Electric and Plug-in Hybrid Vehicles

HIGHLIGHTS

■ **PROCESS AND TECHNOLOGY STATUS –** Battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) share characteristics that provide a range of benefits such as lower CO_2 emissions (potentially zero for pure EVs); no local pollution; competitive operating costs, quiet operation; high acceleration; regenerative braking and other systems that help improve energy efficiency. Both BEVs and PHEVs have batteries that can be charged from grid electricity to provide all the motive power of the vehicle. While BEVs rely only on the battery technology for both powering the vehicle and storing energy, PHEVs have smaller batteries (and therefore reduced range powered by grid electricity) that rely on the use of a conventional Internal Combustion Engine (ICE) for topping up the battery during use and/or as back up power when the battery charge has depleted, thus delivering drive range and refuelling time equivalent to those of conventional vehicles. Volume manufactured BEVs and PHEVs will be available in a few years.

■ **PERFORMANCE AND COSTS –** For both BEVs and PHEVs, performance and cost are inextricably linked to those of the battery technology, although this affects BEVs to a greater extent. Lithium-ion (Li-ion) is the battery technology with the most promise, however these still need further development in terms of cost, performance, abuse-tolerance and reliability over a longer lifetime. PHEVs offer performance and drive range similar to their conventional equivalents, but could provide a 40-55% improvement in fuel economy. BEVs currently offer significantly reduced range (typically up to 100km) compared to their conventional equivalents, but could provide improvement in fuel economy /energy consumption equivalent to 60-70% or more. The current cost differential for small-medium sized PHEVs and BEVs is in the order of +150-200% and +200-300% respectively more than conventional gasoline vehicles (depending on the battery size and range). This differential is expected to decrease significantly on mainstream adoption of these technologies through technology learning and reduction in costs through mass-production.

■ **POTENTIAL AND BARRIERS –** Key barriers to both BEVs and PHEVs are the cost of the vehicles, the battery lifetime and the public perception regarding the drive range, vehicle availability and reliability, especially for BEVs. Also a particular barrier for BEVs is the lack of infrastructure and charging stations. The limited drive range of the vehicles means that, although home recharging is available and use for short distance journeys in urban areas is possible, a widespread charging network is required for more widespread use. Consumers are unlikely to purchase BEVs in significant numbers until this infrastructure is available. PHEVs are not so restricted, although in the absence of ~~pubic~~ public recharging infrastructure home charging is necessary, which may not be possible in many cases (i.e. where parking on a driveway or in a garage is not available). However, the investment for recharging facilities is costly and is unlikely to happen on a large scale until consumers start to buy the vehicles. Also the time for recharging batteries using existing technology is relatively much slower than refuelling conventional vehicles, even with fast-charging stations available. Alternative battery lease and 'hot-swapping' schemes are therefore also under investigation as a means of countering this issue, together with reducing the high initial capital costs of the vehicles. Other alternatives include in-road wireless recharging infrastructure, but this would be considerably more expensive to install than standard recharging infrastructure and is currently a lot less energy-efficient.

PROCESS AND TECHNOLOGIES - Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs) and Hybrid Electric Vehicles (HEVs) are electrical vehicles (EV) powered by electrical motors with different reliance on electrical power. While BEVs are powered solely by electricity, PHEVs and HEVs are also equipped with an additional power source (i.e. an internal combustion engine, ICE, or – in the future - a fuel cell system), either as back-up/range-extender or main power systems.

■ **Battery Electric Vehicles (BEVs)** are powered solely by electricity stored in onboard batteries. BEVs do not feature on-board ICEs, but relies only on electrical motors powered by batteries that are charged by plugging into the electrical grid or - on a limited number of models - by swapping the battery. Apart from the emissions associated to electricity generation, BEVs produce no emissions during operation. In addition, electrical motors are more efficient than ICEs and the electricity grid is more reliable in terms of energy supply [1]. Electric commercial vehicles are currently available with Gross Vehicle Weight up to 12 tonnes, and benefit from lower running costs and taxes than conventional ICE vehicles [2].

The first volume manufactured battery electric vehicles (the Mitsubishi i-MiEV and Citroen C1 ev'ie) were originally expected be released in the UK towards the end of 2009 [3], but are now going to be released in 2010-11. A significant number of large electric cars are already available or will become available in the next couple of years. Other early BEV models are likely to be small cars since the lower mass allows smaller and

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cheaper batteries to be used [6]. Manufacture volumes will be low initially before beginning to rise toward mass manufacture around 2011 or 2012. However, there are several ranges of BEV vans already available either for purchasing or leasing, with larger manufacturers such as Ford and Chrysler having recently announced additional planned models. Ford is also the only mainstream manufacturer that has announced they are working on medium-size BEVs [4]. BEVs currently typically offer ranges of around 100km, although larger ranges are available on some premium models, such as up to 200km on the Tesla Roadster. Fuel economy/energy consumption improvements are typically equivalent to 60-70% or more over conventional ICEs [24].

■ **Plug-in Hybrid Electric Vehicles (PHEVs) -** also known as range extended hybrid Vehicles (RE-HEVs) - can also be plugged into the electrical grid for battery recharging. **PHEVs** battery is larger than those installed on current full hybrid commercial vehicles, smaller than those of BEVs, therefore requiring an ICE for recharging and to extend the drive range. PHEVs store enough electricity for the first tens of miles to be driven solely on electrical power. Beyond this range, they perform like a currently available full hybrid vehicle, with better electric capability. In comparison with BEV configuration, PHEV removes the need for the consumer to worry about the remaining level of charge in the battery as the ICE can cut in if the battery gets low. In comparison with commercially available hybrid vehicles, PHEVs can utilise electricity from the grid, rather than on electrical power produced via vehicle's ICE from petrol or diesel. Many PHEVs are designed to enable the engine to take over when a significant amount of charge (40% for the Chevrolet Volt) still remains. This however may change as soon as further advances improve the electrical energy storage. [3] PHEVs offer performance and drive range similar to their conventional equivalents, but could provide a 40-55% improvement in fuel economy [1].

TECHNOLOGY STATUS - Electric vehicles have existed since the early 1900s, being used in niche markets such as golf carts, milk floats and mobility scooters [4]. Launching this technology for mainstream road vehicles has proved difficult however, and previous attempts, for example the General Motors' EV1, have failed. This was mostly due to a lack of consumer appetite for the technology, and failure of battery technology to progress [5].

Due to significant advances in battery technology, a new generation of EVs and PHEVs has emerged. Lithium-ion (Li-ion) batteries are now the battery technology of choice [6]., and it is believed that they will be used by nearly all of the new HEV and EV development programs of the global automakers [1]. Li-ion batteries allow the same amount of energy to be stored in a much smaller volume than their predecessors such as Nickel Metal Hydride (Ni-MH) or lead acid batteries. Previous 'packaging' issues related to EV battery, with little space left to accommodate passengers and baggage, are now being solved by batteries with higher energy density [3]. The new batteries are also lighter and therefore use less of their generated power to move their own mass [1].

The first volume manufactured PHEVs is available in the UK since 2010 (the GM Volt and the plug-in version of the Toyota Prius). There are currently no small PHEVs in development although it is expected that these will be developed by 2020 [6]. Several companies are developing medium size PHEVs which are anticipated to be released before 2012, while a number of large manufacturers have announced the development of large PHEVs. This trend reflects the growing belief that in the medium term PHEVs could be an important bridging technologybetween conventional vehicles and BEVs [3].

PERFORMANCE - The most prominent argument for the rapid uptake of BEVs and PHEVs is their ability to reduce carbon emissions in the automotive sector [3]. ■ **BEVs** already produce less CO_2 per km than gasoline or diesel vehicles, even with the current energy mix for electricity generation [7]. The electric power train itself is more energy efficient than that of conventional ICE vehicles, with overall vehicle efficiency typically 65% for BEVs versus 18%-23% for conventional ICE vehicles [3]. A study published on the 'Institute of Lifecycle Analysis' website details a range of possible values for the entire lifecycle CO_2 emissions of BEVs vehicle over the lifetime of the vehicle, depending on the type of generation. The "Usage" phase (i.e. the emissions arising from using the vehicle) ranges from less than 1 tonne CO_2 for hydro electricity, to 17 tonnes CO_2 for coal [8]. In comparison, the usage phase for a gasoline vehicle produced around 21 tonnes CO_2. Such studies demonstrate that the extent of the carbon benefits of BEVs is heavily dependent upon the energy mix that charges the battery. A BEV uses around 0.2 kWh/km. Currently an electric car is a low-carbon option, producing just over 100 gCO_2/km, based on the current carbon intensity of electricity production in the UK (around 515 gCO_2/kWh). Some conventional cars achieve a lower carbon performance than this, but the real carbon benefits of BEVs will be seen as the carbon intensity of electricity falls towards zero. Electric cars could reach virtually 0 gCO_2/km [17]; a level not attainable for conventional vehicles. ■ **PHEVs** will also produce lower carbon emissions than conventional vehicles, although not to quite the same extent as BEVs. The CO_2 emissions associated with PHEVs are much harder to predict than those of BEVs. This is because the CO_2 emissions from PHEVs will also vary according to the proportion of vehicle km that are driven in electric-only mode, and the proportion driven whilst the ICE provides traction power [3]. These

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proportions will be influenced by the following factors: the accessibility of recharging infrastructure and the drive range; the price of electricity, petrol and diesel [1], [3]; and the user profile and habit (in theory, a PHEV could be driven as a pure EV, tough this is unlikely).

A study by EPRI in 2007 [9] reported that when electricity is generated using coal, PHEVs delivered a 28%-34% lower well-to-wheel greenhouse gas emissions than conventional ICE vehicles. As with pure EVs, this advantage will increase as the electricity grid is further decarbonised. However, the fact that PHEVs will in most cases also use gasoline or diesel via their range-extending engine for a significant part of their operation means that EVs are almost certain to achieve higher carbon savings.

In terms of drive range, PHEVs have an electric-only range of between 20 miles (Toyota Prius PHEV) and 40 miles (Chevrolet Volt). This is lower than EVs due to the smaller battery capacities. Once the 'range extending' petrol or diesel ICE is taken into account the range becomes several hundred miles. Urban BEVs that are close to release have a range of around 100 miles on a single charge [6], such as the Mitsubishi i-MiEV, which will provide 80 to 100 miles depending on the driving style. Tesla have announced that their 'Roadster' EV sports car will deliver a range of 220 miles [6], but from €100,000 the model will only suit niche markets. [10] In contrast, the new Tesla Model S, an EV available in 2011 from €33,430 [11], promises a range of 300 miles. It is intended for mass production and will be more popular with the mass market.

Battery electric vehicles have a positive impact on air quality [4] and noise, especially at low speeds which are typical in urban areas. Air quality emissions such as particulate matter (PM) and oxides of nitrogen (NOx) are linked to various public health issues, for example respiratory disease [3]. Electric cars are also much quieter than conventional cars at high speeds and virtually silent when slow [3].

CURRENT COSTS AND COST PROJECTIONS – It is difficult to estimate the cost of introducing BEVs and PHEVs on a large scale because it is reliant on both the battery price and the extent to which manufacturers and governments are willing to subsidise the vehicles. The Mitsubishi i-MiEV BEV is being launched and will be available for €38,500 [12]. This price creates an additional cost compared to conventional ICE vehicles of around €25,300. Furthermore, the i-MiEV is only a small BEV; for larger models the price premium could reach €77,000. This is because there is a trade off between battery range and cost; an increasing range requires disproportionately large and expensive battery technology. [6] The motor and transmission of a BEV is relatively simple, the purchase cost premium is derived almost entirely from the cost of the batteries. Once mass manufacture has begun, BEVs would be cheaper to produce than conventional vehicles if the batteries were not so expensive. Consequently, a price premium compared to conventional vehicles will be maintained until Li-ion batteries are significantly cheaper than their current prices. Table 2 shows the additional costs for buying a PHEV rather than a conventional ICE vehicle. The additional cost is greater for larger PHEVs; the price of both these and BEVs is largely determined by the cost of Li-ion batteries.

POTENTIAL & BARRIERS - A number of factors may drive the introduction of electric vehicles. These include the inherent benefits of the technology, such as lower fuel consumption, emissions and noise, as well as the incentive for producers and manufacturers to enhance the green image of their brands against competitors.

A high uptake of electric vehicles would significantly reduce the usage of fossil fuels in road transport and therefore decarbonise the transport sector. The transition from cars relying on foreign oil to vehicles relying on power generation and the electricity grid will also increase energy security. This is a further driver for the long-term deployment of electric vehicles.

Legislation plays a key role. Various countries such as the US, Spain and Japan have set ambitious targets for the future deployment of electric vehicles. These targets form a major component of national and international policies for tackling climate change. [4] In particular, Europe is subject to an array of regulations that restrict the emissions of the automotive sector. A recent addition is an average 130gCO_2/km limit, which will be required of all new cars between 2012 and 2015. In addition, the European Commission has suggested a tighter restriction of 95gCO_2/km for 2020. Car manufacturers are obliged to meet these targets and it is hoped that electric vehicles will benefit. Hybrid technologies that reach the 130gCO_2/km target are already available [3].

The 2020 target of 95gCO_2/km is more challenging. It could be met by advanced diesel technology. Therefore, EVs will need to compete with this significantly cheaper technology. In this sense, further regulations imposed by governments may help to improve the performance characteristics of EVs by 2020. Technological developments and refinement, and advanced materials will deliver improved performance through greater efficiency and lower CO_2 emissions.

Volume Manufactured - In Europe and the USA, governments have introduced financial support packages to help stimulate the early uptake of electric vehicles. However, the International Energy Agency suggests that subsidies could not be enough to create a sustainable electric car market [13]. This is because large availability of fast-recharging infrastructure and longer driving range are needed to improve public acceptance of BEVs. Volume manufactured EVs are being launched in the short term in very small numbers

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(e.g. the initial global production for the Mitsubishi I-MiEV is just 2,000 vehicles [4]). Other EV models will be launched over the next couple of years, but until 2015 it is expected that manufacture volumes will remain modest, particularly given the current global economic crisis. Significant levels of uptake are unlikely to be achieved until the early 2020's [14]. BEVs are however expected to be particularly successful in niche markets. In Norway and Switzerland they offer real advantages including easier access to city centres, easier parking and faster commuting, with low operating costs [13]. PHEVs are viewed as a more viable technology for the short to medium term, bridging the gap between hybrid electric vehicles (HEVs) and pure EVs [3]. This is largely because they are less reliant on a charging infrastructure.

Business Models - Various business models (e.g. battery leasing, vehicle leasing, car-clubs, etc.) have been designed to encourage the uptake of BEVs and PHEVs. **Battery Leasing -** If the manufacturer retains liability for the performance of the vehicle battery, a significant element of the financial risk for consumers is removed. This also removes the question as to how the residual life of the battery should be valued at resale, when the performance of most battery technologies deteriorates with use. A monthly fee would be paid to lease the battery, and a new owner could easily take over those payments. This model also enables the manufacturer to replace batteries with new battery technology if improvements are made [4]. **Vehicle Leasing -** This business model is being considered for the Mitsubishi i-MiEV electric small car, which is currently expected for released in the UK in early 2011. Vehicle leasing is an extension of battery leasing; it further reduces financial risks for consumers whilst also minimising upfront capital costs [6]. **Car-clubs -** This is a business model that enables the public to test BEVs and PHEVs in real operating conditions, without making a financial commitment or paying upfront costs. It could effectively introduce the public to hybrid vehicles and change the public perception of hybrid vehicles as they become integrated in road transport and become accepted in the short term [4]. **Mobile Phone-style Transportation Contracts -** The 'Project Better Place' contracts offer a range of EV models through different subscription packages, providing access to a network of battery swap stations and charging points [15]. It is a flexible approach aimed at suiting various different customer groups, whilst a network of charging points, rapid battery swap stations and car batteries are all owned by Better Place [4]. This business model shows promise, as the organisation has secured 103 million Euros to invest in a recharging network in Copenhagen (Denmark) and have started to build the first slow-charging network in Israel [3]. The International Energy Agency expects the number of electric cars in new car sales to be lower than hybrid cars until 2015 [13]. Deutsche Bank has predicted that the automotive Li-ion battery market could grow to €6.7-€10bn by 2015, and reach €20.1-€26.8bn by 2020 [1].

Barriers to development and deployment (but also opportunities for possible breakthroughs) include drive range, battery size, performance and cost of new-generation batteries, battery charging, power infrastructure, and public acceptance. **Drive Range and Battery Size -** A major concern regarding BEVs is that the vehicle will always have a lower drive range than a comparable petrol or diesel vehicle, due to its lower energy density. In addition, a battery would need to be 10x the size of a petrol fuel tank in order to deliver the equivalent driving range[1]. PHEVs share this bottleneck to a lesser extent, as their range is extended through the use of an ICE once the vehicle reaches a certain speed. **New-generation Batteries**, i.e. Li-ion batteries face some safety and performance challenges. Conditions such as overcharging or charging in extremely cold weather could potentially destroy the battery or create safety problems [1]. In addition, Li-ion cells do not operate as effectively at very low or high temperatures, and they can deteriorate at very low or high charge levels [1]. According to a 2008 study by Cenex/Arup [14] the current cost of Li-ion batteries is between €670/kWh and €1,340/kWh. Given that the Mitsubishi i-MiEV has a 16kWh battery, the expense of the batteries quickly becomes apparent. Nonetheless there seemed to be a consensus from the study that prices will fall to some €170-200/kWh if manufacture volumes rise to 100,000 battery packs per annum [14]. **Battery Charging –** This is one of the largest problem faced by BEVs. A widespread recharging or battery swap infrastructure is essential if significant sales are to be achieved. Consumers are likely to demand such infrastructure before committing to purchase BEVs, and to a lesser extent PHEVs, in any great numbers. Installing a comprehensive network of charging points will be an expensive process An infrastructure to support roll-out to 2020 could cost between the low hundreds of millions to around €1.65 billion [6]. The Committee on Climate Change has reported that off-street home charging could be provided for up to 75% of car-owning households, but other locations would also be necessary such as on-street charging; charging at the workplace and in public places, e.g. car parks, supermarkets (the Mayor of London has proposed the installation of 25,000 electric vehicle charging points (ECPs) across London by 2015 [16]). Slow-charging a BEV using single-phase grid electricity will typically take between 6 to 8 hours. Fast charging technology is already available and can charge an EV battery in around half an hour [19], but it requires a three-phase electricity supply and sufficient space to house the equipment [3]. Charging issues would not necessarily pose a major problem for PHEVs, due to their capability of switching to a conventional engine to avoid waiting for the battery to recharge. Another important aspect is the need for plug connector

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regulations. At present, car manufactures have their own plug design for reasons of design simplicity or patent. However, in the near future, regulations accepted by all car makers are needed to make possible the recharge vehicles using the same type of facilities, connectors and plugs. **Power Infrastructure -** The overnight charging of electric vehicles should have limited implications for the power system to 2020. Beyond this date however, the need for electricity generation and distribution upgrading will depend on the real uptake of the EVs technology and on the widespread use of day- or night-time charging [6]. The different aspects of the deployment of PHEVs, such as the required additional power and grid capacity,, the impact on GHG and pollutant emissions, have to be carefully analysed [22]. **Public Acceptance -** Although EVs can be used for almost all typical daily driving needs, consumers may not accept the restricted range [1] and public perception is arguably the greatest barrier facing electric vehicles.

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Table 1 – Summary Table: Key Data and Figures for Plug-in Hybrid Electric Vehicles and Battery Electric Vehicles, and Comparison with Baseline Conventional Vehicles [18, 20, 21, 22]

Plug-in Hybrid Electric Vehicles (Gasoline) [18, 20, 21, 22]			
Technical Performance	**Small Cars**	**Medium Cars**	**Large Cars**
Energy Input	Gasoline, Electricity		
Base Energy Consumption (l/km)	N/A	N/A	N/A
Base Energy Consumption (MJ/km)	N/A	0.98	1.37
Technical Lifetime, yrs	N/A	12	12
Environmental Impact			
CO_2 and other GHG emissions, g/km [(a)]	N/A	97.8	135.9
CO_2 and other GHG emissions, g/km [(b)]	N/A	34.0	47.1
Costs			
Capital Cost, overnight, Euro/unit	N/A	27,812	44,645
O&M cost (fixed and variable), Euro/km	N/A	0.051	0.063
Economic Lifetime, yrs	N/A	12	12
Plug-in Hybrid Electric Vehicles (Diesel) [18, 20, 21, 22]			
Technical Performance	**Small Cars**	**Medium Cars**	**Large Cars**
Energy Input	Diesel, Electricity		
Base Energy Consumption (l/km)	N/A	N/A	N/A
Base Energy Consumption (MJ/km)	N/A	0.99	1.36
Technical Lifetime, yrs	N/A	12	12
Environmental Impact			
CO_2 and other GHG emissions, g/km [(a)]	N/A	100.2	137.9
CO_2 and other GHG emissions, g/km [(b)]	N/A	35.9	49.5
Costs			
Capital Cost, overnight, Euro/unit	N/A	28,667	45,300
O&M cost (fixed and variable), Euro/km	N/A	0.054	0.066
Economic Lifetime, yrs	N/A	12	12
Battery Electric Vehicles [18, 20, 21, 22]			
Technical Performance	**Small Cars**	**Medium Cars**	**Large Cars**
Energy Input	Electricity		
Base Energy Consumption (l/km)	N/A	N/A	N/A
Base Energy Consumption (MJ/km)	0.57	0.69	0.95
Technical Lifetime, yrs	12	12	12
Environmental Impact			
CO_2 and other GHG emissions, g/km [(a)]	73.6	89.0	122.9
Costs			
Capital Cost, overnight, Euro/unit	23,127	37,446	57,386
O&M cost (fixed and variable), Euro/km	0.036	0.051	0.063
Economic Lifetime, yrs	12	12	12
Baseline Gasoline Vehicles [20]			
Technical Performance	**Small Cars**	**Medium Cars**	**Large Cars**
Energy Input	Gasoline		
Base Energy Consumption (l/km)	0.062	0.072	0.111
Base Energy Consumption (MJ/km)	2.05	2.38	3.64
Technical Lifetime, yrs	12	12	12
Environmental Impact			
CO_2 and other GHG emissions, g/km (WTT)	143.5	166.7	255.0
CO_2 and other GHG emissions, g/km (WTW)	169.1	196.4	300.5
Costs			
Capital Cost, overnight, Euro/unit	10,279	16,643	25,505
O&M cost (fixed and variable), Euro/km	0.03	0.04	0.05
Economic Lifetime, yrs	12	12	12

Source: Capital costs and efficiencies adapted from [18], [20]. Assumes approximately 50:50 use of electricity and gasoline/diesel (per unit energy) for PHEVs. Electricity carbon intensity assumed to be (a) EU average mix (129.8 gCO_2/MJ) from JEC (2008), (b) Renewable (0 gCO_2/MJ). Operating costs adapted from [22]. Dataset is for current (2010) performance and costs.

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Table 2 – Additional Cost of EVs and PHEVs over Conventional Vehicles [18, 20]

Electric and Plug-In Hybrid Electric Vehicles	Retail price (2006)		Additional cost vs ICE	
	Low	High	Low	High
1st small EV: Mitsubishi iMiEV	€ 20,350.00	€ 30,360.00	€ 12,430.00	€ 22,440.00
2nd small EV: Think! City	€ 25,850.00	€ 25,850.00	€ 17,930.00	€ 17,930.00
3rd small EV: Citroen C1 ev'ie	€ 14,630.00	€ 14,630.00	€ 6,930.00	€ 7,700.00
Additional cost for small EVs			€ 6,930.00	€ 22,440.00
1st scaled up EV: Mitsubishi iMiEV	€ 24,640.00	€ 36,740.00	€ 12,430.00	€ 24,420.00
2nd scaled up EV: Think! City	€ 31,240.00	€ 31,240.00	€ 19,030.00	€ 19,030.00
Additional cost for medium EVs*			€ 12,430.00	€ 24,420.00
1st large EV: Tesla Roadster	€ 78,870.00	€ 79,750.00	€ 54,670.00	€ 55,550.00
2nd large EV: Liberty Land Rover (Conversion)	€ 82,280.00	€ 108,240.00	€ 32,560.00	€ 43,450.00
Additional cost for large EVs			€ 32,560.00	€ 55,550.00
1st medium PHEV: Chevrolet Volt	€ 31,020.00	€ 31,020.00	€ 15,290.00	€ 15,290.00
2nd medium PHEV: Toyota Prius Plug-In (Conversion)	€ 22,110.00	€ 22,110.00	€ 9,240.00	€ 9,240.00
Additional cost for medium PHEVs			€ 9,240.00	€ 15,290.00
1st large PHEV: Fisker Karma	€ 68,200.00	€ 68,200.00	€ 13,310.00	€ 32,010.00
Additional cost for large PHEVs			€ 13,310.00	€ 32,010.00

Source: Adapted from [18]. *For medium EVs the sale price and hence additional cost (also referred to as marginal cost) has been estimated by scaling up small representative vehicles, due to a lack of data on medium EVs. Dataset is for current (2010) performance and costs.

Table 3 - Upfront Price Support for Low-Carbon Vehicles [6].

Country/Vehicle Details	Price Support		
	Value of support in country of origin	Value of support in £	Value of support as % total vehicle price
Canada: (Federal and provincial rebates for vehicles,e.g. Toyota Prius 1.5l, Honda Civic Hybrid 1.3l, and for PHEVs and HEVs)	C$2,000 / C$3,000	£1,115 / £1,675	
Belgium: (vehicles with emissions up to 105 gCO_2/km)	€4,350	£4,000	20% to 40%
Ireland: (Hybrid and Flexi-Fuel first registration)	€2,500	£2,300	Up to 15%
Sweden: (Hybrids with emissions less than 120g CO_2/km, electric cars – less than 37 kWh)	SEK 10,000	£850	Up to 5%
France: (Class A, vehicles under 100g CO_2/km)	€2,000	£1,850	Up to 15%
France: (Class A+, vehicles under 60g CO_2/km)	€5,000	£4,700	Up to 25%
USA: (Plug-in electric, batteries of at least 4kWh)	$2,500	£1,700	Up to 8%
USA: (Plug-in electric, gross vehicle weight up to 10 klbs)	$7,500	£5,250	Up to 20%
USA: (Plug-in electric, gross vehicle weight up to 14 klbs)	$10,000	£6,800	
USA: (Plug-in electric, gross vehicle from 14 klbs to 26 klbs)	$12,500	£8,500	
USA: (Plug-in electric, gross vehicle weight over 26 klbs)	$15,000	£10,160	
Japan: (Nissan Hypermini – electric car)	¥940,000	£50,40	27%
Japan: (Mitsuoka CONVOY88 – electric car)	¥210,000	£1,125	24%
Japan: (Zero Sports Exelceed RS - Hybrid)	¥380,000	£2,040	19%
Japan: (Toyota Prius Hybrid)	¥210,000	£1,125	10%
Japan: (Honda Civic Hybrid)	¥230,000	£1,240	11%

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