs including the Nissan Leaf (BEV) and Vauxhall Ampera (REEV). The use of 'hard-linking' technology (e.g. QR Code) to deliver additional information to that provided on the printed label was also demonstrated.[8] The objective was to explore the potential benefits of using the 'web' as an additional resource – either to provide detailed 'flat' glossary type information for new technologies such as plug-in electric vehicles, or online calculators with which to personalise fuel cost and related information.[9]

The online survey participants were also presented with a series of visual elements for their comments and responses; in most cases, these visual stimuli were simplified versions of the focus group test materials. While the main content of the web-based survey shared many elements in common with the focus group discussion guide, it was more oriented to the collection of quantitative data through the use of multiple-response questions and 5-point Likert scales. Open-style responses were also used, the responses being categorised during analysis.

The online survey also assessed the level of knowledge of car buyers regarding their car's official performance data by asking participants for 'official figures' for the car recently purchased. The question gave them the opportunity to enter values for: fuel economy (in 'mpg' and 'litres/100 km'), fuel cost (per year, per month and per mile), engine size (litres), CO_2 emissions (g/km) and road tax (VED band and annual cost). Participants' responses were checked with their car's actual official data using the CarweB database based on a car's Vehicle Registration Mark (provided on a voluntary basis by over 75 % of the online sample).

Key findings of UK label study

When presented with the current UK Fuel Economy Label (for conventional vehicles), the vast majority of focus group participants responded very positively to A-M coloured band design (used to indicate the VED tax band). Almost all participants had prior experience of seeing the bands in a non-automotive context, the most common application being their use in energy rating 'white goods'.

However, when the focus groups were asked to consider information content on the label, participants' comments strongly suggest that fuel economy expressed as 'miles-per-gallon' (information which is positioned on the lower half of the label in relatively small text) is of more importance to them as car buyers than CO_2 emissions and VED band (which is given prominence at the top of the label).

This assertion is supported by the results from the online quantitative survey. While only 20 % of the whole sample was able to volunteer a CO_2 emissions figure for their recently acquired vehicle, 69 % of the sample was able to provide a figure for their car's fuel economy in 'miles-per-gallon'.[10] Participants were also more able to accurately quote their vehicle's official 'mpg' (to within 10 %) than its CO_2 emissions (42 % versus 27 % for all those volunteering a value). The response rates and reporting accuracy for a range of vehicle attributes are shown in Figure 1.

Taking the number of responses (correct or otherwise) for each factor, together with the accuracy with which they were answered, to represent the degree to which these factors are 'front of mind' for consumers, these results explain, in part, the higher importance attributed to official fuel economy information appearing on the label expressed as 'miles-per-gallon' than official CO_2 emissions expressed in g/km. This conclusion also accords with the findings of previous studies which have shown that UK car buyers place great emphasis on fuel economy as a proxy for running costs, a key concern of UK motorists (Lane and Banks 2010).

This question also provides an interesting second-order result – the minority of the sample who were 'very' or 'fairly' confident about knowing their CO_2 emissions (18 % compared to 48 % for 'mpg') were more accurate in their knowledge of CO_2 emissions than 'miles-per-gallon (86 % compared to 50 % for 'mpg'). One interpretation is that, whereas more car buyers have an idea of their car's fuel economy (through daily use), the value is likely to be different from the 'official' combined figure. In contrast, unable to test CO_2 themselves, they either know their car's official CO_2 emissions (accurately) or they don't, in which case they are unable to even 'guesstimate' a value.

Almost without exception, the transcribed comments from all six focus groups reveal a very strong preference for fuel economy expressed in imperial units (expressed in terms of 'miles-per-gallon') as opposed to metric units. This is very much an issue for UK car buyers where imperial units are still widely used, and is unlikely to be applicable elsewhere in the EU. However, the central finding – that fuel economy is more important to consumers than CO_2 emissions – may well apply in other EU Member States if fuel economy is expressed in local units.

In the light of these findings, the study concludes that the UK Fuel Economy Label would be more effective (in conveying information) if the space given to CO_2 information was reduced

8. For more information, visit: http://en.wikipedia.org/wiki/QR_Code.

9. Links to the target URLs can be found at: http://www.nextgreencar.com/mobile-calculate/26041/VW-Polo-Diesel-Manual-5-speed; and http://www.nextgreencar.com/mobile-calculate/26041/VW-Polo-Diesel-Manual-5-speed.

10. It was assumed that, as most car buyers would know the engine size of their car reasonably accurately, the response rate of 71 % for 'engine size' was used as a baseline with which to compare the results for the other metrics.

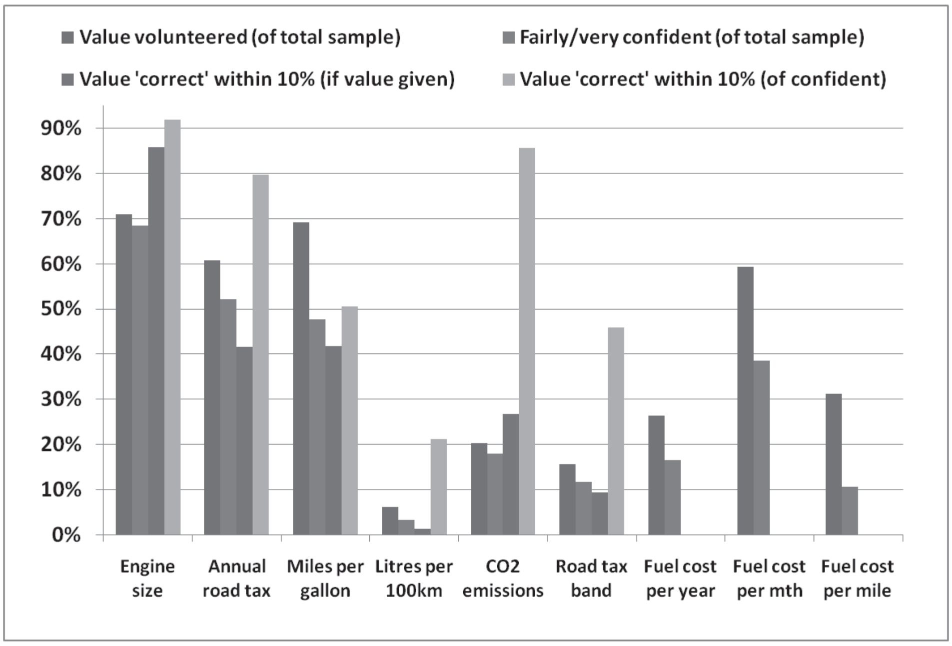

Figure 1. Knowledge of car's official performance data (online survey). With the exception of 'annual road tax', percentages shown are either proportion of total sample or of sample giving values which are correct to within 10 % of actual value. For 'annual road tax', percentages express proportion of sub-sample which includes only cars paying VED at standard rate.

(while retaining the coloured bands which are well received) and the prominence of fuel economy information increased. Not only would these changes accord with the findings of this and previous surveys, it would also make the title of the current label 'Fuel Economy Label' more relevant to the information contained.

This conclusion is supported by the finding that, of the alternatives labels tested, the 'dashboard' design was particularly well received in the focus groups due to the prominence of the 'mpg' information, and also its overall design – see Figure 2 (right) – the vast majority of survey participants preferring designs that present 'mpg' information using a large, clear font, placed alongside the CO_2 emissions figures (presented in a coloured banding format). Results from the online survey also found a strong preference for CO_2 information presented in the alternative format, with 79 % of the opinion that the format used in Figure 2 (right) displayed the information more *clearly*.

Focusing on fuel and VED costs, which are currently quoted on the label on an annual basis, the study aimed to establish whether other costing periods would also be useful to car buyers. Without prompting, comment made by focus groups participants *suggested* that, while 'per month' costs would be of interest to some car owners due to the tendency for households to budget on a monthly basis, more would prefer a 'per mile' estimate due to the simplicity of calculating journey costs by multiplying fuel cost per mile by the journey distance to be covered. This finding is supported by the quantitative results from the online survey which found that, of three metrics presented, 'per mile' was selected by 58 % of the sample, 'per month' 31 %, and 'per week' 12 %.

ISSUES SPECIFIC TO BATTERY ELECTRIC VEHICLES

During the introduction of the electric vehicles, many of the focus group participants (who had no direct experience of owning or driving EVs) spontaneously voiced concerns about some of the limitations of electric vehicle technology. In no particular order, these included the high cost of vehicles and batteries, the maximum driving range, the length of time to recharge the battery, and the uncertainty about the location of publicly available recharging points.

One of the key objectives of the study was to ascertain the most effective way to convey (official) electricity consumption as opposed to fuel economy information. In contrast to the popularity of 'miles-per-gallon' (as already reported), the qualitative evidence from the focus group discussions suggest a very low understanding of both 'Wh/km' and 'kWh/100 km', two of the electricity consumption units trialled on the EV test labels – one example of which is shown in Figure 3. Focus group participants also commented on the use of kilometres in this context, preferring distance to be expressed in miles. (This issue is linked with the general preference for fuel economy to be presented in imperial rather than metric units as already described.)

Given the strong preference for fuel economy to be presented in 'mpg' for conventional vehicles, EV test labels were used to test focus groups reaction to presenting electricity consumption in terms of its petrol 'mpg equivalent' using an energy equivalence with petrol fuel.[11] While only an indicative observation (due to the statistically small focus group sample), this option was generally well received due to its comprehension by participants who were able to contextualise the figures and compare them with conventional vehicles.

In order to better quantify the relative popularity of the different options for presenting electricity consumption information, the online survey presented a list of six possible metrics and asked respondents to select the option(s) that they would

11. An energy equivalence of 8.9 kWh per litre of petrol was assumed.

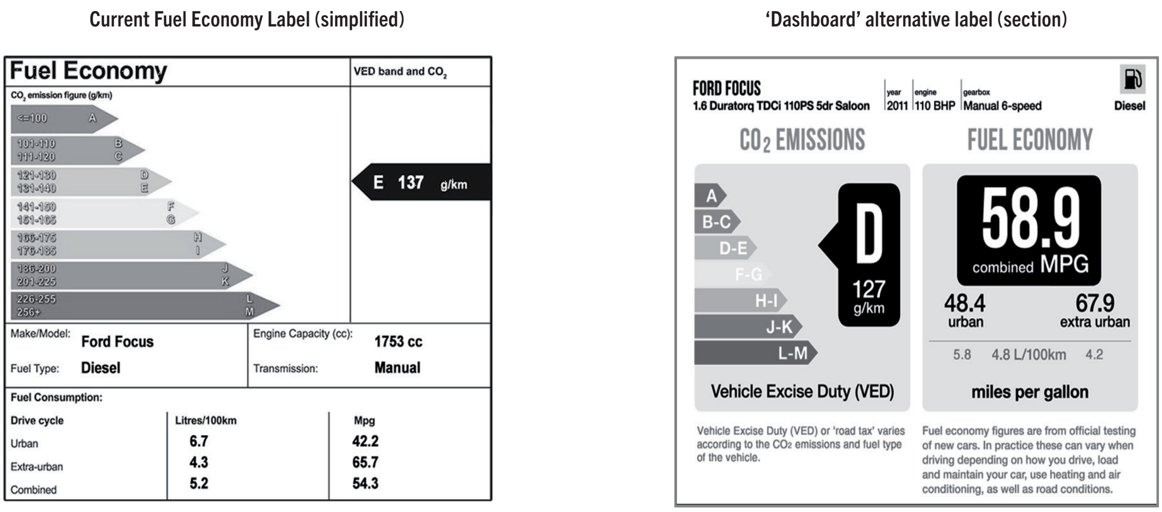

Figure 2. Selected visual test elements for CO_2 and MPG presented to focus groups (Round 2). The coloured bands which range from green for cars with the lowest tailpipe CO_2 emissions through the colours of the spectrum to red for cars with the highest CO_2 are shown in shades of grey.

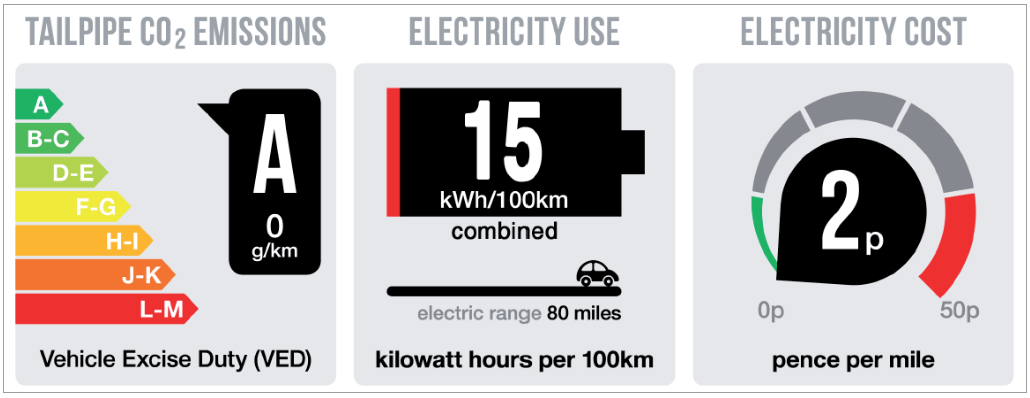

Figure 3. Example of visual test element for electric vehicle presented to focus groups (Round 2). The coloured bands which range from green for cars with the lowest tailpipe CO_2 emissions through the colours of the spectrum to red for cars with the highest CO_2 are shown in shades of grey.

prefer to appear on a future EV label. These results clearly show a preference for 'mpg equivalent' with 41 % selecting this option, the next most popular being 'miles-per-kilowatt hour' (29 %). All other options (including those suggested by respondents) were selected by fewer than 12 % of the sample.

Test labels showing electricity and tax costs for electric vehicles were also presented to the focus groups for consideration. Against the issue of high capital cost, the focus groups provided some qualitative evidence that participants did note the lower fuel costs offered by EVs. While opinion was generally divided as to whether the EV labels should present comparisons with conventional cars or only with other EV models, if a 'per mile' fuel cost were to be adopted (as strongly supported by the online survey), the focus group discussions indicate that this would become a *de facto* comparator for all vehicle types regardless of their technology. However, time limitations, precluded this issue being further explored in the quantitative survey.

Given the novelty of EVs for most consumers, focus group conversations included a discussion as to whether car buyers would find it useful to have additional EV information included on the label. In general, the group comments suggested a strong demand for additional EV information, the most popular suggestions including driving range, charging time and the locations of public charging points. Vehicle and battery costs were also mentioned.

To quantify the demand for additional EV information, an optional open-response style question was included on the web-based survey; an optional question answered by 41 % of the total sample. Broadly confirming the focus group findings, the most popular issues according to online respondents were: driving range (listed by 37 % of those answering this question), the time for full charge (36 %), cost of electricity/recharge (19 %), battery life (17 %), vehicle depreciation (11 %), with all other responses (after textual analysis) being noted by fewer than 7 %.

ISSUES SPECIFIC TO PLUG-IN HYBRIDS

Plug-in hybrid EVs present particular challenges to the presentation of information to car buyers. Not only are the electricity consumption units difficult for the consumer to understand (as already discussed), there is the additional problem of how to present fuel economy information when two fuels can be used simultaneously or independently to propel the vehicle.

Given the large number of data permutations and possible forms that could be adopted by a future PHEV/ REEV label (see Table 1), a series of test labels was devised that used the type-approval data as its starting point. However, in the light of the low level of understanding of 'litre/100 km' (metric fuel consumption) and 'Wh/km' (electricity consumption), the use of alternative units was also explored to aid consumer understanding. Figure 4 gives a schematic overview of the test labels presentation of fuel economy and electricity consumption information. The data is based on the Vauxhall Ampera/GM Volt REEV using test figures as quoted in the vehicle's CoC.[12]

Although the sample size was small (30 focus group participants in Round 2), when only the CoC data was presented for consideration (Figure 4, top two images), no participants were able to adequately understand the information as shown. The reported reasons for this lack of comprehension were the use of metric units (already discussed in connection with EVs), little understanding of the meaning of the term 'weighted combined', and the difficulty of comprehending two energy metrics simultaneously. The resulting experience reported by many participants was one of 'information overload'.

While the CoC inspired label using imperial units was the better received of these two labels (Figure 4, top right) as evidenced by participator comments, presenting a mixture of imperial and metric units on the same label created a new problem; namely only the imperial units are 'seen', the metric units being ignored. The effect is to misrepresent the energy information – instead of the label conveying '235 mpg *and* 130 Wh/km', the label is read as '235 mpg'. Consequently, participants treated this partial information with some incredulity commenting that it was unlikely (they thought) that you could drive such a PHEV for 235 miles on one gallon of fuel. (This links to the 'trust' issue already discussed.)

Another approach explored, and one already adopted in for the US Vehicle Label,[13] is to present 'Condition A' and 'Condition B' fuel/electricity consumption information in place of the 'weighted combined' figures (Figure 4, lower left). When tested in the focus groups, while there was a degree of support for this approach, many participants also wanted to see the 'weighted combined' figures.

A final PHEV/REEV label tested was based on CoC data with the addition of a total measure of energy used (petrol and electricity combined) as shown in Figure 4 (lower right). While the sample size (30 focus group participants in Round 2) was too small to draw firm conclusions, there was some evidence from participants' comments that this label offered the most usable combination of numerical information – an overall 'mpg equivalent' figure (based on energy equivalence), accompanied by the published test data as currently appears on the CoC.

In order to quantitatively assess the most popular format and information that could be used for a future PHEV/REEV label, a question was included as part of the online survey. Given the low level of comprehension of standard electricity consumption units, the question was posed using only fuel economy data, the electricity use data being expressed in words – see Figure 5. The intention was to clarify the central issue posed by the question; namely to ask respondents which *data format* was most preferable for inclusion on a future plug-in hybrid label.

The results supported the qualitative findings reported by focus groups participants; the most popular option selected was total energy use expressed in terms of the single metric of 'mpg equivalent' (44 %) followed by the separate 'Condition A' and 'Condition B' data (37 %). The third option (closest to the CoC determined 'weighted combined' figures) was the least preferred, being selected by fewer than 20 % of the sample.

Hard-linking with QR Codes

During the focus groups, a QR Code and reader (loaded on to an iPod Touch), which was first demonstrated and then tried by the focus groups participants. The QR Codes linked to one of two live tools: a personalised fuel costs calculator, and a 'glossary' providing detailed information regarding a terms used for electric vehicles.

While the evidence is qualitative and limited due to the small sample size, across all six focus groups the vast majority of participants were impressed by the ability of the QR Code reader to automatically link the printed label to live online information. Even those who had never seen a QR Code before voiced positive opinions about the technology. A minority however did express a lack of interest or reservation about using such a device, with most negative comments highlighting the fact that the tools were only as good as the target website, or raising privacy concerns associate with stored data.

It is apparent that use of the QR Code could also limit the danger of 'information overload' on the consumer label by enabling more detailed and complicated data to be accessible through use of the Code and a link to a suitable website

Of the majority who expressed support for including a QR Code on the label, many were quick to imagine how such a tool might be used in a car buying context (e.g. when researching models or in a showroom), and to highlight the advantages of having fast access to information under one's own control. Of the two QR Code reader tools tested, all focus groups were clear that the 'fuel cost calculator' was by far the most useful, preferring it to the less interactive information glossary. The main reason for this view was the ability to *personalise* the calculation resulting in a more relevant, and more trusted, estimate of fuel costs.

Discussion and conclusions

If EVs are to succeed in the automotive marketplace, consumers will need to be better informed as to their potential advantages, and their compatibility (or otherwise) with particular applications and users. As noted by Peters et al. (2011): "Information, demonstration and opportunities to test EVs in daily life, in particular for a longer time period, could help consumers to decide and ideally assure them that EVs are really compatible with their daily needs and with their habits." While information alone is insufficient to guarantee a change in purchasing behaviours, it has an important role to play in supporting the emerging EV market.

12. These may be subject to change as new test data is released and as new model variants are developed.

13. For more information, visit the EPA website. URL: http://www.epa.gov/carlabel/ [Accessed April 2012].

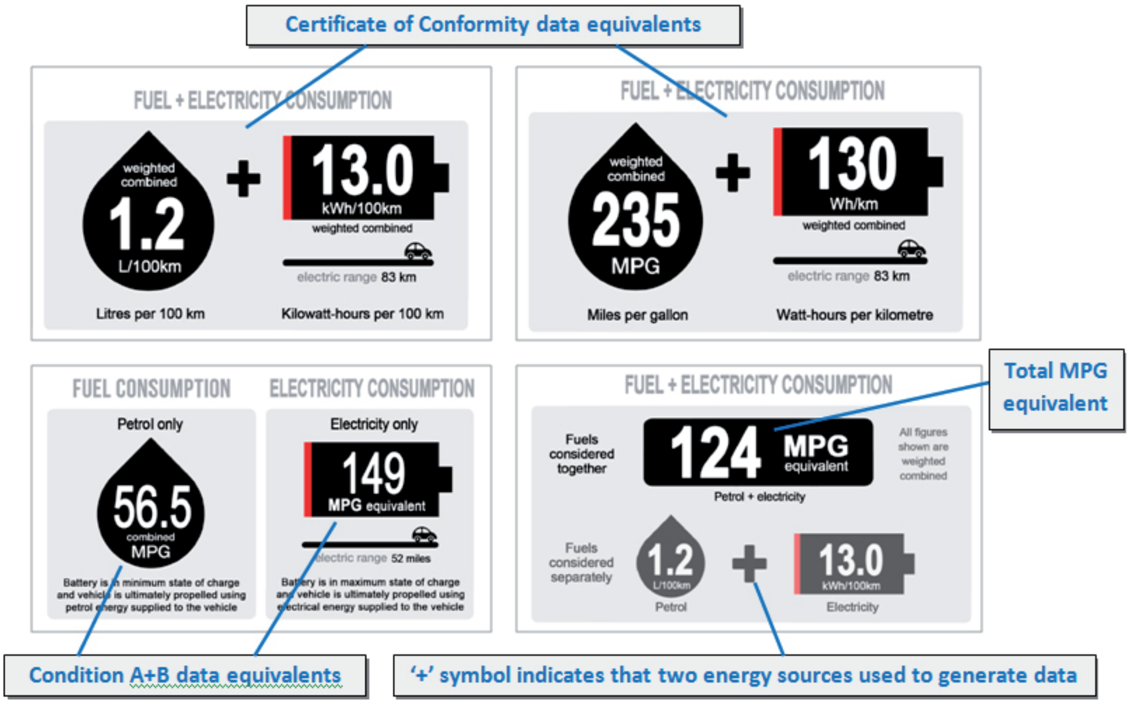

Figure 4. PHEV/REEV test label elements presented to focus groups (Round 2). Top left: 'weighted combined' data with 130 Wh/km converted to 13 kWh/100 km; Top right: 'weighted combined' data with 1.2 litre/100 km converted to 235 'mpg'; Lower left: 'Condition A' data with 169 Wh/km converted to 149 'mpg-equivalent'; and 'Condition B' data with 5.0 litre/100 km converted to 56.5 'mpg'; Lower right: 'weighted combined' data with 130 Wh/km converted to 13 kWh/100 km and total energy consumption of approx. 73.3 MJ/100 km converted to 124 'mpg-equivalent'.

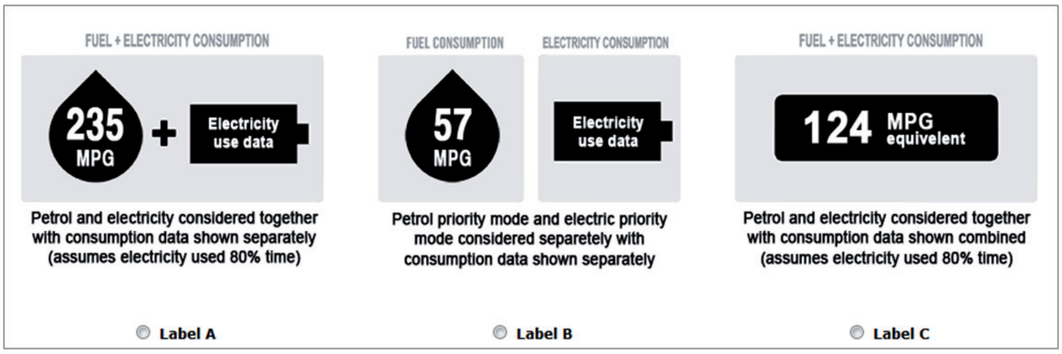

Figure 5. PHEV/REEV label format options presented to online survey participants.

The increasing complexity posed by the growing range of EV technologies and the difficulty in comparing electric with conventional vehicles will also require improved marketing and education. Examples where better information and data-driven tools are likely to be particularly important include the comparison of financial and environmental costs of EVs with their conventional equivalents, tailored where possible to a consumer's individual circumstances. Even basic information detailing (in simple terms) the technical capabilities of EVs (such as driving range and recharge times) can help remove those barriers that may be based more on misconceptions than actual deficiencies in vehicle performance.

In this context, the research reported in this paper finds that the Fuel Economy Label, an important information channel for new and used car buyers in several EU Member States, could be improved. For all vehicle types, the research identifies why (for a UK audience at least) the relative importance given to environmental and fuel economy information on the current UK label should be changed; the latter being given more prominence due to its higher level of comprehension by UK consumers, and its importance during car purchase (Anable et al. 2009; Lane and Banks 2010).

While the authors note that the scope of the Fuel Economy Label has recently (UK Government, 2013(2)) been extended to include EVs (and support this development),[14] the study

14. Examples of the new UK label for EVs are available at: http://www.lowcvp.org.uk/news/1959/new-carfuel-economy-label-extended-to-electric-and-hydrogen-cars/.

identified key issues to improve the comparison of EVs with all other vehicle types, maximise the comprehension of electricity consumption data, and provide an educational role regarding the capabilities of particular EV models. Based in part on the survey findings, the new EV label in the UK has therefore adopted a 'miles/kilowatt hours' metric for electricity consumption, as this was considered the closest possible link with the 'miles-per-gallon metric' used on the label for conventional vehicles which was acceptable to industry stakeholders.

The study also revealed that car buyers were interested in seeing additional information relating to electric vehicles on the Fuel Economy Label. In response to this, the new EV label has included information relating to driving range and the location of publicly available recharging points via a website link.

The study highlights the potential of new technologies to positively disrupt current information channels such as the current paper-based Fuel Economy Label. For example, 'hard-links', such as provided by the increasingly ubiquitous QR Code, can be used to link a fuel economy label to a target website/URL (typically accessed on a smart phone or mobile device) where further information can be found. (Indeed the EPA Vehicle Label now used in the U.S. includes a QR Code for precisely this reason.) The research reported here strongly supports the inclusion of a QR Code on a future EU Fuel Economy Label. To avoid the danger of information overload for car buyers on the EV and PHEV labels, it is advised that some of this information could be made accessible through an attached QR Code, rather than on the label itself. Indeed, the provision of 'hard-links' may provide a solution to the problem of offering ever-more complex information related to new vehicle types. Not only could this technology be used to educate potential users about the technology's capabilities, it could also deliver the additional information required by potential EV owners. Indeed, the authors believe that omitting to include such a technology would significantly limit future options for consumer-focused information provision within the increasingly electric automotive sector.

In conclusion, this LowCVP-funded study suggests how existing consumer information can be improved and highlights the future challenges of effective vehicle information provision posed by new vehicle technologies such as electric vehicles. The findings of the research point to the need to revisit the information content and format as provided by the current European Fuel Economy Label both to increase its effectiveness for conventional vehicles, and to ensure its continued applicability for future powertrains.

Moreover, in addition to demonstrating the benefits of new information technologies (such as QR Codes) for conveying vehicle information to consumers, the research strongly suggests that it may, in future, play an essential role in providing car buyers with highly relevant, personalised and live vehicle data; information which is set to become ever more complex with the continued development of vehicle technologies and increasing consumer demands.

Endnote

The Low Carbon Vehicle Partnership, established in 2003, is a public-private partnership that exists to accelerate a sustainable shift to lower carbon vehicles and fuels and create opportunities for UK businesses. Nearly 200 organisations are engaged from diverse backgrounds including automotive and fuel supply chains, vehicle users, academics, environment groups and others. The LowCVP facilitated the voluntary introduction in 2005 of the UK's colour-coded fuel economy label, now widely used in new and used car showrooms. The LowCVP is active in policy discussions focusing on consumer information as a means of lowering the barriers to cleaner vehicle uptake.

Ecolane Transport Consultancy focuses on the evaluation and promotion of sustainable transport technologies and measures. Ecolane's services are designed to help clients assess their transport environmental footprint, develop cleaner low carbon vehicle fleets, implement climate change and air quality strategies, and reduce transport costs. The company's consultancy services include: life cycle assessments (LCAs) of low carbon vehicles, vehicle emissions audits, consumer attitude surveys and information, analysis of vehicle purchasing behaviour, and modelling the impacts of new systems of vehicle taxation. Ecolane is based in Bristol, England.

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