SUSTAINABLE ENERGY IRELAND

Hybrid Electric and Battery Electric Vehicles

Buyers Guide

Buyers' Guide for Electric and Hybrid Vehicles

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1 Electric vehicles

1.1 What are electric vehicles?

Electric vehicles (EVs) come in three main types:

- **Battery electric vehicles (BEVs)** are powered solely by electricity stored in large batteries within the vehicles. The battery powers an electric motor, or motors, which in turn drives the vehicle. The battery needs to be recharged by plugging into recharging points, for example, the mains electricity supply.
- **Hybrid electric vehicles (HEVs)**, often simply referred to as hybrid vehicles, are powered by a combination of electricity stored in a battery and either a petrol or diesel internal combustion engine. A hybrid vehicle ***does not*** need to be plugged in to recharge its battery, as this is recharged automatically as the vehicle is being driven.
- **Plug-in hybrid electric vehicles (PHEVs)** work similarly to conventional hybrids in that they operate using the vehicle's petrol or diesel engine or by using electricity to power an on-board electric motor. However, PHEVs have much larger batteries than conventional HEVs and so can also be charged from the mains when not in use – hence 'plug-in' – and this means the vehicle can cover a greater distance. There are two key types of PHEV:
    - The first can run indefinitely with the petrol/diesel motor providing power as in a normal car.
    - The second is effectively a battery-powered vehicle with a small onboard generator to extend the distance the car can travel.

Most new electric vehicles also use an advanced braking system – known as 'regenerative braking' – that allows the electric motor to re-capture the energy expended during braking that would normally be lost. This improves energy efficiency and reduces wear on the brakes.

1.2 Why buy an electric vehicle?

Good for the environment: Electric vehicles emit lower levels of a range of air pollutants, e.g. nitrogen oxides, particulate matter and greenhouse gases (e.g. carbon dioxide, CO_2) than vehicles using conventional petrol and diesel engines. Using electricity to power a vehicle means there is no pollution at all when the vehicle is in use, unlike petrol and diesel cars. A car powered purely by a battery has zero emissions when in operation, whereas the emissions from hybrids and plug-in hybrids are lower than conventional vehicles as they use electricity for at least part of the journey. When in use, all electric vehicles contribute less to air pollution in towns and cities and so have much less impact on the climate than conventional vehicles.

Cheaper to run: As electricity is cheaper than petrol or diesel, the running costs of EVs are less than conventional vehicles.

Quieter than conventional vehicles: EVs are also quieter than conventional vehicles – battery-operated cars operate in almost complete silence, except for noise from the tyres.

Perfect for urban use: Reduced levels of pollution and noise make EVs ideal for inner city and urban use.

Smooth acceleration and deceleration: BEVs benefit from smooth gearless acceleration and deceleration, as a result of the characteristics of the electric motor.

1.3 Disadvantages of electric vehicles

More expensive to buy: EVs generally cost more to buy than conventional vehicles.

EVs contribute to higher emissions elsewhere: Although electric-powered vehicles create zero or fewer emissions than petrol or diesel cars when in use, there are emissions released when the any mains electricity used is actually being produced. These emissions should be taken into account when assessing the net environmental benefits of EVs. If renewable energy is used to generate the electricity then the impact on the environment is much less than other vehicle technologies. If non-renewable energy is used, then the environmental benefits are reduced. In addition, hybrid electric vehicles cause greater pollution during manufacture and disposal than conventional vehicles.

Limited range: The distance that battery electric vehicles and some plug-in hybrids can travel without the need for refuelling is shorter than conventional vehicles. However, hybrids and plug-in hybrids can travel broadly the same distance, and in some cases further, than petrol and diesel cars.

Smaller vehicles and lower top speeds: Battery-powered vehicles tend to be smaller in size and have lower top speeds than conventional cars. However, hybrids and plug-in hybrids are comparable in size and speed.

1.4 When is it worth buying an electric vehicle?

Electric vehicles are cheaper to run, but more costly to buy, than conventional vehicles. So, for some owners electric vehicles are potentially cost-effective, but not for others. This guide aims to provide information to help potential buyers of electric cars, vans and buses to decide whether buying an electric vehicle would be cost effective for them.

2 Considering Buying an Electric Car?

2.1 Buying a Battery Electric Car

Costs

Buying a battery electric car: Battery-powered cars generally cost more to buy than conventional cars, partly because electric batteries are expensive. However, it is likely that the cost of a battery will reduce in the future as the number of batteries manufactured increases. To help reduce costs, batteries can often be leased or rented instead of bought, e.g. the Th!ink City car's battery pack is leased to consumers at a fee of approximately €120 per month.

Operational and maintenance costs: It costs substantially less to operate a battery electric car than a conventional car, for example, the Reva G-Wiz costs just 0.08 cents per kilometre (0.13 cents per mile) to run[1]. Maintenance costs are also much reduced as battery electric cars are mechanically very simple.

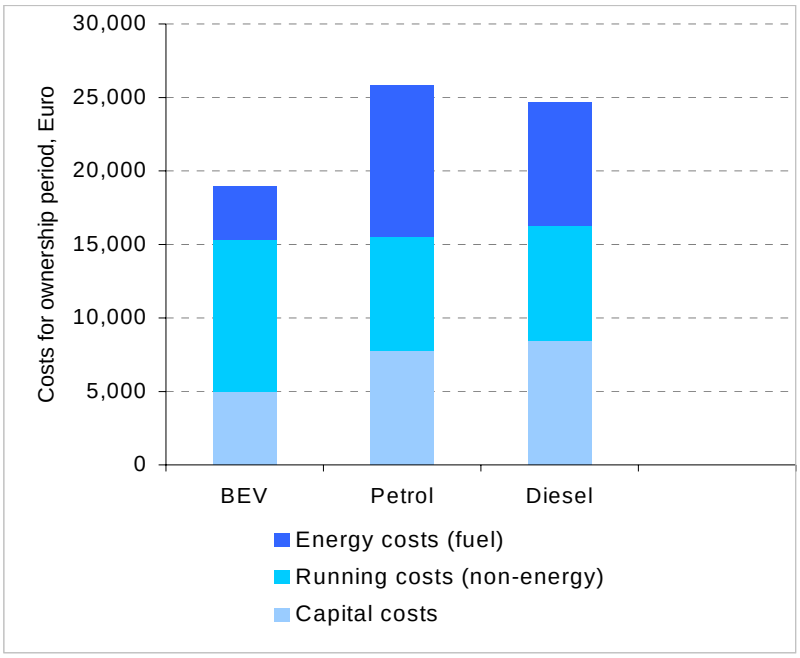
Taxes: Owners of electric cars pay lower taxes than owners of other cars. In 2007, electric cars solely propelled by a re-chargeable battery were entitled to up to a 50% reduction in vehicle registration tax (VRT). Similarly, for the annual motor tax, owners of electric vehicles currently pay €146 per year, whereas the fee for a conventional private car ranges from €151 for cars with an engine size less than or equal to 1,000cc up to €1,343 for a car with an engine size over 3,000cc. In 2008, new systems of VRT and annual motor taxation are likely to be introduced, which could require buyers and users of higher polluting vehicles to pay even more tax.

Who would benefit from buying a battery electric car?

As can be seen in Figure 1, below, an average car user, who owns a car for 10 years and drives around 17,000 kilometres a year, would benefit financially from buying an electric car. Over the lifetime of the car, the owner could save around €6,900 by using an electric car instead of a petrol car and around €5,700 if they bought an electric car instead of a diesel car. These savings relate to the use of relatively small cars, as these are the most common size of electric car available in 2007.

[1] Reva G-Wiz promotional literature

Figure 1: Comparison of the relative costs of ownership of battery electric cars compared to petrol and diesel equivalents



Practicalities

Driving range: Currently, a limitation of battery electric cars is the relatively short distance they can be driven before they need recharging. Many of the smaller commuting battery-powered cars, such as the Reva, have a range of around 50 to 100 kilometres (30 to 60 miles) while some high performance examples, such as the Teslar Roadster, can travel around 240 kilometres (150 miles).

Recharging: Electric cars are recharged by plugging them into an existing conventional mains socket. The Reva vehicle can be fully charged in six hours, whilst an 80% charge can be achieved in as little as two-and-a-half hours.

Battery lifetime: The length of time a battery lasts will depend on how often it is used, charged and discharged. Regular fast-charging can reduce the lifetime of current batteries. However, for average usage, the battery should only need to be replaced a couple of times in the vehicle's lifetime. The manufacturer of the car will be able to advise how best to look after the battery to extend its life. Battery technology is also improving rapidly – over the last three years there has been a significant increase in the battery lifetimes.

Top speed: Small urban battery electric cars typically have top speeds of 65 kilometres (40 miles) per hour.

Vehicle availability: The following is a list of battery electric cars currently on sale in Ireland:

- The Reva G-wiz (http://www.greenmachines.ie/)
- Micro-Vett - Ydea city car (http://www.micro-vett.it/english/ydeaing.html)
- Micro-Vett - Doblo vehicle (http://www.micro-vett.it/english/company.html)

Other battery electric cars not currently available in Ireland, but available in Europe, include:

- The MEGA City car (http://www.niceccarcompany.co.uk)
- The Maranello 4cycle (http://www.maranello4cycle.com/)
- Fiat Fiorino, developed by Micro-Vett

Other battery electric cars currently under development in Europe include:

- Th!ink City car (http://en.think.no/)
- EV Smart for 2 (being developed for Mercedes)

High performance sports cars (mainly currently only available in the United States) include:

- Teslar Roadster (www.teslamotors.com)
- Zap-X
- WrightSpeed X1
- Tango T600 (other smaller models under development)

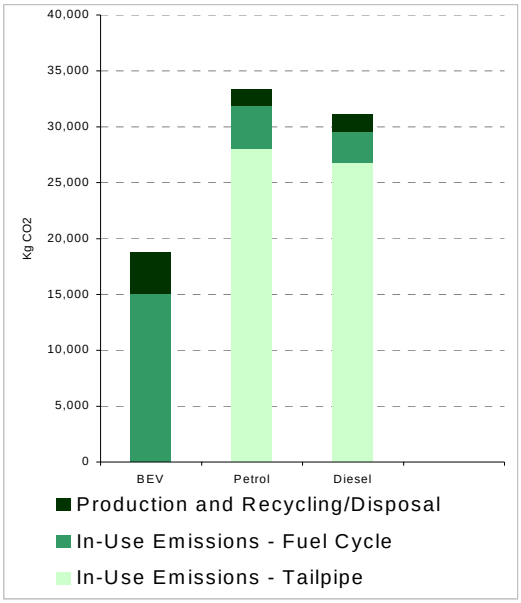
Sports electric cars being developed in Japan are:

- Mitsubishi's MIEV
- Subaru R1e

How much better are battery cars for the environment?

Figure 2 shows estimated CO_2 emissions for battery electric cars and those of conventional petrol and diesel cars, for average ownership and use[2]. As can be seen, a battery electric car emits less CO_2 than a conventional car.

Figure 2: Estimated CO_2 emissions arising from the production, disposal and use of battery electric and conventional petrol and diesel cars



Life-cycle CO_2 emissions

[2] i.e. driving 17,000 kilometres a year and owning the car for 10 years

2.2 Buying a Hybrid Electric Car

Purchase costs: On average, hybrid electric cars can cost around 20-25% more than a petrol or diesel model to purchase. However, manufacturers are planning to increase their production of hybrid vehicles, which will result in the manufacturing costs being reduced, and so should bring down the price of hybrids.

Operational costs: Hybrid electric cars cost less to operate than conventional cars, as fuel expenditure will be less, which will help to balance out the higher initial purchase costs. The rate at which the lower cost of use makes up for the higher cost of purchase will depend on particular use patterns and fuel prices. For example, the further a car is driven, the more it is used in urban areas and the higher then fuel price, the sooner the owner will start to save money.

Maintenance costs: Given the fact that hybrid cars have both a petrol or diesel engine and an electric motor, their maintenance costs are likely to be higher than cars which have either an electric motor or a conventional engine. On the other hand, the use of 'regenerative' braking systems in electric cars means that the vehicle's brake discs and pads do not wear as quickly and so do not need to be replaced as often. Additionally, the electric drive systems of hybrid cars also have very low maintenance requirements.

Taxes: Owners of some hybrid electric cars pay lower taxes than owners of other cars. In 2007, this amounted to 50% relief from vehicle registration tax (VRT). In 2008, a new system of VRT is likely to be introduced, which could require buyers and users of higher polluting vehicles to pay more tax.

Who would benefit from buying a hybrid electric car?
Owners who have a high annual mileage rate are likely to benefit most from having a hybrid electric car because although more expensive to buy, hybrids are cheaper to run. As Tables 3 and 4 show, hybrids have to be used more intensively than conventional cars[3] or kept for longer in order for owners to save money. For example, someone who plans to own a hybrid car for only 5 years will have to travel 38,000 kilometres (23,500 miles) each year – more than twice the average annual distance driven in Ireland – to make the purchase of a hybrid petrol car worthwhile. Alternatively, someone who owns a petrol hybrid car for 10 years (the average length of ownership) will need to travel 25,500 kilometres (16,000 miles) each year to make the additional costs of purchasing a hybrid worthwhile. The equivalent distances to make the purchase of a diesel hybrid worthwhile are even further due to the cheaper fuels costs associated with running conventional diesel cars (compared to petrol cars).

Drivers who travel the average distance of 17,000 kilometres a year would have to own a petrol hybrid car for 21 years to recover the additional costs of buying the car, and a diesel hybrid for more than 25 years.

Table 1: When is it worth buying a petrol hybrid electric car?[4]

Assumption:	**Average ownership**	**Short-term ownership/ high use**	**Average use/ Long-term ownership**
Ownership period (years)	10	5	21
Annual distance driven (km)	25,500	38,000	17,000
% of driving in city areas	25%	25%	25%
Financial costs:			
Capital cost (after discount and including resale)	€25,500	€23,600	€27,100
Running costs (non-energy i.e. tax + maintenance)	€7,800	€4,800	€12,200
Running costs (energy)	€12,300	€11,200	€12,900
Total cost (over ownership period)	€45,500	€39,600	€52,200

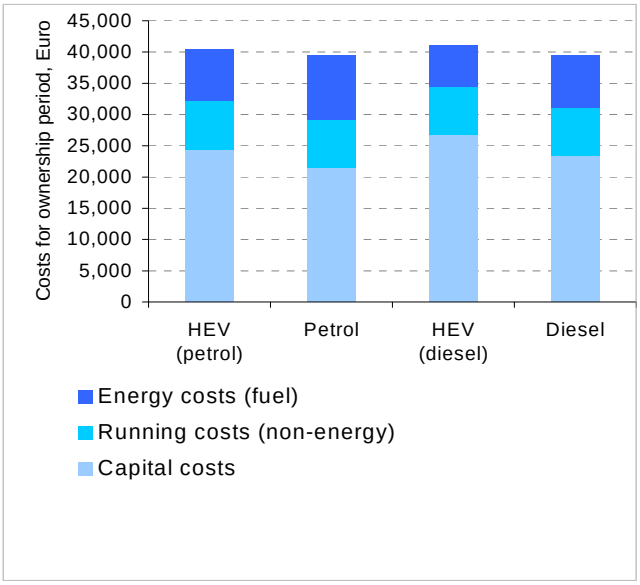
[3] The average car is driven 17,000 kilometres (10,500 miles) per year in Ireland
[4] Compared to a conventional petrol car

Table 2: When is it worth buying a diesel hybrid electric car?[5]

Assumption:	**Average ownership**	**Short-term ownership/ high use**
Ownership period (years)	10	5
Annual distance driven (km)	34,500	53,500
% of driving in city areas	25%	25%
Financial costs:		
Capital cost (after discount and including resale)	€28,800	€27,300
Running costs (non-energy i.e. tax + maintenance)	€7,800	€4,800
Running costs (energy)	€13,400	€12,800
Total cost (over ownership period)	€50,000	€44,900

Figure 2 shows the differences in total costs for an average driver in Ireland. At this level of usage, hybrid cars are marginally more expensive than conventional cars.

Figure 2: Relative costs of ownership of hybrid petrol and hybrid diesel cars compared to petrol and diesel equivalents for an average driver in Ireland



Practicalities

There are essentially no practical limitations of hybrid electric cars compared to regular petrol and diesel equivalents.

Driving range: The range of a hybrid will be further than that of a conventional petrol or diesel car, as it uses petrol or diesel as well as a battery.

Recharging: None, as a hybrid's electric motor is recharged automatically as the car is being driven.

Battery lifetime: Batteries can last several years, e.g. for the Prius, Toyota provides an 8-year (or 160,000 kilometres) warranty for its entire hybrid system including the battery. Experience suggests that batteries can last longer than this.

Top speed: A hybrid electric car can reach similar speeds as a conventional car.

[5] Compared to a conventional diesel car

Vehicle availability: The following hybrid cars are currently available for purchase in Ireland:

- Toyota Prius www.toyota.ie
- Lexus RX 400h and Lexus GS 450h http://www.lexus.ie/
- Honda Civic IMA www.honda.ie

Other hybrids currently under development include:

- Peugeot 308 Hybride Hdi (on sale in 2009)
- Citroën C4 Hybride Hdi (diesel; demonstration model)
- Opel Astra Diesel Hybrid (being tested by General Motors)
- Volkswagen has made a prototype diesel-electric hybrid car

Other benefits

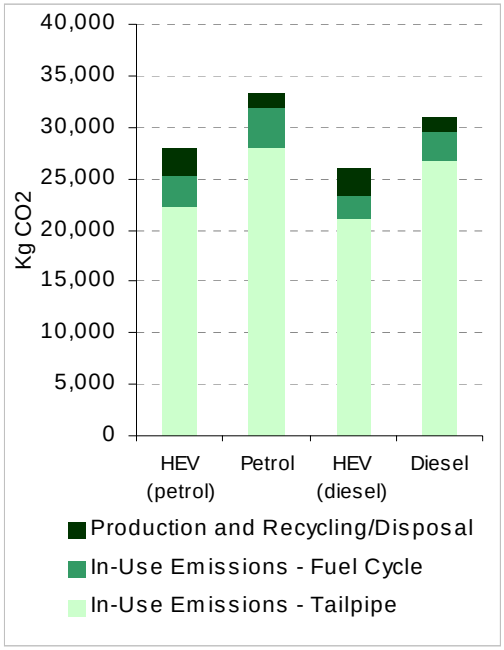
- There is the potential for reduced motor insurance premiums. For example, the Royal Sun Alliance announced in December 2006 that it would offer a 25% discount to new and existing customers with hybrid vehicles. The discount currently applies to the Toyota Prius, the Lexus RX400H, the Lexus GS450H and the Honda Civic IMA.
- Some hybrid electric vehicles can operate on pure electric mode for short distances at low speeds so that they are almost completely silent (except for tyre noise, which is low at typical urban speeds).

How much better are hybrids for the environment?

The figures below show estimated CO_2 emissions arising from petrol and diesel hybrids compared to conventional petrol and diesel cars, for average ownership and use[6]. As can be seen, a hybrid car emits less CO_2 than a conventional car.

[6] i.e. driving 17,000 kilometres a year and owning the car for 10 years

Figure 3: Estimated CO_2 emissions arising from the production, disposal and use of petrol and diesel hybrid cars under average use.



Life-cycle CO_2 emissions

2.3 Buying a Plug-in Hybrid Electric Car

Costs

Buying a plug-in hybrid electric car: It is anticipated that plug-in hybrid electric cars may cost up to 40-50% more than a conventional petrol or diesel car to buy, due mainly to the additional cost of the batteries. However, the difference in cost will come down, as more hybrids come on to the market.

Current plug-in hybrid cars are modified versions of conventional cars and hybrid cars. However, manufacturers such as Toyota have announced that they are considering developing original plug-in hybrids, in order to increase the number of hybrid cars on the market.

Operational costs: The fuel costs over the lifetime of a plug-in hybrid car will be significantly lower than for a car with only a petrol or diesel engine. Owners can therefore make significant savings on fuel expenditure, which will help to balance out the initial higher purchase costs (see below).
Maintenance costs: As a result of having both an electric motor and a conventional engine, plug-in hybrids are likely to have higher maintenance costs than those cars with either a motor or an engine. On the other hand, as with ordinary hybrids, the use of regenerative braking systems in plug-in hybrids means that brake discs and pads do not wear out as quickly as they would in a conventional car. Additionally, the electric drive systems in plug-in hybrids have comparatively low maintenance requirements.

Taxes: Owners of some plug-in hybrid electric cars also pay lower taxes than owners of other cars. In 2007, this amounted to a 50% reduction in vehicle registration tax (VRT). In 2008, a new system of VRT is likely to be introduced, which could require buyers and users of higher polluting vehicles to pay more tax.

Who would benefit from buying a plug-in hybrid electric car?

The benefits of plug-in hybrids are the same as those of ordinary hybrids. They are more expensive to buy than conventional cars, but cheaper to run, and the further a hybrid is driven, the sooner the owner will start to save money (see Table 3 and Table 4). For example, an owner planning to keep a plug-in hybrid car for only five years before selling it on, would save money if they drove a petrol plug-in hybrid car over 50,000 kilometres a year (compared to a conventional petrol car). If a petrol plug-in hybrid car were to be kept for 10 years, then the owner would have to drive at least 33,500 kilometres a year to save money. The equivalent figures for a diesel plug-in hybrid (compared to a conventional diesel car) are much higher at 50,000 kilometres and 77,000 kilometres, respectively. The average driver (i.e. one who drives 17,000 kilometres a year) would have to keep their car for more than 25 years to make buying a plug-in hybrid car worthwhile.

Table 3: When does it become worthwhile to buy a petrol plug-in hybrid electric car?[7]

Assumption:	**Average ownership**	**Short-term ownership/ high use**
Ownership period (years)	10	5
Annual distance driven (km)	33,500	50,000
% of driving in city areas	25%	25%
% of time battery is charged over-night	80%	80%
% of time running off grid electricity	50%	50%
Financial costs:		
Capital cost (after discount and including resale)	€30,600	€28,800
Running costs (non-energy i.e. tax + maintenance)	€8,200	€5,000
Running costs (energy)	€12,300	€11,200
Total cost (over ownership period)	€51,100	€45,000

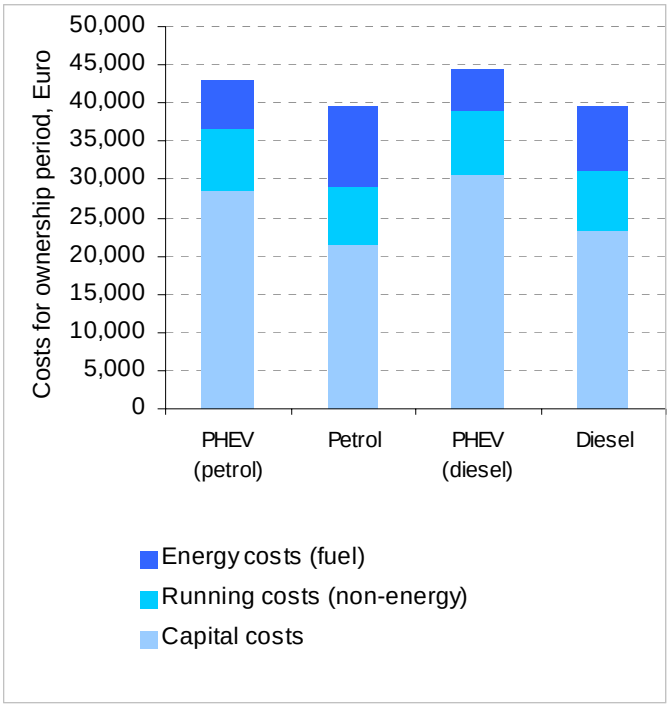
Table 4: When does it become worthwhile to buy a diesel petrol plug-in hybrid car?[8]

Assumption:	**Average ownership**	**Short-term ownership/ high use**
Ownership period (years)	10	5
Annual distance driven (km)	50,000	77,000
% of driving in city areas	25%	25%
% of time battery is charged over-night	80%	80%
% of time running off grid electricity	50%	50%
Financial costs:		
Capital cost (after discount and including resale)	€34,400	€33,300
Running costs (non-energy i.e. tax + maintenance)	€8,200	€5,000
Running costs (energy)	€16,000	€15,100
Total cost (over ownership period)	€58,600	€53,400

Figure 4 shows the differences in total costs for an average driver in Ireland. At this level of usage, plug-in hybrid cars are more expensive than conventional cars.

[7] Compared to a petrol car
[8] Compared to a diesel car

Figure 4: Relative costs of ownership of plug-in hybrid petrol and plug-in hybrid diesel cars compared to petrol and diesel equivalents under the "average" scenario



Practicalities

Driving range: The driving range of plug-in hybrid car is further than that of a battery electric car, as for longer journeys, the car uses the electric motor first before switching to the petrol or diesel engine. It can be expected that the range of a plug-in hybrid car would be similar to that of a conventional hybrid car.

Recharging: Plug-in hybrids can be recharged both from the engine and from the mains electricity supply. The normal charging time from the mains is around 8 to 9 hours.

Battery lifetime: Battery life is shorter than for ordinary hybrids due to the fact that the battery is used more regularly in a plug-in.

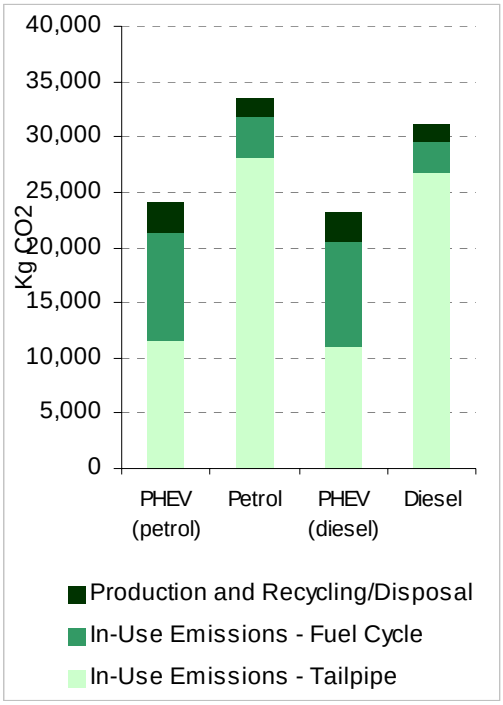
Top speed: The top speed of a plug-in hybrid car is likely to be similar to the top speed of a hybrid or conventional car.

Vehicle availability: There are no plug-in hybrid electric cars currently available for sale in Ireland, but it is likely that they will become available over the next few years. For example, Toyota has announced plans to develop a plug-in version of the Prius (www.toyota.ie), while other manufacturers, such as General Motors, Ford and Chinese automaker BYD Auto, have announced their intention to introduce plug-in hybrid cars.

How much better are plug-in hybrids for the environment?

The figure below compares CO_2 emissions for petrol and diesel plug-in hybrids compared to conventional petrol and diesel cars, for average ownership and use. As can be seen, a plug-in hybrid car emits less CO_2 than a conventional car.

Figure 5: Estimated CO_2 emissions arising from the production, disposal and use of petrol and diesel plug-in hybrid cars



Life-cycle CO_2 emissions

3 Considering Buying an Electric Van?

3.1 Buying a Battery Electric Van

Costs

Buying a battery electric van: On average, a battery electric van will cost more than a conventional petrol or diesel van, although it is possible to find electric vans which are not much more than a diesel model. It is likely that the cost of a battery will decline in the future as the number of batteries manufactured increases. It is also anticipated that conventional diesel vans may increase in price over the next few years due to increased manufacturing costs and the development of costlier pollution control systems. This will therefore reduce the price difference between diesel and battery electric vans.

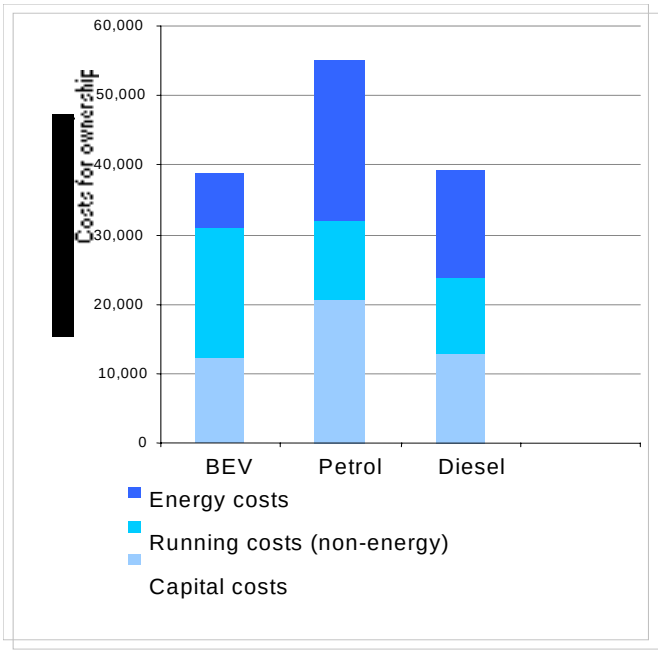
Operational and maintenance costs: It costs substantially less to run a battery electric van than a conventional van. Maintenance costs are also comparatively low, estimated at only a few hundred euros per year.

Taxes: Battery electric vans benefit from a discounted rate of tax (€80 per annum) for electric goods vehicles not over 1,500kg, compared to petrol and diesel equivalents.

Who would benefit from buying a battery electric van?

As can be seen from Figure 6, below, an average van user, i.e. one who owns a van for 10 years and drives 22,500 kilometres a year, would benefit from buying an electric van. Over the lifetime of the van, the owner would make a saving of around €600. It should be noted that the comparison in the table below is based on relatively small vans, as these are the most commonly used.

Figure 6: Comparison of the relative costs of ownership of battery electric vans compared to petrol and diesel equivalents



Practicalities

Driving range: Battery electric vans currently available (see below) have a range of between 70 to 160 kilometres (45 to 100 miles).

Recharging: Vans generally require an overnight (8 hour) charge. Some battery electric vans can be recharged by plugging them into an existing conventional socket; whilst fast-charging stations are also available.

Battery lifetime: The length of time a battery lasts will depend on how often it is used, charged and discharged, although regular fast charging can reduce the lifetime of current batteries. However, for average usage, an owner of a battery electric van could be expected to replace the battery a couple of times in the lifetime of the vehicle. The van manufacturer will be able to advise how best to look after the battery to extend its life. Battery technology is improving – in recent years there has been a significant increase in the expected life of a battery.

Top speed: The battery electric vans currently available in Ireland have top speeds of between 60 (Micro-Vett Porter) and 80 (Modec) kilometres (37.5 to 50 miles) per hour.

Vehicle availability: There are currently two European manufacturers of battery electric vans accessible in Ireland:

- UK-based Modec (www.modec.co.uk); and
- Italian Micro-Vett (http://www.micro-vett.it/eng/indexing.html)

Other companies that are producing electric vans, include

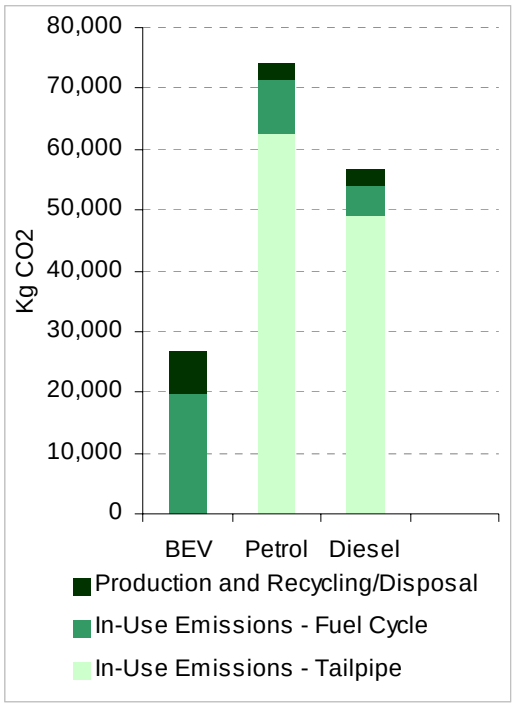
- Smith Electric Vehicles (SEV) (http://www.smithelectricvehicles.com/)
- NICE (No Internal Combustion Engine) (http://www.nicecarcompany.co.uk/megatruck/)
- Zap Truck XL: all electric multipurpose urban truck (http://www.zapworld.com/electric-vehicles/electric-cars)

How much better are battery electric vans for the environment?

The figure below shows estimated emissions of CO_2 from battery electric vans compared to those of conventional petrol and diesel vans, for average ownership and use[9]. The data shows that a battery electric van emits less CO_2 than a conventional van.

[9] i.e. driving 22,500 kilometres a year and owning the van for 10 years

Figure 7: Estimated CO_2 emissions arising from the production, disposal and use of battery electric and petrol and diesel vans



Life-cycle CO_2 emissions

3.2 Buying a Hybrid Electric Van

Costs

Purchase costs: On average, hybrid electric vans can cost around 25% more than conventional petrol or diesel vans. However, manufacturers are planning to increase their production of hybrid vehicles, which should quickly drive down the costs, and thus the price of hybrids.

Operational costs: Operating a hybrid van costs less than operating a conventional van, as fuel expenditure will be less, which will help to balance out the initial purchase costs (see below). The rate at which the higher purchase costs are recovered will depend on the particular use patterns and fuel prices. The costs will be recovered fastest when the van is driven long distances, used mainly in urban areas and when fuel prices are high.

Maintenance costs: Given the fact that hybrid vans have both a conventional (petrol or diesel) engine and an electric motor, their maintenance costs are likely to be higher than vans with either an electric motor or a conventional engine. On the other hand, the use of regenerative braking systems means that the conventional brake discs and pads receive lower rates of wear and require less frequent replacement. Furthermore, the electric drive systems of hybrid vans also have very low maintenance requirements.

Taxes: There are currently no direct tax incentives for hybrid electric vans relative to conventional petrol and diesel equivalents in Ireland.

Who would benefit from buying a hybrid electric van?
As can be seen from Table 5, the average owner of a petrol van would save approximately €1,600 a year if they were to use a petrol hybrid van instead. However, petrol vans are more expensive than hybrid vans, and are less common than diesel vans, so a better comparison of the costs are the figures given for diesel vans (see Table 6). These are less favourable, although an average owner of a hybrid diesel van (i.e. one who keeps the van for 10 years) could save money if they were to travel more than 26,500 kilometres a year, which is about 20% further than an average van would be driven in a year. Owners who only keep a diesel hybrid van for five years would have to travel 39,500 kilometres a year – 75% more than average – to make the purchase of a diesel hybrid van worthwhile. Alternatively, an owner who drives the average distance for vans each year – 22,500 kilometres – would have to own the van for 13 years to make the additional costs of purchase worthwhile.

Table 5: When is it worth buying a petrol hybrid electric van?[10]

Assumption:	**Average use and ownership**	**Average ownership**	**Short-term ownership**
Ownership period (years)	10	10	5
Annual distance driven (km)	22,500	15,000	22,000
% of driving in city areas	30%	30%	30%
Financial costs:			
Capital cost (after discount and including resale)	€24,400	€23,000	€20,700
Running costs (non-energy i.e. tax + maintenance)	€11,200	€11,200	€6,900
Running costs (energy)	€18,000	€12,000	€10,800
Total cost (over ownership period)	€53,600	€46,200	€38,400
Savings compared to conventional petrol van	€1,600	-*	-*

* Nominal

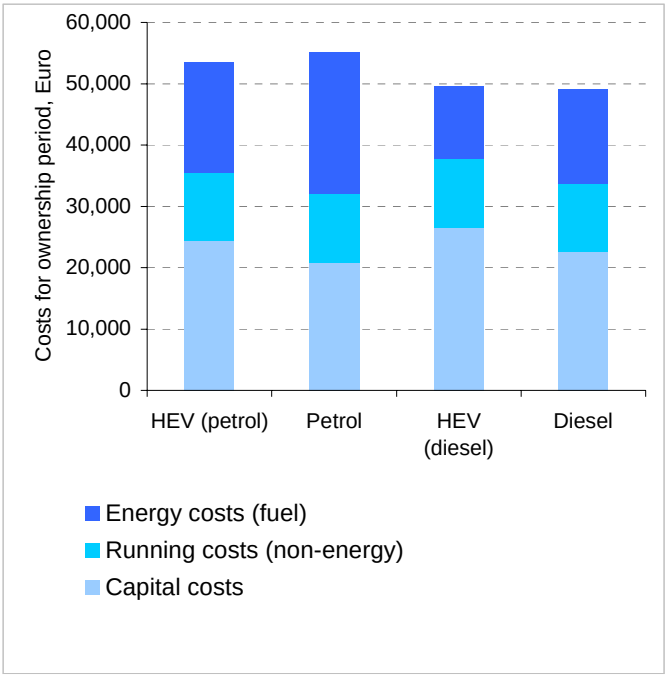
Table 6: When is it worth buying a diesel hybrid electric van?[11]

Assumption:	**Average ownership**	**Short-term ownership**	**Average use/ Long-term ownership**
Ownership period (years)	10	5	13
Annual distance driven (km)	26,500	39,500	22,500
% of driving in city areas	30%	30%	30%
Financial costs:			
Capital cost (after discount and including resale)	€27,200	€25,200	€27,700
Running costs (non-energy i.e. tax + maintenance)	€11,200	€6,900	€13,300
Running costs (energy)	€14,000	€12,800	€14,200
Total cost (over ownership period)	€52,400	€44,900	€55,200

Figure 8 shows the differences in total costs for an average van driver in Ireland[12]. At this level of usage, diesel vans are marginally cheaper than hybrid vehicles.

[10] Compared to a conventional petrol van
[11] Compared to a conventional diesel van
[12] i.e. one who drives 22,500 kilometres a year and keeps their van for 10 years

Figure 8: Relative costs of ownership of hybrid petrol and hybrid diesel vans compared to petrol and diesel equivalents



Practicalities

One of the main practical differences between a hybrid electric van and a conventional diesel van would be that the batteries take up space that could otherwise be used for carrying loads.

Driving range: The range of a hybrid van will be further than that of a conventional petrol or diesel van, as a hybrid electric van has an engine that uses petrol or diesel, as well as a battery.

Recharging: None, as a hybrid van's electric motor is recharged automatically as the van is being driven.

Battery lifetime: In theory, batteries in hybrid vans should last the same time as those used in hybrid cars over the same distance. However, in practice, as vans are usually used more intensively than cars, the battery is unlikely to last as long.

Top speed: A hybrid electric van can reach similar speeds to a conventional petrol or diesel van.

Vehicle availability: Current hybrid van manufacturers include:

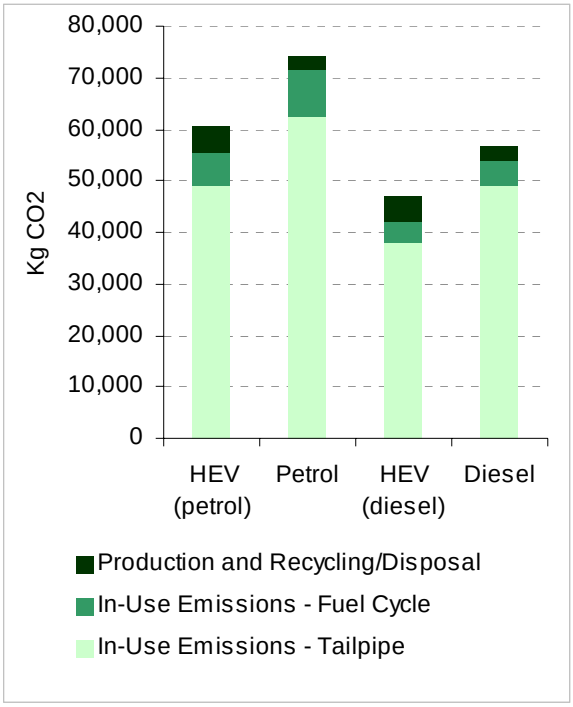
- XGEM: http://www.xgem.net/
- DaimlerChrysler: http://www.daimlerchrysler.com/
- Azure Dynamics: http://www.azuredynamics.com/index.htm
- Micro-Vett: http://www.micro-vett.it/english/bimodaleing.html

How much better are hybrid vans for the environment?

The figure below provides estimated CO_2 emissions for petrol and diesel hybrid vans compared to conventional petrol and diesel vans, for average ownership and use[13]. As can be seen, a hybrid van emits less CO_2 than a conventional van.

[13] i.e. driving 22,500 kilometres and owning the van for 10 years

Figure 9: Estimated CO_2 emissions arising from the production, disposal and use of petrol and diesel hybrid vans



Life-cycle CO_2 emissions

3.3 Buying a Plug-in Hybrid Electric Van

Costs

Purchase costs: Plug-in hybrid electric vehicles can cost over 60% more than a conventional petrol or diesel vehicle, due mainly to the additional cost of batteries. However, as higher numbers of plug-in hybrid vehicles come onto the market and the technology develops, the difference in price will become less.

Operational costs: The fuels costs over the lifetime of a plug-in hybrid van will be significantly lower than for a van with only a petrol or diesel engine. Owners can therefore save significant amounts of money on fuel expenditure, which will help to balance out the initial purchase costs (see below).

Maintenance costs: As for conventional hybrid vehicles, maintenance costs are likely to be higher, as a result of having both an electric motor and a conventional engine. On the other hand, the use of regenerative braking systems in plug-ins means that brake discs and pads do not wear out as quickly. Additionally, the electric drive systems in plug-in hybrids have comparatively low maintenance requirements.

Taxes: At the moment, there are no direct tax incentives for plug-in hybrid vans relative to their conventional petrol and diesel equivalents in Ireland. However, it is possible that the discount that currently applies to battery electric vans (electrical goods vehicles not over 1,500kg benefit from a discounted rate of tax (€80 per annum) compared to petrol and diesel equivalents) could be extended to plug-in hybrids.

Who would benefit from buying a plug-in hybrid electric van?

Currently the cost of plug-in hybrid electric vans means that only those owners who use vans – either petrol or diesel – intensively would benefit financially from buying and using such a vehicle (see Table 7and Table 8).

Table 7: When is it worth buying a petrol plug-in hybrid electric van?[14]

Assumption:	**Average ownership**	**Short-term ownership**
Ownership period (years)	10	5
Annual distance driven (km)	53,500	79,500
% of driving in city areas	30%	30%
% of time battery is charged over-night	40%	40%
Financial costs:		
Capital cost (after discount and including resale)	€36,600	€35,500
Running costs (non-energy i.e. tax + maintenance)	€13,400	€8,200
Running costs (energy)	€39,500	€36,000
Total cost (over ownership period)	€89,500	€79,600

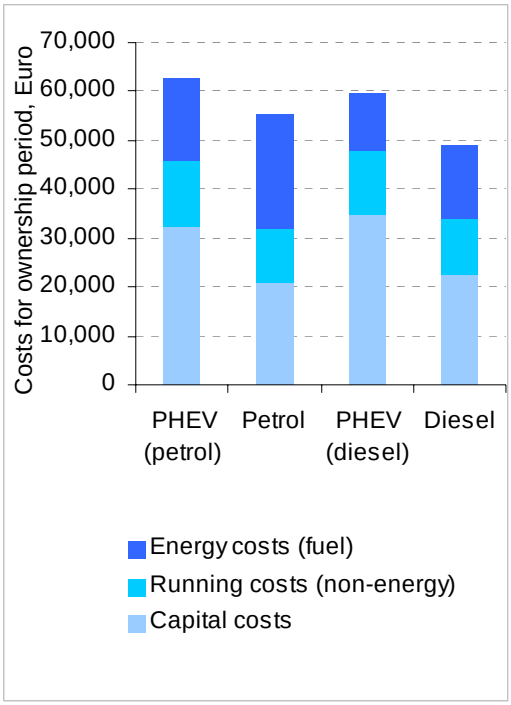
Table 8: When is it worth buying a diesel plug-in hybrid electric van?[15]

Assumption:	**Average ownership**	**Short-term ownership**
Ownership period (years)	10	5
Annual distance driven (km)	97,000	148,500
% of driving in city areas	30%	30%
% of time battery is charged over-night	40%	40%
Financial costs:		
Capital cost (after discount and including resale)	€40,600	€ 40,500
Running costs (non-energy i.e. tax + maintenance)	€13,400	€ 8,200
Running costs (energy)	€49,900	€ 46,800
Total cost (over ownership period)	€103,800	€ 95,500

Figure 10 shows the differences in total costs for an average van driver in Ireland[16]. At this level of usage, plug-in hybrids are more expensive than conventional vans.

[14] Compared to a conventional petrol van
[15] Compared to a conventional diesel van
[16] i.e. one who drives 22,500 kilometres a year and keeps their van for 10 years

Figure 10: Relative costs of ownership of plug-in hybrid petrol and plug-in hybrid diesel vans compared to petrol and diesel equivalents



Practicalities

Driving range: The driving range of plug-hybrid van is longer than that of a battery electric van, as for longer journeys, the van uses the electric motor first before using the petrol or diesel engine. The range of a plug-in hybrid van is similar to that of an ordinary hybrid van.

Recharging: Plug-in hybrid vans can be recharged both from the engine and from the mains electricity supply. The usual charging time from the mains is around 8 to 9 hours, although some models, such as the Citroen Berlingo Electrique allow a fast charge, in which a ten-minute charge time will provide 20 kilometres (12 miles) operation. In addition, photovoltaic panels can be used in some cases to allow re-charging whilst the vehicle is parked, as available on the XGEM-HEV. The distance travelled on one tank of fuel – for either a petrol or a diesel plug-in hybrid van – is typically two to three times greater than the distance that a conventional van would travel on the same amount of fuel.

Battery lifetime: Battery life for plug-in hybrids is shorter than for ordinary hybrids due to the fact that the battery is used more regularly in a plug-in. Battery technology is currently not fully developed, as it has high production and warranty costs.

Top speed: The top speed of a plug-in hybrid van is broadly similar to the top speed of a hybrid or conventional petrol or diesel van.

Vehicle availability: A variety of companies are currently producing plug-in hybrid vans such as Mercedes-Benz/ DaimlerChrysler (Germany/USA), UQM Technologies, Inc. (USA), Azure Dynamics (USA), XGEM (USA), MICRO-VETT (Italy) and Citroen (France).

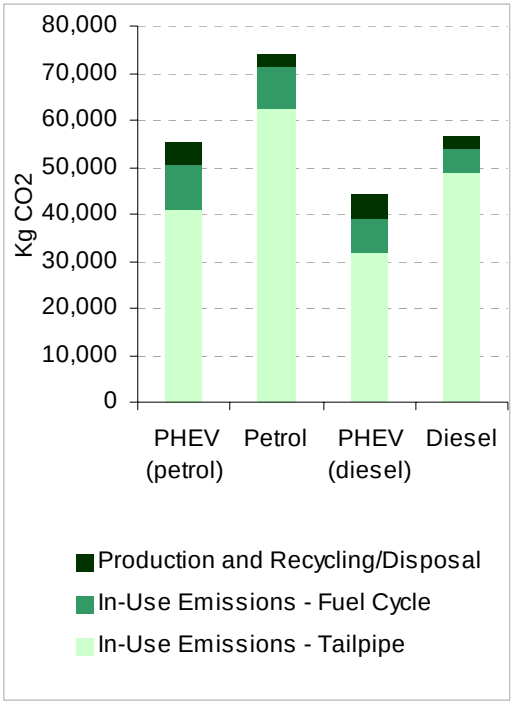
Other benefits

- When operating in pure electric mode, plug-in hybrids are almost completely silent (except for tyre noise, which is low at typical urban speeds) offering significant benefits for use in sensitive areas or at night-time.

How much better are plug-in hybrids for the environment?

The figure below provides estimated CO_2 emissions for petrol and diesel plug-in hybrids compared to conventional petrol and diesel vans, for average ownership and use. Plug-in hybrid vans emit less CO_2 than conventionally fuelled vans.

Figure 11: Estimated CO_2 emissions arising from the production, disposal and in-use emissions of petrol and diesel plug-in hybrid vans



Life-cycle CO_2 emissions

4 Considering Buying an Electric Bus?

4.1 Buying a Battery Electric Bus

Costs

Purchase costs: Estimates in the United States suggest that a 7.5m battery electric bus would cost somewhere between 50% and 100% more than a diesel bus, falling to about 33% for larger 10m versions.

Operational and maintenance costs: The fact that battery electric buses have relatively simple electric transmissions should mean that maintenance costs are greatly reduced compared to a diesel bus. However, given that there is little experience with maintaining such vehicles at present (due to the fact that there are few battery electric buses in operation), it is likely that maintenance costs might currently be high.

Taxes: There are currently no direct tax incentives for battery electric buses relative to conventional diesel equivalents in Ireland.

Who would benefit from buying a battery electric bus?

As can be seen from Table 9, below, if owned for 10 years, a battery electric bus would need to be used intensively to recover the additional purchase costs of the vehicle. The owner would need to operate the bus for a minimum of 130,000 kilometres before starting to save money.

On the basis of average usage[17], battery electric buses would have to be operated for more than 25 years to recover the additional costs of purchase.

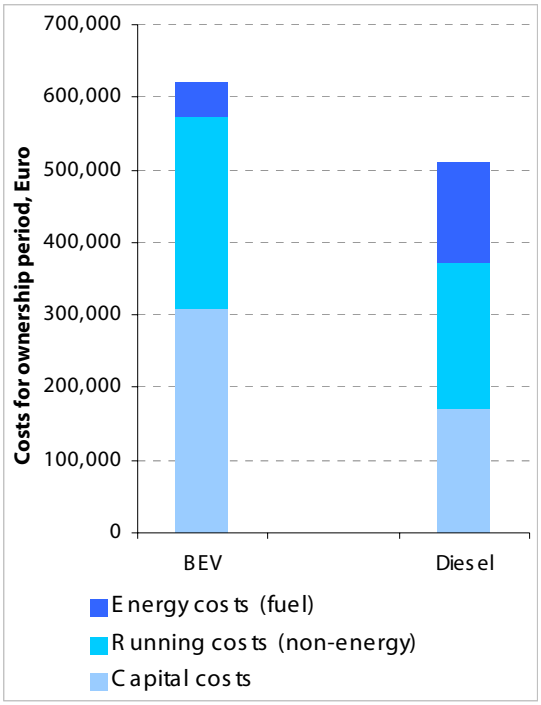
Table 9: When is it worth buying a battery electric bus?

Assumption:	Full size or midi-bus			Minibus
	Urban	Inter-urban	Express	Average life-time
Ownership period (years)	10	10	10	10
Annual distance driven (km)	130,000	207,000	320,000	130,000
% of driving in city areas	90%	40%	10%	40%
% of time battery is charged over-night	30%	20%	10%	60%
Financial costs:				
Capital cost (after discount and including resale)	€418,500	€422,200	€422,300	€82,200
Running costs (non-energy i.e. tax + maintenance)	€265,600	€265,600	€265,600	€24,100
Running costs (energy)	€121,300	€212,300	€345,900	€41,900
Total cost (over ownership period)	€805,500	€900,100	€1,033,800	€148,200

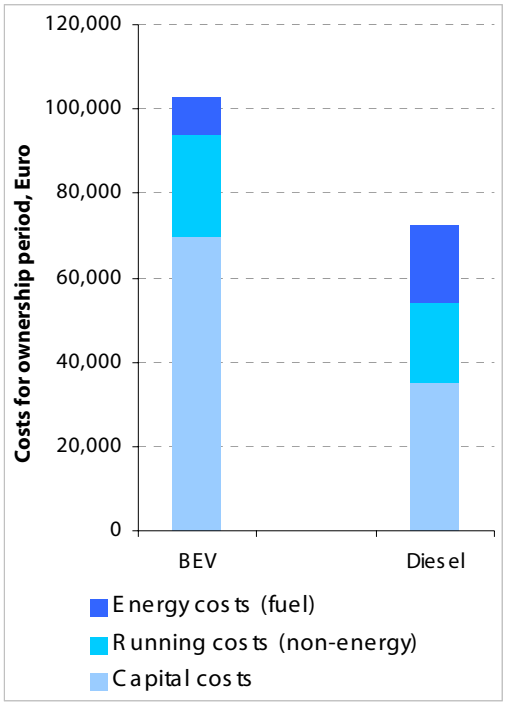
Figure 12 shows that, for comparable use and ownership characteristics, diesel buses are cheaper to own and operate than battery electric buses.

[17] Where average annual bus usage is taken to be 27,500 kilometres for mini buses, 48,500 kilometres for urban buses, 80,500 kilometres for inter-urban buses and 112,500 kilometres for express buses

Figure 12: Comparison of the relative costs of ownership of battery electric and diesel buses in urban areas, and battery electric and diesel minibuses for average usage



Full size/Midi-Bus - Urban



Minibus – Average use

Practicalities

Driving range: Battery electric buses suffer heavily from lack of range due to their weight. This technology is therefore generally limited to mini- or midi-buses which are very well suited to certain types of journeys, such as transit buses at airports or large industrial sites where a recharging infrastructure is easy to establish. Alternatively, they could be used in areas of comparatively light usage, such as parks or other tourist areas where they operate as an attraction as well as a viable means of transport. One example of this is the Ebus transit shuttle that is manufactured in California and has an operational range of approximately 95 to 145 kilometres (60 to 90 miles) when operating on nickel cadmium batteries.

Recharging: In general, recharging is a slow process that can take several hours and this is one of the biggest barriers to large-scale usage of battery electric buses. However, the technology is developing and faster charging is now possible. For example, the Ebus transit shuttle allows 'opportunity charging', with approximately 1.6 kilometres of range added for every minute of charge added to the battery pack. Such a quick charge approach, however, may have an adverse affect on battery life.

Vehicle availability: There are no totally independent large electric buses at present, although some have the capability to operate away from the grid for a short time. The weight inherent in utilising battery electric technology also has limitations on the size of vehicles available. Currently, most independent electric buses are in the mini to midi size ranges and are suited to specific usages. For example, Ebus sell a shuttle-sized electric bus ideal for use in small towns or locations such as airports, as well as heritage style trolleys for use in historic areas, parks or seafront areas.

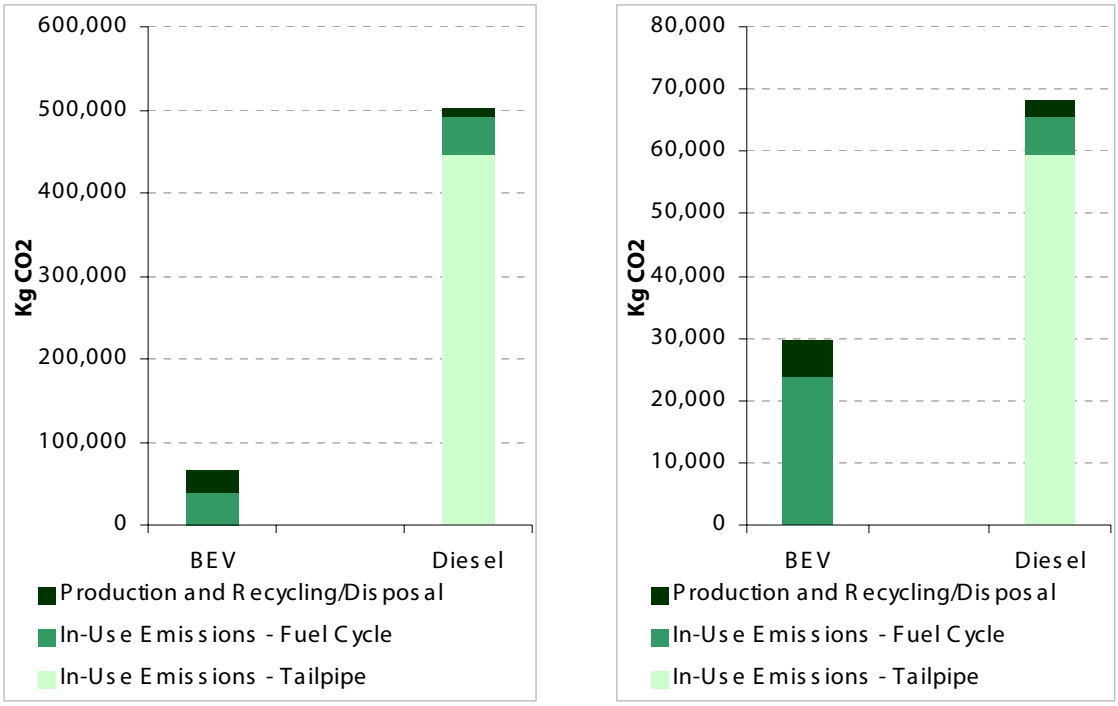
Other benefits

- As with other electric vehicles, battery electric buses operate quietly, with smooth acceleration through the gearless transmission and deceleration through the regenerative braking system. The electric motor is suited to inner city and urban usage, as well as steep hills.
- Some battery electric vehicles do not have the need for gear shifting, giving both smoother acceleration and braking.

How much better are battery electric buses for the environment?

The figures below compare CO_2 emissions for diesel, hybrid and plug-in hybrid buses, both full-sized/midi-buses and minibuses, for comparable ownership and use characteristics. The figures for full-size/midi-buses represent typical urban use, while those for minibuses represent 'average' use[18]. The figures show that battery electric buses are better for the environment than diesel buses.

Figure 13: Estimated CO_2 emissions arising from the production, disposal and use of battery electric and diesel buses



Full size/Midi-Bus **Minibus**

Life-cycle CO_2 emissions

[18] i.e. driving 27,500 kilometres a year and owning the bus for 10 years

4.2 Buying a Hybrid or Plug-in Hybrid Electric Bus

Costs

Purchase costs: Hybrid buses are more expensive to buy then diesel buses, although if hybrid buses are used extensively, there is the potential to save money in the longer-term.

Operational costs: In general, hybrid electric buses use significantly less fuel than regular diesels and this can lead to large cost savings over the operational lifetime of the vehicle.

Maintenance costs: At the moment, hybrid buses are expensive to maintain mainly because the technology is very new. Also, there are few hybrid buses in operation and this means that the market is too small to provide cheap parts and servicing. However, if more hybrid buses enter into operation, then maintenance costs are expected to fall.

Taxes: There are currently no direct tax incentives for hybrid buses relative to conventional diesel equivalents in Ireland.

Who would benefit from buying a hybrid electric bus?
As can be seen from the tables below, if owned for 10 years, hybrid buses would need to be used intensively to recover the additional purchase and maintenance costs of the vehicle, compared to a diesel bus. The shortest annual distance travelled after which the operator would start to make cost savings is 121,000 kilometres. On the basis of average usage[19], hybrid buses would have to be operated for more than 25 years to recover the additional costs of purchase.

Table 10: When is it worth buying a hybrid diesel or plug-in hybrid diesel bus?

Assumption:	Hybrid bus			Plug-in hybrid bus		
	Urban	**Inter-urban**	**Express**	**Urban**	**Inter-urban**	**Express**
Ownership period (years)	10	10	10	10	10	10
Annual distance driven (km)	121,000	196,000	305,000	124,000	201,000	325,000
% of driving in city areas	90%	40%	10%	90%	40%	10%
Financial costs:						
Capital cost (after discount and including resale)	€365,900	€370,900	€371,000	€392,300	€397,000	€371,000
Running costs (non-energy i.e. tax + maintenance)	€201,400	€201,400	€201,400	€222,100	€222,100	€201,400
Running costs (energy)	€211,700	€303,100	€435,000	€173,800	€267,900	€462,900
Total cost (over ownership period)	€779,000	€875,400	€1,006,800	€788,200	€887,000	€1,035,300

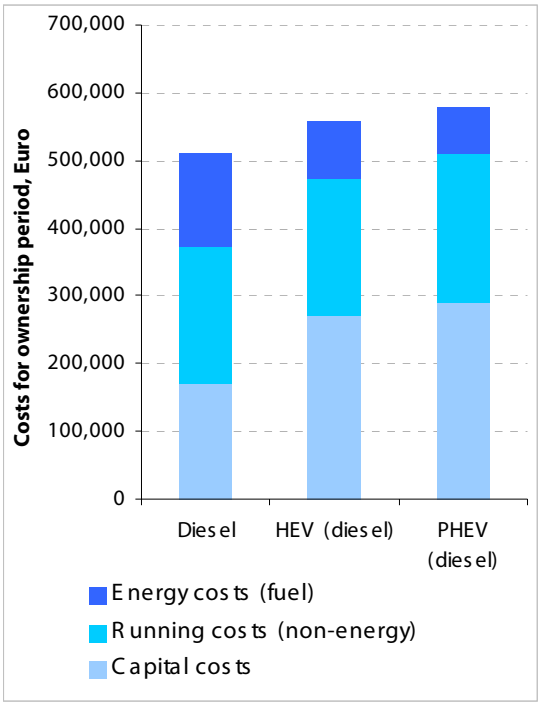
[19] Where average annual bus usage is taken to be 27,500 kilometres for mini buses, 48,500 kilometres for urban buses, 80,500 kilometres for inter-urban buses and 112,500 kilometres for express buses

Table 11: When is it worth buying a hybrid diesel or plug-in hybrid diesel mini bus?

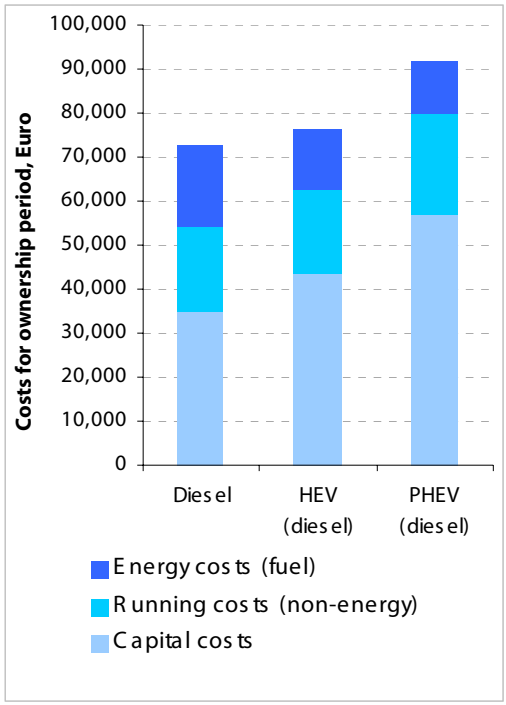
Assumption:	Hybrid mini bus		Plug-in hybrid
	Average ownership	**Average ownership and city use**	**Average ownership**
Ownership period (years)	10	10	10
Annual distance driven (km)	58,000	43,000	125,000
% of driving in city areas	40%	100%	40%
Financial costs:			
Capital cost (after discount and including resale)	€49,000	€47,000	€66,900
Running costs (non-energy i.e. tax + maintenance)	€19,000	€19,000	€22,900
Running costs (energy)	€29,500	€28,100	€54,800
Total cost (over ownership period)	€97,500	€94,100	€144,600

Figure 14 shows that, for comparable use and ownership characteristics, diesel buses are cheaper to own and operate than hybrid or plug-in hybrid buses.

Figure 14: Relative costs of ownership of diesel, hybrid diesel and plug-in diesel full size/midi-buses and minibuses



Full size/Midi-Bus (urban conditions)



Minibus (average use and ownership)

Practicalities

Driving range: The fact that a hybrid bus has a diesel engine means that there is no significant limit on the range of these vehicles. Fuel consumption in a hybrid bus is better than a diesel model so this means that hybrid buses can travel further. Also, the fuel tank of a hybrid bus can be made smaller, thus reducing the weight of the vehicle and providing further fuel economy without any loss of range.

Recharging: Hybrid buses operate exactly as diesel buses and can be fuelled in much the same manner. There are none of the charging time issues relating to electric buses and as such, turn around times will be similar to those experienced in a conventional fleet. Plug-in hybrid buses can, however, be charged using mains electricity to increase the range.

Battery lifetime: The length of a hybrid bus battery's life will depend on how often it is used, charged and discharged, although regular fast charging can significantly reduce the lifetime of current batteries. Further information on looking after the battery in order to extend its life can be obtained from the manufacturer. Over the last three years, there has been a significant increase in the expected length of a battery's life.

Top speed: Hybrid buses can travel at similar speeds to diesel buses and are more than capable at operating at the speeds required for transporting passengers.

Vehicle availability: Wrightbus, based in Northern Ireland (www.wrightbus.com), is one of the largest hybrid bus manufacturers and offers hybrid versions of its single and double-deck buses, as well as an articulated tram-style bus. Currently, there are six test buses in London and trial of a hybrid double-deck bus was due to begin in Dublin in 2007.

Other operational issues: There are a number of specific issues relating to the use and maintenance of hybrid and plug-in hybrid electric drive buses. It should be noted that the difference in technology leads to different skills and requirements for maintenance. For example, a study conducted for New York City Transit found that there was a need to 'condition' the batteries once every sixth months. This required the batteries to be connected to a specific charger for a period of about 8-10 hours. Manufacturers would be able to provide greater information as to the specific maintenance requirements of different vehicles.

Other benefits

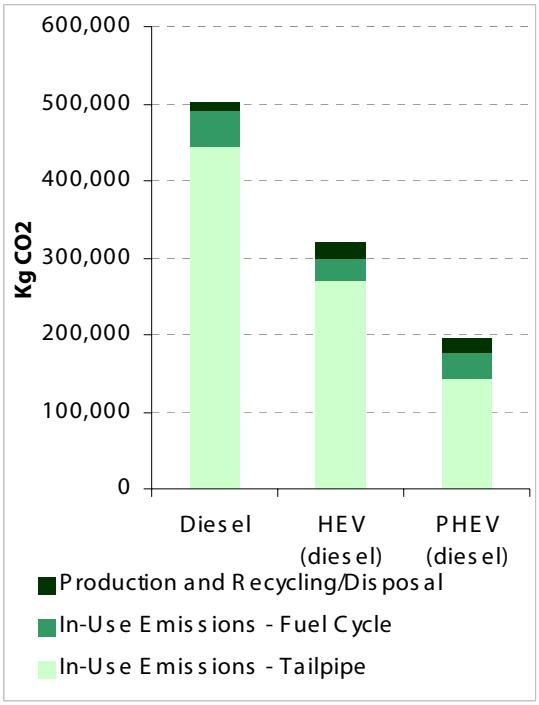
- An electric motor is particularly suited to climbing hills and accelerating, making it an ideal system to power an urban bus
- Electric drive systems are very reliable. This, along with the ability to reduce the size of the combustion engine allows for less frequent maintenance.

How much better are hybrid buses for the environment?

The figures below provide estimated CO_2 emissions for diesel, hybrid and plug-in hybrid buses, both full-sized/midi-buses and minibuses, for comparable ownership and use characteristics. As above, the figures for full-size/midi-buses represent typical urban use, while those for minibuses represent 'average' use[20]. The figures show that generally plug-in buses are better for the environment than hybrid buses, which are in turn significantly better for the environment than diesel buses.

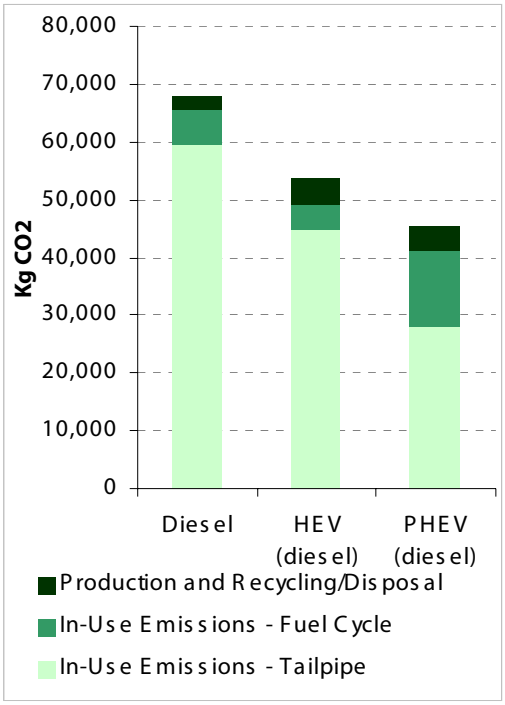
[20] i.e. driving 27,500 kilometres a year and owning the bus for 10 years

Figure 15: Estimated CO_2 emissions arising from the production, disposal and use of diesel, hybrid and plug-in hybrid urban buses



Life-cycle CO_2 emissions

Figure 16: Estimated CO_2 emissions arising from the production, disposal and use of diesel, hybrid and plug-in hybrid minibuses



Life-cycle CO_2 emissions

5 Additional Sources of Information

International Energy Agency - hybrid and electric vehicle implementing agreement:
http://www.ieahev.org/

Anderman, 2007. Status and prospects of battery technology for hybrid electric vehicles, including plug-in hybrid electric vehicles. Briefing to the U.S. Senate committee on energy and natural resources. January 26, 2007.

Duvall, 2003. Advanced batteries for electric drive vehicles. A technology and cost-effectiveness assessment for battery electric, power assist hybrid electric and plug-in hybrid electric vehicles. March 25th, 2003. EPRI, California, USA.

The US Department of Energy, Clean Cities Programme: http://www.eere.energy.gov/cleancities/hev/

Well to wheel analysis of future automotive fuels and powertrains in the European context:
http://www.senternovem.nl/mmfiles/114333_tcm24-124321.pdf
Hybrid buses in London:
http://www.tfl.gov.uk/corporate/projectsandschemes/environment/2019.aspx

Information from the UK's Energy Saving Trust on hybrid and battery operated vehicles:
http://www.energysavingtrust.org.uk/fleet/technology/lowcarbonvehicles/hybridvehicles/

http://www.energysavingtrust.org.uk/fleet/technology/lowcarbonvehicles/electricvehicles/

6 Glossary

Carbon dioxide (CO_2) – A gas that is present in a low concentration in the Earth's atmosphere and is essential for life. It therefore does not have a direct impact on human health. However, the gas is a greenhouse gas that contributes to global warming and climate change.

Midibus - a classification of single decker buses which are between minibuses and full size buses in terms of size, with seating capacities between 20 to 40 people. Midibuses are often designed to be light weight to save on fuel (e.g. smaller wheels than on larger buses), but are then less durable than full size buses.

Regenerative Braking – Technology that allows energy that would otherwise be wasted as heat during braking to be recycled back into the electrical storage system.

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