An tÚdarás um Bóithre Náisiúnta
National Roads Authority

Transport Research & Information Note

Potential Penetration of Electric Vehicles in Irelands Road Vehicle Fleet

February 2011

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1. Purpose of Report

1.1. This Report reviews the potential penetration of electric vehicles in the road vehicle fleet in Ireland and assesses its impact on road system development, operation and use.

2. Policy Context

2.1. The recent increased emphasis on the electrification of road vehicles can be traced to the EU Climate and Energy Package and the Renewable Energy Directive (2009/28/EC). Under the Climate and Energy Package, the EU Heads of State and Government set a series of demanding climate and energy targets to be met by 2020, known as the "20-20-20" targets. These are:

- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels;
- 20% of EU energy consumption to come from renewable resources; and
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

2.2. The Renewable Energy Directive sets specific targets for the transport sector - the share of energy from renewable sources must amount to at least 10 % of final energy consumption in the sector by 2020.

2.3. Electric vehicles, powered at night-time from renewable energy sources, have zero well-to-wheel emissions and therefore address both policy initiatives provided, of course, sufficient customer uptake can be generated. Indeed, the electrification of road vehicles becomes an even more attractive policy option given the more intractable problems associated with Ireland’s agriculture emissions. It is against this background that the Irish Government has set a target that 10 per cent of all vehicles will be electric (battery or Plug-in Hybrid Electric Vehicles) by 2020, estimated to be 250,000 cars.

3. Types of Electric Vehicle

3.1. The precise path by which the road vehicle fleet will transition itself from being based almost exclusively on the internal combustion engine (ICE) to comprising a significant proportion of pure electric vehicles (EVs) is still unclear. However, it is likely to involve a number of intermediate technologies with the critical differentiators being whether a conventional ICE is present (and the use to which it is put), whether it can be plugged in and the extent to which an electric battery is used. The main vehicle types can be described as follows:

- Micro-hybrid Vehicle (MHEV): A vehicle with an ICE and a start-stop system that shuts down the engine when the vehicle is stopped and restarts the engine when the vehicle begins moving.
- Hybrid Electric Vehicle (HEV): A vehicle with an ICE and battery-powered electric motor that assists the ICE in powering the vehicle or provides electric-only power for short distances. The battery is charged through regenerative braking and an on-board generator.

- Plug-in Hybrid Electric Vehicle (PHEV): A vehicle with battery-powered electric motor that can power the vehicle for 30 to 160 kilometres in electric-only mode. The battery is charged by plugging the vehicle into an electrical outlet. An on-board generator (a small ICE) powered with fuel recharges the battery to extend its driving range. This is sometimes called a range-extended electric vehicle.
- Electric Vehicle (EV): A vehicle with a battery-powered electric motor that is charged through an electric outlet. In some cases, the battery can be exchanged for a fully-charged battery.
- Fuel Cell Electric Vehicle (FCEV): Any of the above vehicles with an electric motor that is powered by a hydrogen-powered fuel cell either directly or through a battery.

The significant differences between each vehicle type are summarised in Table 1 below.

Table 1: Different Types of Electric Vehicles

Vehicle Type	Abbreviation	Internal Combustion Engine	Electric Battery	Plug In
Micro Hybrid	MHEV	✓	✗	✗
Hybrid	HEV	✓	✓	✗
Plug-In Hybrid	PHEV	✓	✓	✓
Electric Vehicle	EV	✗	✓	✓

Source: The Aecom Consortium

4. Key Drivers Towards Electrification

4.1. The penetration rate of electric vehicles (EVs) in Ireland's road traffic fleet will be largely dependent on:

- The high level targets set by the EU for the reduction of emissions and CO2;
- Government intervention, in the form of subsidies and reductions in tariffs, to enable the domestic EV market to attain critical size quickly;
- The precise technology paths adopted by the automotive industry worldwide; and
- The natural turnover rate of the fleet i.e. the rate at which new cars are sold.

4.2. As already explained, European emissions targets out to 2020 have already been set, thereby setting the general glide path towards lower fleet emissions throughout Europe. Not all of the cleaner vehicles, however, will be electric – micro hybrids, for instance, are currently achieving very low emissions ratings.

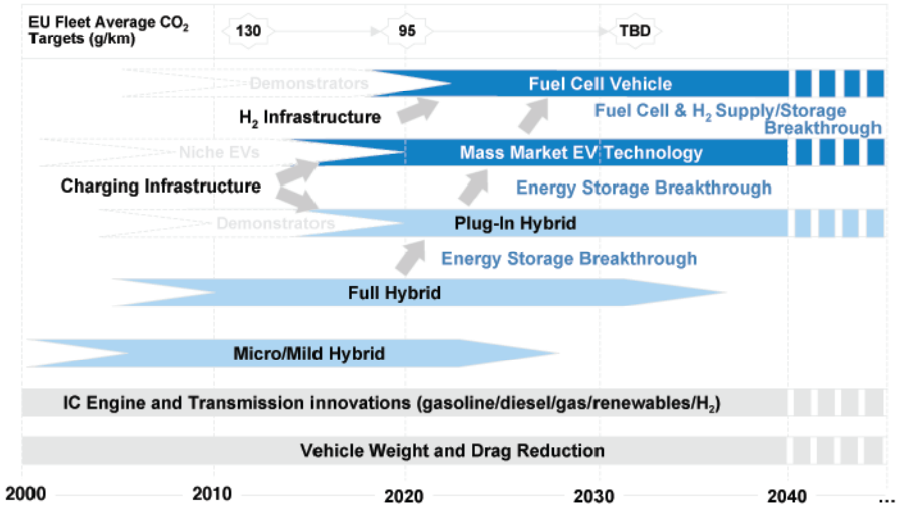
The proportion of EVs in future fleets will be dependent on the extent of government intervention and the technology mix employed by car manufacturers. Irish Government subsidies and reductions in tariffs were initially designed to offset the higher upfront costs of EVs and to position Ireland as a European leader in electric transport. However, these have since been broadly matched by other European countries. With this comparative advantage negated, there is little scope for the penetration rate of EVs in Ireland to deviate much from the European average. It follows, therefore, that the eventual penetration rate of EVs in Ireland will be principally determined by the technology path eventually adopted by the car industry in Europe and worldwide.

Alternative Technology Path

4.3. In May 2009, the New Automotive Innovation and Growth Team (NAIGT) in the UK used a Technology Roadmap, as shown in Figure 1 below, to illustrate the roles to be played by the alternative technologies and infrastructures in the development of the road vehicle market over the next 20 to 30 years.

4.4. The Report highlighted how evolutionary changes within existing technologies (e.g. changes in vehicle weight and drag reduction, and innovations in internal combustion engines, represented in the diagram above by the lower two bands) would have to run in parallel with step changes in technology (e.g. hybrids, mass market EVs and fuel cell vehicles as represented by the upper bands) to deliver on longer-term CO2 targets. Significantly, however, in the near to medium term, the greater reliance is likely to be placed on the evolutionary changes within existing technologies as the benefits, though moderate, apply to such a large proportion of the fleet and require minimal changes in consumer behaviour and purchasing patterns. The most significant short-term reduction in fleet average CO2 is therefore likely to be delivered by improvements in conventional powertrains and transmissions.

Figure 1: NAIGT Alternative Technology Roadmap



Source: NAIGT

4.5. Widespread uptake of electric vehicle technology would certainly make the long-term CO2 targets easier to achieve but the introduction of increasing levels of hybridisation and electrification is critically dependent on the availability of smaller batteries with higher energy densities and lower cost. Estimates vary but industry sources consider that it will be 2018 before the key metrics of kWh/kg and €/kWh have fallen to levels whereupon they can compete on a sustainable basis with conventional technologies, unsupported by government intervention. In the meantime, the "range anxiety[1]" issues currently associated with electric vehicles are likely to persist, further delaying their mass penetration of the road vehicle fleet.

5. Forecasted Penetration Rates – Targets and Predictions

5.1. Estimates of the rate at which electric vehicles are like to penetrate road vehicle fleets vary by country and by car manufacturer but the following gives a flavour of expected penetration rates worldwide:

- Japan: The trend towards electrification is strongest in Japan. Official projections suggest that next-generation[2] vehicles would make up fewer than 20 per cent of new passenger car sales in 2020 and 30 to 40 per cent in 2030;
- US: According to Nissan, for example, electric vehicles are likely to be 10 per cent of the 2020 U.S. market with oil prices likely to be the dominant driver of this increased penetration;
- Europe: Germany expects annual EV sales of 250,000 by 2020 by which time there should be 1m EVs on the road; and

[1] Depending on the actual source used, up to 98% of all journeys are reported to be 160 kilometres or less. This range is certainly within the compass of most EV's at present, but the "anxiety" relates to the remaining 2%.

[2] "Next-generation vehicles" are described by the Japanese Ministry of Economy, Trade and Industry as including hybrid vehicles (HV), electric vehicles (EV), plug-in hybrid vehicles (PHEV), fuel cell vehicles (FCV), clean diesel vehicles CDV) and compressed natural gas vehicles(CNGV) and others.

- Ireland: The Irish Government's target is for 10 per cent of Ireland's vehicles to be electric (Battery or PHEV) by 2020;

5.2. This assimilation of EVs into the traffic fleet should allow sufficient time for the necessary recharging infrastructure to be put in place.

6. Performance Characteristics

6.1. Whereas the CO_2 emissions for internal combustion engines are relatively well defined for each vehicle make and model, EV emissions are much more variable, because their carbon emissions are directly related to the mix of power generation by the relevant country. Studies[3] have suggested that net EV emissions range from about 12 g/km or CO_2 in France to almost 200 g/km of CO_2 in China. The UK value is 75g/km of CO_2. The work effectively highlights that, where there is limited clean energy production (such as that which currently exists in China), that the use of EV's can lead to increases in CO_2 emissions.

6.2. Ireland's first electric vehicles, to be launched in 2011 and 2012, will be "fully functional" cars, with a range of approximately 160 kilometres and top speeds in excess of 130 kph. At first inspection, they will be indistinguishable from other cars in the fleet – however, they will be less noisy, having neither an internal combustion engine nor an exhaust. Because of the 'range anxiety' problem, they are likely to appeal to two-car (and therefore high-income) families. They are also expected to gain a lot of traction with short-haul delivery fleet owners.

6.3. Nissan is launching its new, all-electric, five-seater LEAF hatchback in February 2011 with the first private customer in Europe coming from the south of Ireland. Renault hopes to launch its light commercial electric vehicle, Kangoo Z.E., later in the year. By the end of 2011, Renault will also supply 100 pre-production Fluence Z.E.s for a pilot project in Ireland. The Fluence Z.E. is an electric saloon car for both private and professional use and will go on sale in Ireland in 2012.All three vehicles will be fitted with the latest generation of lithium-ion batteries produced by Automotive Energy Supply Corporation (AESC), a joint venture between Nissan, NEC and NEC Tonkin.

6.4. The specification, performance and guided price for the electric models planned for the Irish market are shown in Table 2A.

[3] "Your new electric car emits 75 gCO2/km (at the power station)": Econometrica : March 21011

Table 2: New and Upcoming Electric Vehicles in Ireland – Sourced from various websites

		Make & Model	Vehicle Type:	Seating capacity:	Top speed kph:	Range in km:	Motor Output:	CO2 Emissions	Recharging Method	Available in Ireland	RRP Price in Euro:	Battery Lease
		Renault Fluence ZE	Family Saloon	5	135	160	70 kW (95 hp)	71 g/km	6 to 8 hours for a complete standard recharge.	Autumn 2012	Comparable to an equivalent diesel, after deduction of state subsidies.	
		Renault Kangoo Van ZE	Light Commercial Vehicle	2	130	160	44 kW (70 hp)	93 g/km	6 to 8 hours for a complete standard recharge.	Autumn 2011	RRP: €20,000 exc. VAT (€15,000 incl. Govt grant)	€72/month (4 years, 9K miles p.a.)
		Renault Zoe Preview	Compact 5-door hatchback	5	135	160	60 kW (80 hp)	73 g/km	Standard: 6 to 8 hrs; Quick: 30 mins complete;	Autumn 2012	Comparable to an equivalent diesel, after deduction of state subsidies.	
		Renault Twizy	Urban two-seater	2	75	95	15 kW	32 g/km	3hrs. 30mins. for full recharge	January 2012	Roughly equivalent to that of a three-wheeled scooter.	Similar to a smartphone contract.
		Nissan Leaf	Family Car. 5-seater hatchback.	5	140	160	80 kW	Advertised as having "No CO2 Emissions"	Quick: 80% capacity in 25 mins.	February 2011	€29,995 - €34,995 Less Govt grant of €5,000 - Includes battery	Average running costs of €232* pa

7. The Nationwide Recharging Infrastructure

7.1. Ireland can be considered an ideal location for EVs from a number of perspectives:

- The population is concentrated in a few urban centres with limited range / distance between them;
- It has high levels of single family dwellings;
- It has a high level of Government commitment to the electrification of road vehicles;
- It has a single electricity network company, thereby simplifying the installation of a recharging infrastructure. All electricity suppliers are allowed sell through this EV charging infrastructure;
- It has, and is continuing to target, high levels of wind generation. Night time charging would therefore be very clean;
- It has an ideal climate for batteries; and
- It is a leader in the IT sector making it easier to address problems such as differentiated charging (e.g. by time of day, by supplier) etc.

7.2. While efforts have been made to achieve uniformity in the design of recharging posts and electrical sockets and plugs for EVs throughout Europe, a uniform standard has not been reached. Fundamental differences exist, for example, as regards whether or not the plug should have a signal pin and shutters. In the meantime, individual countries are pressing ahead with their own plans to install a nationwide recharging structure. In Ireland, this will comprise of:

- Public On-Street Standard Charging Points;
- Public On-Street Fast Charging Points; and
- Domestic Standard Charging Points:

7.3. ESB has responsibility for the provision of Ireland's EV network and is generally of the opinion that these problems can be overcome in an Irish context. It expects that more than 30,000 on-street charge points will be required to meet the Government's 10 per cent EV target by 2020. In addition, 29 fast charge spots will be located along Motorway and National Primary routes, approximately 60km apart. Current estimates suggest that controlled charging of 250,000 vehicles would have minimal impact on the electricity grid on an average day.

7.4. If the technology pathway evolves in the long-term more towards fuel cell rather than electric vehicles, the provision of the necessary hydrogen infrastructure may present greater difficulties in terms of production, distribution and storage. Hydrogen is very low density (i.e. a big tank is required) and can evaporate easily unless in solid form – however, extreme heat is then needed for its distribution giving rise to safety issues.

8. Infrastructural Needs

8.1. As the performance characteristics of electric vehicles are very similar to those of internal combustion engines, they should be assimilated easily into existing road traffic as it travels through the road and motorway network.

For example, no change in traffic speed is anticipated and there should be minimal changes, if any, in traffic congestion. A much greater impact is likely to relate to the design, number and location of service areas as cognisance needs to be taken of the differences between the recharging needs of electric vehicles and the refuelling needs of internal combustion engines. Some safety aspects and possible changes in technology should also be kept in mind.

Changes in the Design of Service Areas

8.2. The design of service areas, and also of the approach lanes to them, is likely to be impacted for the following reasons:

- **Time taken to Re-Fuel:** Most vehicles on the road today can take a full tank of fuel on board in 3 to 5 minutes. Provision would have to be made for average recharging times of 20 to 30 minutes in the case of electric vehicles;
- **Size and Layout of Service Areas:** Electric recharging posts must be remote from, rather than alongside, fossil fuel pumps, effectively creating the need for a separate service-point bay. In addition, fast-charging service posts are not as compact as standard chargers and can require additional housing. Service areas must therefore be able to accommodate this larger size and layout requirement. It should be relatively easy to incorporate this into the design of new service areas along motorways. However, it could present significant problems for some existing service stations;
- **Capacity:** As electric vehicles take longer to charge, more individual charging posts are needed in service areas if it is hoped to process the same number of vehicles in a given time period. Consideration of this point alone would justify larger parking bays within service areas and could also create a need for longer approach lanes to them;
- **Increased Concentration of Re-Fuelling Times and Locations:** Existing vehicles, with tank capacity for journeys of approximately 500 kilometres, enjoy considerable latitude as regards both the timing and location of their next re-fuelling stop. However, the re-fuelling ‘window’ is disproportionately reduced for electric vehicles. For instance, consider the likely recharging pattern for a large cohort of commuters planning to depart Dublin for Cork prior to morning rush hour. The majority of them are likely to charge their EVs overnight, depart Dublin at approximately the same time and therefore run out of charge at approximately the same time and distance from Dublin. This would place a very uneven load on service stations 120 to 160 km distant from Dublin, creating additional risks of lengthy queues and / or ‘no power’ breakdowns. The situation would be seriously exacerbated where departure times from Dublin are condensed into even tighter time periods as might occur in the case of major sporting fixtures. These constraints on scheduling charging times and locations could potentially create a need for longer approach lanes to service stations and could also lead to traffic bottlenecks on major routes.
- **Changed Content within Service Areas:** Given the longer recharging time for electric vehicles, greater consideration needs to be given to the safety and needs of drivers and passengers.

For example, should new and existing service areas, whether on busy and remote routes, be canopied and have dedicated safe areas for children?

Changes in the Number and Location of Service Areas

8.3. The number and location of service areas may be impacted, as the maximum driving range on a single load is shorter for electric vehicles than for those powered by fossil fuels. Careful consideration should also be given to the minimum required distance between recharging service areas. How this is interpreted is likely to change over time and it should therefore be actively monitored and assessed. Reliable information on it can only be built up on a phased basis according as owners of electric vehicles reveal their initial recharging preferences before finally settling on a more fixed pattern of behaviour. The network of service areas (i.e. the number, location and distance between stations) will evolve in accordance with changes in the following factors:

- **Changes in Battery Technology:** Rapid advances are currently being made in the size, power, storage capacity and cost of batteries. Apart from being one of the critical determinants of the overall uptake of electric vehicles, these advance also have direct implications for the network of service areas;
- **Observed Recharging Patterns by Vehicle Users:** Unlike conventional fuels, electric vehicles can be charged in a variety of locations – at home at night, at street-side charging posts or in office, shopping centre or restaurant car parks etc. As yet, there are no clear indications as to what proportion of total recharging needs will be done in road or motorway service stations or how the overall pattern of recharging behaviour will emerge[4].
- **Perceived problems over "range anxiety":** These are likely to diminish as users become more familiar and comfortable with the actual capacity of their batteries and according as they become more acutely conscious of their own driving patterns;
- **The Transition to Mass Market:** Early adopters of electric vehicle technology may be more willing to confine their journeys to those involving shorter distances only, with a consequently decreased need for official recharging stations. However, as electric vehicles become more of a mass market phenomenon, there may be a need for more service areas, particularly those offering fast charging facilities; and
- **"Power Shortages":** "Power shortage" breakdowns, which are often preceded by the vehicle going into 'creep mode', could present a hazard along roads and motorways. The incidence of these should decrease as users gain a greater understanding of their recharging needs and as battery technology advances.

Changes in Electrical Standards and Safety Aspects

8.4. As previously explained, manufacturers of electric vehicles and recharging facilities have failed to reach agreement on a uniform set of electrical standards.

[4] In Japan, for instance, fast charging service posts were initially placed on motorways outside towns to cater for long distance journeys. However, it was quickly observed that motorists went out of their way to drive to them simply because they understood that they were there.

As a result, the precise technology to be deployed is still in the balance. In the light of the Government's stated objective of being to the forefront of the electrification of transport in Europe, ESB has placed a small number of equipment orders for product testing purposes. While material changes in the technology to be used in the first phase of electrification are unlikely to occur at this stage, it is important that the NRA should stay abreast of any developments.

8.5. ESB has, in the past, drawn attention to some safety issues associated with "Fast Charging". These generally relate to heat management and electrical safety rather than battery chemistry. Current indications are that these issues seem to have been addressed.

8.6. Breakdowns, due to lack of charge, could present safety issues, particularly on motorways. Consideration may have to be given to the deployment of mobile fast-charger trucks (possibly using combustion-based recharging facilities), in the event of significant EV penetration of the road vehicle fleet.

8.7. Additional road markings may be required in certain areas to ensure designated recharging posts are not otherwise occupied.

9. Implications for the NRA

9.1. Government policy initiatives favouring the electrification of transport have intensified since April 2009, and this pattern is likely to continue in the future. As the on-road performance of electric vehicles is very similar to internal combustion engines, the impact on the actual road and motorway network itself should be minimal. However, the advent of electric vehicles could have a major impact on the infrastructure supporting the road and motorway network, specifically in relation to the provision of, approach to, and design of service stations and areas, be they existing or new.

Liaison on Electrical Design, Technology and Standards

9.2. A lot of progress has been made since the appointment of a single electricity network distributor for the recharging system (ESB) and it is strongly recommended that the NRA keep in close liaison with them. The road-map towards the installation of a full nationwide recharging grid is not at all clear for a number of reasons - for example, there has been immense reluctance to agree uniform electrical standards throughout Europe for basic items such as charging pins and sockets and the standard and fast charging units themselves are only emerging from the embryonic stages of development. The NRA needs to keep itself abreast of new developments in these areas.

Issues in Relation to Location of Service Areas

9.3. The precise location of standard and fast charging stations could have immediate and direct relevance for the NRA in so far as they could lead to blocked lanes or traffic bottlenecks. The situation needs to be kept under immediate and constant review as more information is gained on likely charging patterns both here and abroad.

9.4. The suitability of existing service areas should be reviewed with particular emphasis on approach lanes, size, layout and services.

Coordination, Communication and Integration

9.5. **Coordination of Incentives vs displacement / problems:** Unless pressurised by excessive financial incentives, a rational motorist will not buy electric vehicles or undertake journeys in them beyond the point where the on-road fleet can be recharged without undue delay – i.e. in the ordinary course of events, motorists will try to avoid queues to recharge vehicles. However, such congestion could arise if the price incentives are increased to ensure compliance with CO2 targets. The NRA should therefore monitor Government policy developments in this area.

9.6. **Variable messaging systems:** The solution to the 'range anxiety' problem may well lie in the extent to which motorists' fears about charge shortages can be allayed. While the longer term solution involves advances in battery technology, the problem could be partially allayed in the interim by the provision of real-time information on the proximity and availability of recharging posts. The variable messaging system may consequently need to be upgraded.

9.7. **All-Island Integration:** Notwithstanding the difficulties associated with agreeing uniform electrical standards throughout Europe[5], it is hoped that an integrated recharging network will exist throughout the island of Ireland. Agreement on the location of charging points in the Border counties may be an issue in this respect.

[5] For example, domestic sockets in Britain must have a shutter while there is no similar requirement in Ireland. This incompatibility seems to have a relatively simple solution. Issues also arise in relation to other matters such as currency exchange, metering etc. but these do not seem to have a direct relevance for the NRA