WHAT SHAPE WILL THE VEHICLE OF THE FUTURE TAKE?

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ABSTRACT

The first mass produced car was the Ford Model T in the early 1900s. Since then, vehicle shapes have evolved in different forms by various manufacturers and designers around the world. It has been found that with the availability and cost of fuel, the engine and vehicle sizes have increased rapidly and the type of environment can determine the shape of vehicles.

One prominent factor for individuals and organisations when making a decision on the type of private or commercial vehicle to buy is the purpose of the vehicle (e.g. family car, sports car, convenience, utility etc.). This correlates to the size of the vehicle - engine, storage capacity, head-room. For example, the shape, aerodynamics and noise of a Ferrari tends to attract a special type of consumer. From manufacturing to scrappage any single vehicle creates a high level of waste material throughout its lifecycle. This can accumulate to a vast quantity of energy consumption, use of raw materials and high volume of non-recyclable materials.

In terms of the vehicle of the future, as the supply of fuel will diminish over the years ahead and although electric vehicles are being promoted and incentivised, alternative sustainable fuel types will enter the market - such as rape seed oil and bio-diesel. In that respect it is proposed that this paper will open the discussion and thinking for various scenarios for shapes of the vehicle of the future.

1 INTRODUCTION

This paper aims to present an understanding of how the shape of a vehicle will be developed in the future. To answer this question, we must first look back to the past and discuss the devolvement of vehicles over the last 240 years.

2. THE BEGINNING

In the beginning man transported people and goods by hand then by horse and cart.

The first vehicle to be used to transport people was a three wheeled steam powered vehicle designed by Nicolas Joseph Cugnot in 1769.

He also designed a steam powered tricycle which could carry up to 3 people.

The Cugnot vehicle used steam as its power source which is known in technical terms as the external combustion engine, which means that combustion takes place outside of the pistons.

The disadvantage of the steam engine (external combustion engine) at this time, was that, the
vehicle was too heavy and had to stop every few minutes to re-pressurize. The steam engine had a maximum speed of 4km per hour, so the steam engine vehicle, was not suited to road travel, but is more suited to powering factories (stationary engines). Railway engines and powering ships. Over the years the steam engine has been developed in these areas.

The internal combustion engine was invented by Isaac Rivaz in 1806. This is where combustion takes place directly on the piston.

It was not until the year 1877 that Nikolaus Otto developed the internal combustion engine, so it was suitable for use in the motor vehicle.

Anderson’s electrical vehicle, was powered by “primary batteries” (non rechargeable). It was Thomas Davenport and another Scotsman Robert Davidson, who developed the electric vehicle, using “secondary batteries” (i.e. rechargeable type). In the 1840’s.,

During the 1870’s and 1900’s both the electric and the internal combustion powered vehicles, were been constantly developed, to gain the attention of the general public. Around this time the electric vehicle was winning this race. The electric vehicle operates in the following way. Electricity stored in the batteries, is connected to the electric motor, through some form of switching systems. The motor in turn is connected to the road wheels, driving the vehicle.
Figure 7 shows a simple system which makes the electric vehicle very popular due to following various factors.

i. No need to cranked it to get the system to start;

ii. Small number of parts;

iii. Very quiet.;

iv. Very clean.

![Figure 7 A simple electric vehicle power system](image)

Both types of vehicles had to overcome various problems to do with the steering system as shown in Figure 8. This shows the pivot or fifth wheel type steering system found on early vehicles due to the increase in the speed. This type of steering could not control the vehicle. This caused a lot of deaths and injuries. The same problem was caused by the brake system which again was only designed to stop a horse drawn carriage.

![Figure 8. Pivot steering [6]](image)

In the early years the brake system was just a simple wooden block forced against the outside of the rim of the wheel as in Figure 9.

![Figure 9 Early braking system](image)

With reference to Figure 5, we can see that both internal combustion powered and electric powered vehicles are just horse drawn vehicles, with the new power systems, fitted to the existing vehicles hence the name “horseless vehicle”.

This led to problems due to bad steering and brakes, because of the increase in speed, as the first horseless vehicles only had the steering and brake systems which existed at this time.
One drawback of the electric vehicle is its range. Early electric vehicles only had a range of about 15 to 20 kilometres. This meant it was only suited to town driving. So in New York the first real commercial use of the electric vehicles was the setting up of a fleet, of electrical taxis, one of which is shown in Figure 10.

At this time, the electric vehicle out sold all other vehicles, but this was not to last too long, due to new developments in the vehicles systems the internal combustion powered vehicles, and the reduced cost of fuel. The Automobile (as it was now called) got the interest of the general public.

This was assisted by the low price and availability of petrol and diesel

3. THE PRESENT

From 1920 many manufacturers decided to design and manufacture various types of vehicles from light vehicles, heavy commercial vehicles, farm vehicles, off-road vehicles and construction vehicles.

When we look at the light vehicle, we can see that the shape of the vehicle has roughly stayed the same since the Ford Model T, (i.e. four wheels, front / rear mounted engine front /rear wheel drive) with the steering wheel on the front left or right hand side. This shape of vehicle has a minimum size based on four persons occupying the vehicle plus some luggage space.

Most manufacturers achieved this by the use of a standard design platform and H-points as shown in Figure 11.

![Figure 11 Different models of the Ford model T](image1.png)

Vehicle manufacturers have modified body shapes as shown in Figure 12. The only real changes that have occurred are to the vehicle systems which are under the body work.
One of the main innovations that has taken place is in relation to existing vehicle systems is the ignition systems. It is now controlled electronically, but the way in which the fuel is ignited has remained the same. The carburettor has been replaced with fuel injection systems, which are also electronically controlled. There are many extra accessories and gadgets that have been added to the modern vehicle to assist in the comfort and safety of the driver and passengers. This also helped manufacturers to market their vehicle, to achieve a large market share in the sales of vehicles, worldwide.

Manufacturers have now turned their attention to the effect that the modern vehicles has on the environment, due to public concerns, and national and international policies and regulations. The modern vehicle has had a large impact on daily life, and the environment. The effects the modern vehicle has on the environment starts from the design process and finishes when the vehicle is scrapped.

Data from the Irish Central Statistics Office indicates that,

- According to latest figures there were 2,283,971 new cars registered in Ireland between 1998 to 2009; (CSO 1982-2009). [10]
- The life of the modern car is 10 years;
- Mass of the average vehicle is 1000 kg (1 tonne);
- 80% of the average vehicle is manufactured from metal;
- During it’s life it travels approximately 16,000 kilometres per year;
- Average fuel consumption is 1lt per 10 kilometres, when moving;
- This means that the average automobile uses 16,000 litres of fuel in its life time; Most vehicles today are powered by the internal combustion engine. The internal combustion engine only converts 27% - 30% of the energy stored in the fuel which it burns. This means that up to 70% is wasted. Making the internal combustion engine very inefficient. This means that in Ireland we waste 372715.0159 litres per day (at a efficiently of 33%) at a cost of € 540102.9984 per day.
- On top of this we can add on the energy used to manufacturer each vehicle is 25600mj.
- It’s effect on the environmental each vehicle produces 8344366.027 litres of exhaust fumes and is used to transport an average of 1 person of which is only 1/12 of the total weight of the vehicle from A to B.
- Number of people employed in the motor industry in Ireland in 2009 was 35,000b [11].

4. WHAT SHAPE WILL THE VEHICLE OF THE FUTURE TAKE?

In terms of the vehicle of the future, as the supply of fuel will diminish over the years ahead we will have to answer the following questions:

- What will power this vehicle (as we are running out of natural fuels)?
- The uses in which this vehicle will be used?
- Does everyone need a vehicle?
- What price are we willing to pay?
- Do we need such large vehicles as most private vehicles are being used to transport one person to and from work?
- What effect will any changes have on the motor industry in terms of job creation and maintaining jobs?

Although electric vehicles are being promoted and incentivised, all that most vehicles manufacturers are doing at the moment is using the normal body shell and adding an electric transmissions system. Alternative sustainable fuel types have entered the market such as rape seed oil and bio-diesel. This is
just replacing one fuel with another, but the vehicle stays the same.

The vehicle of the future may require a whole new revised design in terms of body shape and power transmission and this may be a very daunting task which will require a new way of thinking by designers and manufacturers.

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REFERENCES


ELECTRIC VEHICLES: INFRASTRUCTURE REGULATORY REQUIREMENTS

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ABSTRACT

In 2009 the European Union (EU) Directive on Renewable Energy placed an obligation on each Member State to ensure that 10% of transport energy (excluding aviation and marine transport) come from renewable sources by 2020. The Irish Government intends to achieve part of this target by making sure that 10% of all vehicles in its transport fleet are powered by electricity by 2020. Stakeholder groups include but are not limited to policy makers, the public, regulatory bodies, participants in the electricity retail market, the transmission and distribution system grid operators, the automotive industry, private enterprise, civil engineers, electrical engineers, electricians, architects, builders, building owners, building developers, building managers, fleet managers and EV owners. Currently it appears both internationally and Nationally the automotive industry is focused on EV manufacture, governments and policy makers have highlighted the potential environmental and job creation opportunities while the electricity sector is preparing for an additional electrical load on the grid system. The focus of this paper is to produce an international EV roadmap. A review of current international best practice and guidelines under consideration or recommended is presented. An update on any EV infrastructure charging equipment standards is also provided. Finally the regulatory modifications to existing National legislation as well as additional infrastructure items which may need control via new regulations are identified.

Keywords: Charging infrastructure, electric vehicles, guidelines, regulations, standards

1 INTRODUCTION

The successful deployment of electric vehicles (EVs) over the next decade is connected to the introduction of internationally agreed EV standards, universal charging hardware infrastructure, associated universal peripherals and user-friendly software on public and private property. A number of workgroups have been formed by key organizations such as the International Energy Agency (IEA), the Society for Automobile Engineers (SAE) and the Institute of Electrical and Electronic Engineers (IEEE).

Automobile manufacturers, the electricity industry and governments have identified that EVs have the potential to reduce carbon dioxide (CO₂) emissions as well as some other pollutants associated with road transport such as particulate matter (PM), carbon monoxide (CO), oxide of nitrous (NOₓ), nitrogen dioxide (NO₂), oxides of sulphur (SOₓ), sulphur dioxide (SO₂) and volatile organic compounds (VOC), to name just a few. However if the deployment of electric vehicles (EV’s) is to be successful apart from the introduction of an international standardised engineering terminology, charging hardware infrastructure, associated peripherals and user-friendly universal software on public and private property considerable National regulatory issues must be properly considered. In generally all stakeholders are not fully familiar with these requirements. Regulatory changes include additions to current planning permission, health and safety, building and the road traffic signs regulations. Other associated legislative requirements include bylaws at a local authority level to enable a mechanism to allow the erection of charging infrastructure and associated peripherals on public property. Additional issues are the ownership of the charging hardware equipment and software, insurance and public liabilities.

The focus of this paper is to introduce the current international roadmap towards EV. A detailed review of current international best practice and guidelines under consideration or recommended is presented. An update on any EV infrastructure charging equipment standards is also provided. Finally the regulatory modifications to existing National legislation as well as additional items which may need control via new regulations are identified.
2 INTERNATIONAL GOVERNMENT & INDUSTRY TARGETS

Reference [1] provides a detailed review of over 40 studies carried out in the USA to examine the effects of EVs on well-to-wheel emissions. More recent studies, which examine potential greenhouse gas (GHG) emissions reductions from EVs include References [2, 3, 4, 5, 6 and 7]. A number of countries including some European Union (EU) member states, Japan, South Korea, Canada, China, Israel and the United States of America (USA) have established electric vehicle (EV) targets, policies and plans. EVs are supported due to potential benefits in employment via technology research and development opportunities and the manufacture and deployment of EV infrastructure. EVs are also presented as an opportunity to integrate renewable energy sources (RES), for example EV charging by wind power, which should result in a better security of energy supply by reducing oil imports. Table 1 presents some international targets adapted from References [8 and 9]. European policies on EVs are provided in Reference [10].

European policies on EVs are provided in Reference [10].

Table 1. Some International EV Target Objectives

<table>
<thead>
<tr>
<th>Country</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>2020: 100,000 EVs deployed¹</td>
</tr>
<tr>
<td>Australia</td>
<td>2012: first cars on road, 2018: mass deployment, 2050: up to 65% of car stock¹</td>
</tr>
<tr>
<td>Canada</td>
<td>2018: 500,000 EVs deployed¹</td>
</tr>
<tr>
<td>China</td>
<td>2011: 50,000 annual production of EVs¹</td>
</tr>
<tr>
<td>Denmark</td>
<td>2020: 200,000 EVs¹</td>
</tr>
<tr>
<td>France</td>
<td>2020: 2,000,000 EVs¹</td>
</tr>
<tr>
<td>Germany</td>
<td>2020: 1,000,000 EVs deployed¹</td>
</tr>
<tr>
<td>Ireland</td>
<td>2020: 10% EV market share²</td>
</tr>
<tr>
<td>Israel</td>
<td>2011: 40,000 EVs, 2012: 40,000 to 100,000 EVs annually³</td>
</tr>
<tr>
<td>Japan</td>
<td>2020: 50% market share of next generation vehicles⁵</td>
</tr>
<tr>
<td>New Zealand</td>
<td>2020: 5% market share, 2040: 60% market share⁷</td>
</tr>
<tr>
<td>Spain</td>
<td>2014: 1,000,000 EVs deployed²</td>
</tr>
<tr>
<td>Sweden</td>
<td>2020: 600,000 EVs deployed²</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>No target figures, but policy to support EVs⁸</td>
</tr>
<tr>
<td>USA</td>
<td>2015: 1,000,000 PHEV stock¹</td>
</tr>
</tbody>
</table>

Table 2 presents the latest data available with regard to a number of original equipment manufacturers (OEM) in terms of a technology roadmap [8 and 11]. The development of EVs involves two sectors, the battery manufacturers and the EV manufacturers. BMW announced in early June 2010 that it was ceasing further work on the electric mini, as it was too expensive to build and that other manufacturers were heavily subsidising their EVs and that the stage of battery development is comparable with the ICE 100 years ago [12]. BMW’s preference is for a battery swopping programme in order that drivers are not inconvenienced at charging points, such as that proposed by the Israeli Better Place company [13].

Table 2. OEM Technology Roadmap

<table>
<thead>
<tr>
<th>Car manufacturer</th>
<th>Battery manufacturer</th>
<th>Production Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>BYD Auto</td>
<td>BYD Group</td>
<td>2015: 100,000¹</td>
</tr>
<tr>
<td>Fiat-Chrysler</td>
<td>A123 Systems</td>
<td>No date, no numbers²</td>
</tr>
<tr>
<td>Ford</td>
<td>Johnston Controls-Saft</td>
<td>5,000 per annum</td>
</tr>
<tr>
<td>GM</td>
<td>LG Chem</td>
<td>2011: 10,000 &amp; 2012: 60,000³</td>
</tr>
<tr>
<td>Hyundai</td>
<td>LG Chem, SK Energy and SB Limotive</td>
<td>2018: 500,000</td>
</tr>
<tr>
<td>Mercedes-Benz</td>
<td>Continental and Johnston Controls-Saft</td>
<td>No date, no numbers⁵</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>GS Yuasa Corp.</td>
<td>2010: 5,000, 2011: 15,000</td>
</tr>
<tr>
<td>Nissan</td>
<td>AESC</td>
<td>2010: 50,000, 2012: 100,000</td>
</tr>
<tr>
<td>REVA</td>
<td>Indocel Technologies</td>
<td>No date, no numbers⁶</td>
</tr>
<tr>
<td>Renault</td>
<td>AESC</td>
<td>By 2010 150,000/annum</td>
</tr>
<tr>
<td>Subaru</td>
<td>AESC</td>
<td>2010: 100⁷</td>
</tr>
<tr>
<td>Tata</td>
<td>Electrovaya</td>
<td>No date, no numbers</td>
</tr>
<tr>
<td>Toyota</td>
<td>Panasonic</td>
<td>No date, no numbers</td>
</tr>
<tr>
<td>Volkswagen</td>
<td>Volkswagen and Toshiba Corp.</td>
<td>2011: 500</td>
</tr>
</tbody>
</table>

³ http://www.edmunds.com/greenadvis/or2010/03/bvd-auto-to-offer-f3dm- plug-in-hybrid-to-chinese-individuals-starting-next-week.html
⁴ http://green.autoblog.com/2010/03/22/chrysler-500ev-all-electric-fiat-500- for-us/

3 RELEVANCE & ROLE OF STANDARDISATION

In the next decade the automobile industry and the electricity sector will undergo a series of evolutionary changes. Reference [8] examines this EV roadmap. Automobile standards and best practice have developed over time, initially to
improve safety to acceptable low injury and fatality rates, to avoid litigation and costly recalls, next during the oil crisis of the seventies the Europeans and the Asians particularly became very energy conscious so manufacturers developed more efficient ICE, unlike in North America where oil was cheaper at the pump and then in the eighties air pollution and more recently GHG emissions resulted in tougher government standards to reduce ICE emissions. The drive to electrify transport will result in countries forming new trading alliances and partnerships to ensure the success of their technology. Standards may be used as tools in countries gaining a competitive advantage. The addition of new players and the changing role of existing players will see a massive change in the hitherto status quo of car manufacturing. The electricity sector is a different beast to the automobile industry with its own set of standards and regulations, which vary hugely from country to country and even within a country.

Perhaps unlike the automobile industries traditional reaction to events to mitigate costs and recalls, the rigid approach of the electricity sector because of the nature of power may result in standardization taking more of a front seat. Either way the ‘EVlotion’, will make for a very interesting 10 years for the engineers involved. In October of 2009 European electricity companies called for the standardization of EV charging infrastructure and pledged to apply pre-standards [14].

### 3.1 EV Standards

The main centre of activity in standardization development appears to be in USA and Japan with slower progress in the EU. References [8, 15 and 16] discuss EV technology development. Table 3 provides details of some relevant SAE and the American National Standards Institute EV standards and their status.

#### Table 3. Selected SAE Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFPA 70 NEC/ANSI, Article 625 – Electric Vehicle Charging Equipment</td>
<td>Published January 1996, WIP January 2011</td>
</tr>
<tr>
<td>SAE J-1715: Hybrid Electric Vehicle (HEV) and Electric Vehicle (EV) Terminology</td>
<td>Issued and cancelled October 2002</td>
</tr>
<tr>
<td>SAE J-2293 Part 2: Energy Transfer System for EV Part 2: Communications Requirements and Network Architecture</td>
<td>Published but in review stage to be revised</td>
</tr>
<tr>
<td>SAE J-2847 Part 3: Communication and the Utility Grid</td>
<td>Published October 2009</td>
</tr>
</tbody>
</table>

Table 4 provides details of some relevant Deutsches Institut für Normung e. V. (DIN) EV standards and their status.

#### Table 4. DIN STANDARDS

<table>
<thead>
<tr>
<th>Standard</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIN V VDE V 0510-11 (VDE V 0510-11) Safety requirements for secondary batteries and battery installations - Part 11</td>
<td>Published October 2009</td>
</tr>
<tr>
<td>DIN 43538 Monobloc batteries for electric vehicles; low maintenance types, rated capacities, main dimensions</td>
<td>Published but in review stage to be revised</td>
</tr>
</tbody>
</table>

Table 5 provides details of some relevant International Electromechanical Commission (IEC) EV standards and their status.

#### Table 5. Selected ISO Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 6469-1:2009 Electrically propelled road vehicles - Safety specifications - Part 1: On-board rechargeable energy storage system (RESS)</td>
<td>Published October 2009</td>
</tr>
<tr>
<td>ISO 6469-3:2001 Electric road vehicles - Safety specifications - Part 3: Protection of persons against electric hazards</td>
<td>Committee stage, voting and comments stage closed</td>
</tr>
<tr>
<td>ISO/CD 8713 Electric road vehicles - Vocabulary</td>
<td>Review stage closed</td>
</tr>
<tr>
<td>ISO 8714:2002 Electric road vehicles - Reference energy consumption and range - Test procedures for passenger cars and light commercial vehicles</td>
<td>Enquiry stage but voting closed</td>
</tr>
<tr>
<td>ISO/DIS 12405-1 Electrically propelled road vehicles - Test specification for lithium-ion traction battery systems - Part 1: High power applications</td>
<td>Preliminary stage, proposal for new project received</td>
</tr>
<tr>
<td>ISO/AWI 12405-2 Electrically propelled road vehicles - Test specification for lithium-ion traction battery systems - Part 2: High energy applications</td>
<td>Preliminary stage, proposal for new project received</td>
</tr>
</tbody>
</table>

Table 6 provides details of some relevant International Electromechanical Commission (IEC) EV standards and their status.

#### Table 6. Selected IEC Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric vehicle conductive charging system - Part 1: General requirements</td>
<td>Published October 2009</td>
</tr>
<tr>
<td>Plugs, socket-outlets, vehicle couplers and vehicle inlets - Conductive charging of electric vehicles - Part 1: Charging of electric vehicles up to 250 A a.c. and 400 A d.c. (IEC 23H/222/CD:2010)</td>
<td>Published October 2009</td>
</tr>
<tr>
<td>Plugs, socket-outlets, vehicle couplers and vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories (IEC 23H/222/CD:2010)</td>
<td>Published October 2009</td>
</tr>
<tr>
<td>Future IEC 62196-3: Plugs, socket-outlets, and vehicle couplers - conductive charging of electric vehicles - Part 3: Preparation Dimensional interchangeability requirements for pin and contact-tube coupler with rated operating voltage up to 1000 V d.c. and rated current up to 400 A for dedicated d.c. charging</td>
<td>Published October 2009</td>
</tr>
</tbody>
</table>
Table 7 provides details of some relevant Japan Electric Vehicle Association Standards (JEVS) EV standards, which are all published.

It is obvious from these tables that there are many participants, technical committees and groups internationally. Thus there is much duplication. This was referred to as a ‘tsunami of codes and standards’ by Steven Rosenstock of Edison Electric Institute at the IEEE P1809 Kickoff Meeting on EVs in February [17].

### 3.2 EV Charging Infrastructure

It is important that there is a merging of standards and charging technology so that charging infrastructure is common, customers are comfortable with the technology and manufacturing costs are reduced. Already there exist different plugs, two charging terminology, ‘level’, which is used in the North America mostly and ‘mode’ used by the European based standards organizations. Interestingly, level is used widely in Europe. Earthing requirements also vary. Some EV manufacturers (i.e. Ford, General Motors, Volkswagen, Fiat, Toyota and Mitsubishi) agreed on a common, apparently 3-point (live, neutral and earth) plug standard for charging EVs in April 2009. In the EU there is the multiphase ‘Mennekes’ plug and the Électricité de France (EDF) single-phase or three-phase plugs, which involves Nissan and Renault. Figure 1 shows some of the plugs and sockets.

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### Table 7. Selected JEVS Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C601:2000</td>
<td>Plugs and receptacles for EV charging</td>
</tr>
<tr>
<td>D701-1994</td>
<td>Capacity test procedure of lead-acid batteries for EVs</td>
</tr>
<tr>
<td>D702-1994</td>
<td>Energy density test procedure of lead-acid batteries for EVs</td>
</tr>
<tr>
<td>D703-1994</td>
<td>Power density test procedure of lead-acid batteries for EVs</td>
</tr>
<tr>
<td>D704-1997</td>
<td>Cycle life test procedure of valve regulated lead-acid batteries for EVs</td>
</tr>
<tr>
<td>D705:1999</td>
<td>Capacity test procedure of sealed nickel-metal hydride batteries for EVs</td>
</tr>
<tr>
<td>D706:1999</td>
<td>Energy density test procedure of sealed nickel-metal hydride batteries for EVs</td>
</tr>
<tr>
<td>D707:1999</td>
<td>Specific power and peak power test procedure of sealed nickel-metal hydride batteries for EVs</td>
</tr>
<tr>
<td>D708:1999</td>
<td>Cycle life test procedure of sealed nickel-metal hydride batteries for EVs</td>
</tr>
<tr>
<td>D709:1999</td>
<td>Dynamic capacity test procedure of sealed nickel-metal hydride batteries for EVs</td>
</tr>
<tr>
<td>E701-1994</td>
<td>Combined power measurement of electric motors and controllers for EVs</td>
</tr>
<tr>
<td>E702-1994</td>
<td>Power measurement of electric motors equivalent to the on-board state for EVs</td>
</tr>
<tr>
<td>G101-1993</td>
<td>Chargers applicable to quick charging system at Eco-Station</td>
</tr>
<tr>
<td>G102-1993</td>
<td>Lead-acid batteries applicable to quick charging system at Eco-Station for EVs</td>
</tr>
<tr>
<td>G103-1993</td>
<td>Charging stands applicable to quick charging system at Eco-Station for EVs</td>
</tr>
<tr>
<td>G104-1995</td>
<td>Communications Protocol Applicable to Quick Charging System at Eco-Station</td>
</tr>
<tr>
<td>G105-1993</td>
<td>Connectors applicable to quick charging system at Eco-Station for EVs</td>
</tr>
<tr>
<td>G109-2001</td>
<td>EV inductive charging system: General requirements</td>
</tr>
<tr>
<td>G901-85</td>
<td>Nameplates of battery charger for EVs</td>
</tr>
<tr>
<td>Z101-87</td>
<td>General rules of running test method of EVs</td>
</tr>
<tr>
<td>Z102-87</td>
<td>Maximum speed test method of EVs</td>
</tr>
<tr>
<td>Z103-87</td>
<td>Range test method of EVs</td>
</tr>
<tr>
<td>Z104-87</td>
<td>Climbing hill test method of EVs</td>
</tr>
<tr>
<td>Z105-88</td>
<td>Energy economy test method of EVs</td>
</tr>
<tr>
<td>Z106-88</td>
<td>Energy consumption test method of EVs</td>
</tr>
<tr>
<td>Z107-88</td>
<td>Combined test method of electric motors and controllers for EVs</td>
</tr>
<tr>
<td>Z108-1994</td>
<td>Electric Vehicle - Measurement for driving range and energy consumption</td>
</tr>
<tr>
<td>Z109-1995</td>
<td>EV - Measurement for acceleration</td>
</tr>
<tr>
<td>Z110-1995</td>
<td>EV - Measurement for maximum cruising speed</td>
</tr>
<tr>
<td>Z111-1995</td>
<td>EV - Measurement for reference energy consumption</td>
</tr>
<tr>
<td>Z112-1996</td>
<td>EV - Measurement for climbing</td>
</tr>
<tr>
<td>Z804:1998</td>
<td>Symbols for controls, Indicators &amp; telltales for EVs</td>
</tr>
<tr>
<td>Z805:1998</td>
<td>Glossary of terms relating to EVs (General of vehicles)</td>
</tr>
<tr>
<td>Z806:1998</td>
<td>Glossary of terms relating to EVs (Electric motors &amp; controllers)</td>
</tr>
<tr>
<td>Z807:1998</td>
<td>Glossary of terms relating to EVs (Batteries)</td>
</tr>
<tr>
<td>Z808:1998</td>
<td>Glossary of terms relating to EVs (Chargers)</td>
</tr>
<tr>
<td>Z809-1995</td>
<td>Electric Vehicle - Standard Form of Specification (Form of Main Specification)</td>
</tr>
</tbody>
</table>
Harmonization of certain aspects, particularly a universal socket and plug is vital, but this will not happen over night, rather through trial and error to ensure that the best system is achieved. It is suggested that ‘earthing’ and safety be under the remit of the electricity sector, as it is particular to each geographical areas practices and procedures. This needs attention soon. Billing and the customer graphical user interface on all public charging stations should be standard and user friendly, similar to an Automated Teller Machine (ATM) in the banking sector.

References [18 and 19] provide details of charging infrastructure in the USA and Canada. Such documents are very useful and valuable for local governments, those responsible for building regulation and permitting and property owners. It is recommended that a similar document be prepared for other regions as part of pilot schemes. Aspects which need to be examined and standardized include the following:

- Signage, layouts, access and lighting in areas where public charging is proposed,
- Public parking and bus lane usage,
- Disabled persons requirements,
- Certification of charging equipment,
- Trip hazards, liability issues and public insurance,
- Electric Code, ventilation, installation certification,
- LEED and BRE building certification requirements,
- Engineering design, construction and permitting on public and private property, including location, lighting and shelter, installation in flood zones
- Charging post ownership, maintenance and operation, metering and subscription services,
- Smart metering for home charging to control the time of charging, which can be related to costs, time of day and so forth,
- Battery swopping option,
- Vandal proofing,
- Changes to legislation, including laws, regulations and by-laws e.g. Health & Safety, Building Regulations, Road Traffic Act, Road Signs Manual and Parking By-Laws.

In addition to charging stations an Israeli company called Better Place proposes a battery swapping drive-in station [20]. Figure 2 shows a Better Place Drive-in Station.
Internationally it is expected that there will be three levels of socket charging [21, 22 and 23]. This will vary slightly from country to country depending on the voltage, frequency, transmission standards and plug standards in terms of the rating of the plug in amperes. An EV may have a higher internal electric capacity, but this will be limited by the grid connection [24]. Table 8 gives an indication of the power demand and charging options for Ireland based on the existing grid circuitry.

Table 8. Charging Options & Power

<table>
<thead>
<tr>
<th>Level (Mode)</th>
<th>Type</th>
<th>Electrical</th>
<th>Resulting Charge</th>
<th>Time to Charge</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Standard Domestic</td>
<td>230V 16A 1 or 3 phase</td>
<td>100%</td>
<td>6 to 8 hours</td>
<td>3kW to 10kW</td>
</tr>
<tr>
<td>Level 2</td>
<td>Opportunity</td>
<td>400V 32A</td>
<td>50%</td>
<td>30 minutes</td>
<td>22kW</td>
</tr>
<tr>
<td>Level 2</td>
<td>Emergency</td>
<td>400V 32A</td>
<td>20km</td>
<td>10 minutes</td>
<td>22kW</td>
</tr>
<tr>
<td>Level 3</td>
<td>Range Extension</td>
<td>400V 63A</td>
<td>80%</td>
<td>30 minutes</td>
<td>44kW</td>
</tr>
</tbody>
</table>

4 DISCUSSION & CONCLUSION

It is worth interest to note that technology development roadmap as indicated by the OEM’s is slower than the targets set by government policy targets and very recent comments by BMW in relation to the stage of development of the battery indicate some serious technology questions. This uncertainty and standardisation in charging infrastructure is perhaps one of the weaknesses of the current international government EV policies. However, this has been recognised and various working groups and steering committees have been formed.

It is suggested that the electricity sector is the stronger player in this ‘EVlotion’. Electricity companies have gone and are still going through a period of deregulation and market liberalization. In some countries certain utilities still have a dominant market position. The automobile industry has operated in a very competitive first to market environment. The marriage of these two very different sectors may see strange relationships forming.

What is the ultimate goal of the electrification of transport to truly reduce GHG emissions or just to move them from the transport sector, which is a non-emissions trading scheme (Non-ETS) sector to the electricity sector, which is an ETS sector? Is it to re-invigorate the automobile industry? Irrespective of the reason, EVs can offer alternatives to the ICE and reduce GHG. In order to measure and quantify the results, energy efficiency from the grid-to-the-battery and from the battery-to-the-wheel, driving performance and overall net reduction in GHG emissions under different driving conditions using an international standard test regime must be agreed. Studies have been carried out to estimate benefits, but it is difficult to compare them as like the ICE, no two EVs are the same and no two power systems are the same.

Pilot schemes are probably the most practical way to determine the technology solutions and standards that suits all market participants and more importantly the customer. The some EU Member States, USA, Japan, Korea, China, Taiwan and Korea, to name just a few have a variety of EV pilot projects underway. However, it is obvious from the tables of existing and proposed standards that there are many participants, technical committees and groups internationally. Thus there is much duplication.

It is important that there is a merging of standards and charging technology so that charging infrastructure is common, customers are comfortable with the technology and manufacturing costs are reduced. It is suggested that ‘earthing’ and safety be under the remit of the electricity sector, as it is particular to each geographical areas practices and procedures.

It is recommended that a charging infrastructure document be prepared as part of pilot schemes to establish best practice and share lessons learned. Items which need resolving and investigation include signage, ownership, construction, layout, management, maintenance and operation, certification, vandalism and liability and so forth. An international standard plug, socket and GUI type ATM portal for customer comfort is vital.

In summary the automobile industry and the electricity sector will undergo a series of evolutionary changes as the transport fleet is electrified. There are a number of economic and environmental benefits to the introduction of EVs, including employment in R&D, employment in
manufacturing and deployment, a reduction on fossil fuel dependency, an opportunity to better integrate renewable energy sources and ultimately ensure higher energy efficiency, better security of energy supply with an associated reduction in GHG emissions, localized air and noise pollution. The next stage of this research is to compare and contrast the various standards and prepare a charging infrastructure document for Ireland. In conclusion this paper has established the state-of-the-art in EV charging infrastructure and provided a list of existing and proposed international standards, best practice and guidelines. Finally, this ‘EVlotion’, will make for a very interesting 10 years for the engineers, scientists, policy makers and planners involved.

ACKNOWLEDGEMENTS
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PRIVATE CAR TRANSPORT AND THE 10% RES-T TARGET – QUANTIFYING THE CONTRIBUTION OF EVS AND BIOFUELS

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ABSTRACT

In 2008, renewable energy accounted for less than 1% of final energy consumption in the Irish transport sector. In order to increase this share to 10% by 2020 as required under EU directive 2009/28/EC, the Irish government has introduced two specific measures: 10% of the transport fleet is to be powered by electricity by 2020, and an obligation on road transport fuel suppliers that biofuels account for a certain portion of their fuel sales. This study forecasts the impact of these existing measures towards meeting the 10% RES-T target by 2020, focussing on private car transport. The methodology presented is derived from a forecast of private car fuel demand based on a technological stock model of Ireland’s fleet. This paper demonstrates the use of this as a tool firstly as an energy forecasting technique and secondly as a method for evaluating the effects of policy measures on the technological composition and consequent renewable energy demand and related CO₂ emissions of private cars. Technological scenarios examined in this light are electric vehicles, compressed natural gas vehicles and biofuel blending.

Keywords: Private car, transport, modelling, stock, renewable energy, policy, CNG, Electric vehicles

1 INTRODUCTION

Expanding the share of renewables in Ireland’s energy mix has been the focus of Government policy for a number of reasons. As a goal in itself, the EU has made mandatory renewable energy targets for each member state, with 16% of Ireland’s gross final energy consumption required to come from renewable sources by 2020. Furthermore, increasing the share of renewables has the benefit of contributing to the Government’s stated goals for CO₂ abatement, energy security and cost competitiveness, as set forth in the National Climate Change Strategy 2007 to 2013 (DoEHLG, 2007).

This paper examines the potential for expanding renewable energy consumption in the transport sector through technology and fuel changes in private cars as a result of several Government measures. An econometric model of private car activity and sales is developed, and a bottom-up model of the technological composition of the Irish car fleet is used to forecast a baseline picture of private car energy demand up to 2020. Scenario analysis is then used to measure the expected impact of electric vehicle (EV) deployment and biofuels legislation on energy, emissions and renewable energy consumption. Also, a potential alternative target for compressed natural gas vehicles is discussed, with forecasted energy and emissions compared with EV scenarios.

1.1 Targets and Forecasts

Renewable contribution to overall energy demand (RES) is required to be 16% by 2020, according to the European Renewable Energy Directive (2009/28/EC). In order to reach this goal, separate targets for renewable energy in transport (RES-T), electricity generation (RES-E) and heating (RES-H) have been set for 2020. For Ireland, these targets are 10%, 40% and 12%, respectively.

10% RES-T

First proposed in 2007 and the same for each member state, the 10% binding target for RES-T was originally a target for biofuel use in transport (CEC, 2007 (12)). However, concerns have grown regarding the sustainability of biofuels, in particular those coming from food sources (first generation biofuels). Directive 2009/28/EC revised this target, requiring 10% of transport energy to come from renewable sources, not from biofuels alone. Furthermore, the Directive ensures the sustainability of renewable energy by imposing minimum sustainability criteria on biofuels which can be counted towards meeting RES-T: by 2020, biofuels are to achieve a 60% greenhouse gas
emissions saving on fossil fuels, and the directive prohibits counting biofuels which cause ecosystem damage. The Directive also stimulates renewable energy from sources other than first generation biofuels by allowing a weighting factor of 2.5 to be applied to renewable energy from second generation biofuels (from residues, non-food cellulosic material and lingo-cellulosic material).

The Sustainable Energy Authority of Ireland (SEAI) makes annual energy forecasts using top-down methodologies, relating energy consumption to the forecasted behaviour of the economy. They forecast that in a baseline scenario, RES-T would come to just over 3% by 2020, with renewables in transport almost totally coming from biofuels.

**Non-ETS Emissions**

A second EU decision impacting Ireland’s energy policy, especially in relation to transport, is a target on greenhouse gas (GHG) emissions. In order for the EU to reach its target of 20% GHG reductions by 2020 relative to 1990, it has developed legislation imposing emissions caps on emissions trading sectors (ETS) as a whole, and non-ETS by member state (Decision 606/2009/EC).

From this Decision, Ireland is required to reduce non-ETS emissions by 20% compared to 2005 levels by 2020. The Environmental Protection Agency (EPA) has produced emissions forecasts for non-ETS sectors, indicating an overshoot of the target of 12.4Mt CO₂ in a *With Measures* scenario, a growth in 2005 emissions of 6.6%, and an overshoot of 7.6Mt CO₂ under a *With Additional Measures* scenario, a reduction of 3.6%, assuming that all relevant policies and measures outlined in recent Government policy documents will be adopted, fully implemented and fully successful (EPA, 2010). To put these figures in context, total non-ETS emissions were 67.4Mt CO₂ in 2008, and transport emissions in the *With Measures* scenario are forecast to reach 17.8 Mt CO₂ in 2020.

**1.2 Private Car Transport**

Energy demand in Irish transport has not decoupled from economic growth as it has in other sectors, having grown by 181% in the period 1990-2007 and increased its share of total demand from 28% to 43% in the same period (Howley et al., 2009a). Transport emissions have grown in line with energy demand – emissions grew by 177% between 1990 and 2007 – because transport fuel has not decarbonised: Transport is currently almost entirely fuelled by imported oil.

In the future, transport energy demand is forecast to grow by 1.5% per annum in a baseline scenario (Walker et al., 2009), therefore policies implemented in this sector will have an important role in determining our ability to meet the RES-T and emissions reduction targets.

Private cars, the focus of this research, are the most significant transport mode, accounting for 44% of transport energy demand and 77% of the vehicle fleet in 2008. Between 1990 and 2008 private car energy consumption and the fleet grew by 4.9% and 5% per annum respectively. (Howley et al., 2009a)

Looking ahead, it is forecast that in a baseline scenario (encompassing energy policies implemented from 2008), final energy demand from transport will grow on average 1.5% per annum between 2008 and 2020, increasing transport’s share of total final demand from 42% to 45% in the period. The fuel share of oil in this scenario drops from 99% to 97% owing to an increase in the use of biofuels due to a legal obligation on suppliers put in place in 2008 (Walker et al., 2009). In a ‘Policy’ scenario, a range of measures effecting the efficiency of transport are applied, including electric vehicle deployment, mobility management measures and efficient driving measures. These measures reduce the forecasted annual growth in transport energy from 1.5% to 1.2%, therefore aren’t anticipated to offset the energy demand to fuel the growth in mobility required by the rebounding economy.

**1.3 Current Policies**

In order to move away from fossil fuel based transport, a range of technological options have been mooted and are being introduced through legislative targets; examples include the hydrogen fuel cell, compressed natural gas (CNG) cars running on biomethane, and the electric car. The Irish Government has committed Ireland to the latter option, announcing a target that 10% of vehicles are to be powered by electricity by 2020 (DoEHLG, 2008). A main focus of this paper is to study the implications that this target will have: The concept of path dependency explains how the decisions available in the future will be limited by the decisions taken in the present. With regard to vehicle technology, this implies that policies implemented can create a ‘lock-in’ situation, where investment into capital infrastructure for one type of technology will make it difficult to switch in the
For example, the path dependency of vehicles has created a technological lock-in with regard to the internal combustion engine (Åhman and Nilsson, 2008), which is costly to break. It is important to study in as much detail the consequences of policies such as the EV target, which will lead to a technological lock-in.

Aside from implications for the vehicle fleet and transport energy consumption, electric vehicles will impact electricity supply in Ireland, especially if uncontrolled charging will be allowed, which will likely contribute to the peak electricity load and increase the cost and emissions intensity of supply (Foley et al., 2009). This paper doesn’t focus on charging profiles however, but examines the implications for energy and takes an average electricity emissions factor to estimate the impact on CO₂.

Also studied are the implications of the 10% EV target for RES-T. Directive 2009/28/EC stimulates transport energy from renewable electricity by applying a 2.5 weighting when counting it towards the RES-T target. Furthermore, the Directive also sets out a RES-E target for Ireland, that a 40% share of electricity is generated from renewables by 2020. RES-E in 2009 stood at 14.4% (provisional), exceeding the 2010 EU target for 13.2%, and putting RES-E on track for meeting the government’s target of 15% in 2010 (Dennehy et al., 2010)

A second route for decarbonising private car transportation in Ireland is the increased use of biofuels: the 2010 Biofuels Obligation Bill requires all fuel sold to contain 4% of biofuels by volume by July 2010. According to Ireland’s energy balance, 56 ktoe of the 2181 ktoe consumed by private cars in the country in 2008 came from liquid biofuel, a 2.6% mix by energy. In order to meet the minimum sustainability criteria as defined by Article 17 of Directive 2009/28/EC, biofuels and bioliquids must achieve GHG savings on fossil fuels: 35% to 2016, 50% in 2017 and 60% from 2018. This paper forecasts the effects of the Biofuels Obligation Bill in light of these criteria under different scenarios, including EV scenarios and possible increases in the obligation.

1.4 Structure
The rest of this paper is structured as follows: Section 2 describes the car stock methodology used to forecast the fleet composition and energy demand under technology scenarios until 2020; Section 3 quantifies the impact of EVs on emissions and RES-T; Section 4 examines biofuels and biogas options, and Section 5 summarises

![Figure 1: Historic and forecast economic indicators, fleet activity and car sales](image-url)
2 CAR STOCK METHODOLOGY

The basis for forecasting private car energy demand is founded on two methodologies: Top-down econometric modelling to forecast car activity and sales\(^1\), and bottom-up modelling to generate a car stock model for each year up to 2020.

Scenario analysis is then performed on the makeup of car sales each year, what technologies and which technologies from the baseline are replaced. The composition of fuel is also varied in order to study biofuels.

This approach is beneficial firstly for creating a realistic baseline energy forecast for private cars. While it is a simplification that activity and sales on one hand, and the fleet fuel efficiency on the other are driven by separate drivers – there are rebound effects, for example more driving due to better efficiency and lower fuel cost – car activity and sales in this model are considered as demands derived from external economic forces. The second benefit of this type of modelling is that we can vary the technological parameters of the new stock (as a result of the 10% EV target for example), or of the existing stock (such as modelling the effects of a scrappage scheme (Daly and Ó Gallachóir, 2010a)) while keeping the overall activity level constant. This separates the effects of different policies and allows comparison of different technological scenarios, all else being equal. Another contribution of the bottom-up approach is the detailed picture it gives of energy consumption from a technological level, showing how for example the ageing of the fleet or the shift towards diesel sales adds to energy demand.

2.1 Top-down forecasting: Car fleet activity and sales

The first modelling step is the use of top-down modelling to forecast car sales and the car fleet’s activity (in vehicle kilometres) up to 2020. These variables are modelled as the function of forecasted GNP and oil prices. The approach follows that taken in (Daly and Ó Gallachóir, 2010b), which contains a description of the derivation of the price and income elasticities used to make forecasts. Figure 1 shows historic GNP, fuel price, private car activity and sales from 1990 – 2008, data upon which regression analysis was performed to derive the dependencies between the variables. Projected values for each variable are also shown for 2009 – 2020.

2.2 Bottom-up Stock Model

The following gives a summary of the car stock modelling methodology, which is based on a historic bottom-up study of Irish private car use (Daly and Ó Gallachóir, 2010) and is described in detail elsewhere (Daly and Ó Gallachóir, 2010b), where the approach was used to forecast the structure of Ireland’s car fleet and the impact of efficiency measures on private car emissions.

Disaggregation

The base year fleet (2008) is disaggregated by annual vintage and engine type – for example, internal combustion engine (ICE) vehicles, electric vehicles (EVs), compressed natural gas (CNG) vehicles – and each technology category is subdivided further – for example, ICE vehicles are categorised by engine centilitre capacity (cc) and fuel type, and EVs are divided by battery electric vehicles (BEVs), plug-in hybrids (PHEVs) and hybrids (HEVs).

Car Fleet Profile

The composition of the car fleet in terms of vintage and technology category is approached from two sides: First, the fleet size is determined from fleet activity and average mileage; average mileage per vehicle is linearly extrapolated and reflects the 0.5% decrease per year observed between 2000 and 2008, then stock is the quotient of activity (from the top-down forecast) and average mileage.

Secondly, the composition in terms of age and technology profile is determined from the previous year’s profile plus sales and imports less scrapped cars. Historical analysis on the fleet’s vintage profile indicated the likelihood of cars in each category being scrapped or imported each year.

Mileage

Mileage in each category is weighted from the average for each year to reflect trends observed, for example that diesel cars and newer cars are driven more then average.

Efficiency

The efficiency – the specific energy consumption (SEC), measured in MJ/km – of cars in each technological category in the base-year fleet were calculated by SEAI from official fuel test and vehicle registration data (Howley et al., 2009a).

\(^1\) “Sales” in this paper refers to new-car sales; second-hand sales (which are not imports) are not considered as they do not increase the size of the stock.
The car stock fleet efficiency (in MJ/km) is a key indicator of performance: It is determined for each technology type as a product of new-car SEC (calculated for each ICE category from 2000 – 2008, extrapolated for cars predating 2000, and for future car sales this figure is a key scenario input) age, and an ‘on-road’ factor which counts for the differences between the official test consumption data and actual on-road usage. This last parameter has been calculated for Ireland’s cars using a Household Budget Survey (Daly and Ó Gallachóir, 2010).

The overall fleet efficiency can then be calculated as the average SEC over each technology subcategory, weighted by the overall activity (vehicle kilometres of each subcategory). It is important to weight according to activity as opposed to stock due to differences in average mileage across the stock: for example, in 2008, analysis of National Car Test (NCT) test results indicated that on average, diesel cars drive 59% more than petrol cars.

Energy Consumption

Energy consumption each year is then the sum of energy consumption in each vintage and technology category, which is the product of the stock, mileage and SEC in that category.

2.3 Baseline Forecast

The baseline new-car sales profile and SEC is calculated by assuming that Regulation (EC) 443/2009 will be met, which mandates a cap on average new-car emissions of 130g CO₂/km (equivalent to 1.91MJ/km) through vehicle technology improvements by 2015. The Regulation sets a further target of 95g CO₂/km (1.4MJ/km) to be met by 2020, but this is not reflected in the baseline case. Figure 2 shows baseline energy demand by vehicle technology.

Policy scenarios are prepared by varying the technology profile of new-car sales and of the fuel mix between 2010 and 2020. Therefore for each scenario, the total car stock, total fleet activity and average fleet mileage are constant. Even in a scenario which assumes that EVs displace the sales of smaller petrol cars and have a smaller than average mileage, the mileage of ICE vehicles is increased to keep overall activity constant.

3 IMPACT OF 10% EV

3.1 EV Assumptions

1. We assume that the 10% fleet electrification target is to be met by private passenger cars, resulting in private car electrification of 11.5%, assuming that 87% of the fleet will be private cars in 2020. While it is unrealistic that the technology to electrify freight vehicles or machinery will mature to be viable by 2020, it is likely that some of the target will be met from taxis and other captured fleets. However, we confine the analysis to private cars, which in 2008 made up 97% of these vehicles (CSO, 2009).

2. EV purchasing begins in 2011 and accelerates each year in order to meet the 11.5% necessary to meet the target (262,068 vehicles). The sales and EV stock are illustrated in Figure 3.
3. Three scenarios are considered with regard to the ICE vehicle sales from the baseline that are to be displaced by EVs.

4. Outlines these and consequences for SEC and EV mileage. A first scenario considers an optimistic sales trajectory in terms of ICE displacement: EVs displace large diesel engines, and therefore reduce the number of powerful cars and do more mileage. A second scenario has ICE engines displaced evenly and average EV mileage is the average of the fleet. In a third scenario we consider the situation in which EVs displace only smaller petrol ICE vehicles which have lower mileage and lower SEC.

5. Overall fleet activity isn’t affected by EVs; EVs are assumed to have the same mileage as the

Table 2: Assumptions for different EV technology scenarios and representative vehicles

<table>
<thead>
<tr>
<th>EV Technology</th>
<th>Notes</th>
<th>MJ/km</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEV</td>
<td>Hybrid electric vehicle, e.g., Toyota Prius 2008.</td>
<td>1.50</td>
</tr>
<tr>
<td>PHEV</td>
<td>Plug-in hybrid electric vehicles, e.g., Toyota Plug-in Prius, Assumed 50% driven in all electric mode.</td>
<td>1.20</td>
</tr>
<tr>
<td>BEV: High</td>
<td></td>
<td>0.95</td>
</tr>
<tr>
<td>BEV: Medium</td>
<td>e.g., Nissan LEAF, 120km range; Tesla Roadster.</td>
<td>0.72</td>
</tr>
<tr>
<td>BEV: Low</td>
<td>Mitsubishi iMiEV, 10km range.</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Table 3: SEC and mileage for three different ICE displacement scenarios, derived from baseline forecasts.
6. A plug-to-wheel approach is taken, in which energy consumed from the plug is modelled. A plant-to-battery approach has been adopted previously, which takes losses in the electricity system, the time of charging and impact on electricity load into account (Foley A. M. et al., 2010).

7. For measuring the impact of EVs, the model introduces five archetypal EVs outlined in Table 3 with different efficiencies and fuel mixes, reflecting the range of EVs available and soon for sale in Ireland. For hybrid electric vehicles (HEVs, characterised by having both an electric motor and an internal combustion engine), two models are considered: one in which the battery is charged by the ICE (for example the Toyota Prius) and one in which the battery can be plugged in (a plug-in HEV). Three types of pure battery electric vehicles (BEVs) are considered to reflect the range of efficiencies possible. For example, the Nissan LEAF has a 24kWh battery and an expected cruising range of 160kms²; the smaller Mitsubishi i MiEV has a 16kWh battery with a 130km range³. The 26kWh/100km (0.95MJ/km) is at the lower range of expected EV performance and represents a conservative view of a technology still under development and one representative of figures used in other forecasting studies (Sandy Thomas, 2009).

In calculating the emissions and RES-T impact of EVs it is assumed that the target for 40% RES-E (the share of electricity generated from renewable sources) will be met by 2020. RES-E was 14.4% (provisional) in 2009 (Dennehy et al., 2010). In a scenario with 42% RES-E and electricity demand of 54TWh in 2020, the All-Ireland Grid Study projected that the total energy-related CO₂ emissions associated with electricity generation will be 15.3MtCO₂, giving a projected carbon intensity of the electricity supply of 78.7 gCO₂/MJ in 2020, falling from the 2008 value of 161.5 gCO₂/MJ (Howley et al., 2009b). RES-E and carbon intensity values are linearly interpolated for interim years.

3.2 EV Results

Analysis of the potential impact of the 10% EV target on energy, emissions, renewable energy in private cars and impact towards the RES-T target was done for 15 different technical scenarios, representing the introduction of five different EV technologies displacing three different ranges of ICE vehicle. The technological assumptions for introduced EVs and displaced ICE vehicles are presented in Table 2 and Table 3.

Results are given in Table 4. Unsurprisingly, the most favourable outcomes in terms of emissions reductions and the RES-T targets come from scenarios in which large diesel cars are displaced: in these scenarios EVs are driven more and there is a bigger gap between the SEC of displaced and introduced vehicles.

When it comes to the EV technology introduced it is interesting to note the difference in outcomes in terms of the two targets: The introduction of less efficient BEVs contributes the most to the RES-T target, whereas the most efficient EVs are most favourable in terms of emissions reductions. This difference highlights the opposing goals of the two energy targets.

The calculation of each scenario’s contribution towards the RES-T target encompasses the 2.5 weighting that Directive attributes to electricity from renewable sources, and uses the simplified assumption that in 2020, private car transport has a 51% share of road and rail transport, equal to that of 2008 according to the energy balance (Howley et al., 2009b). The maximum achievable RES-T from the 10% EV target is 3.2%, and this is with very generous mileage and efficiency assumptions. A more likely scenario is medium BEVs displacing small petrol cars, leading to a 1.5% contribution towards RES-T. Considering the significant challenge in reaching the 10% EV target, and indeed the 40% RES-E target, the payback in terms of achieving RES-T seems slight.

Table 4 also quantifies the emissions reductions achievable as a result of each scenario.

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²http://www.reuters.com/article/idUSTRE5710IH2009090802
³http://www.mitsubishi-cars.co.uk/imiev/introduction.aspx
<table>
<thead>
<tr>
<th>ICE Technology</th>
<th>HEV</th>
<th>PHEV</th>
<th>BEV: High</th>
<th>BEV: Medium</th>
<th>BEV: Low</th>
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<tbody>
<tr>
<td>Petrol &lt;1.5L</td>
<td>2,477</td>
<td>3,540</td>
<td>4,399</td>
<td>5,201</td>
<td>5,704</td>
</tr>
<tr>
<td>Stock average</td>
<td>3,135</td>
<td>4,415</td>
<td>5,449</td>
<td>6,415</td>
<td>7,020</td>
</tr>
<tr>
<td>Diesel &gt;1.5L</td>
<td>5,304</td>
<td>6,912</td>
<td>8,212</td>
<td>9,426</td>
<td><strong>10,186</strong></td>
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<table>
<thead>
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<th>Emissions Displaced – kt CO₂</th>
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<tr>
<td>Petrol &lt;1.5L</td>
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<tr>
<td>Stock average</td>
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<tr>
<td>Diesel &gt;1.5L</td>
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<table>
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<tr>
<th>Private Car Renewable Energy %</th>
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<tbody>
<tr>
<td>Petrol &lt;1.5L</td>
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<tr>
<td>Stock average</td>
</tr>
<tr>
<td>Diesel &gt;1.5L</td>
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<tr>
<th>RES-T %</th>
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<tbody>
<tr>
<td>Petrol &lt;1.5L</td>
</tr>
<tr>
<td>Stock average</td>
</tr>
<tr>
<td>Diesel&gt;1.5L</td>
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Table 4: Results for energy displacement, emissions reductions, private car renewable energy and contribution to RES-T for each of the 15 EV scenarios.

### 4 BIOFUELS AND BIOGAS

#### 4.1 CNG Potential: Comparing targets

This section explores a second alternative technology future based on a scenario with a Government target for compressed natural gas vehicles (CNGV) similar to the 10% target for EVs. We present an initial estimate of the emissions reductions and renewable energy demand as a result of meeting such a target from private cars, requiring 11.5% of the private car fleet to be powered by CNG by 2020.

There has been growth in the availability and use of CNGV in recent years. In the EU they are used in Austria, Sweden and Germany, with bi-fuelled vehicles, burning either CNG or gasoline in a standard ICE, for example the Volvo S80 Bi-Fuel car. For private cars there are two possible types of recharging infrastructure, public refuelling stations, which are supplied either by piped natural gas from the grid, or by delivery trailers (O’Brien, 2008).

Table 5: Comparing the emissions reduction and private car renewable energy

<table>
<thead>
<tr>
<th>Scenario</th>
<th>CO₂ Reduction %</th>
<th>Private Car Renewable %</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNGV replacing stock average</td>
<td>1.5%</td>
<td>0.9%</td>
</tr>
<tr>
<td>Med BEV replacing stock average</td>
<td>7%</td>
<td>1.5%</td>
</tr>
<tr>
<td>PHEV replacing small petrol cars</td>
<td>3%</td>
<td>0.7%</td>
</tr>
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</table>

The potential for the production of biomethane from cleaned and upgraded biogas in Ireland has been studied: (Singh et al.) estimates that a maximum potential of 33% of natural gas in Ireland may be substituted with biomethane from sustainable sources, such as residues from slurry
and slaughter waste together with energy crops, with a practical obtainable level of 7.5% estimated. Furthermore, (Smyth et al., 2010) indicates that the sustainability criteria imposed on biofuels in Directive 2009/28/EC and requirements for cross-compliance indicate that biomethane produced from grass is a favourable indigenous biofuel, contributing to RES targets, energy security and emission reduction targets.

We use the stock model to quantify the impact of the introduction of such an CNGV target:

To compare results directly with the 10% EV target we again assume an 11.5% private car penetration of CNGV by 2020 (262,068 vehicles), assume that these vehicles have the same average mileage and efficiency as petrol and diesel engines (Korres et al.), and that 7.5% of the natural gas mix comes from renewable biomethane which meets the minimum sustainability criteria of Directive 2009/28/EC. To calculate emissions we subtract the 7.5% renewable content from the emission factor of natural gas (63.9 gCO₂/MJ) to get 59.1 gCO₂/MJ.

Table 5 compares the emissions reduction and renewable energy demand as a result of this scenario compared with two EV scenarios from the previous section, one of which is an ‘average’

![Figure 4: Comparison of 10 fuel and technology scenarios for their contribution towards private car renewable energy demand. The bottom figure includes a 2.5 weighting of renewable electricity and a double weighting of biogas. EV(A) refers to the “BEV High/Stock Average” scenario; EV(B) refers to the “BEV High/Petrol <1.5L” scenario.](image-url)
scenario, with medium BEVs displacing average ICE vehicles. The second EV scenario is less optimistic, with PHEVs replacing small petrol cars. Both EV scenarios reduce CO₂ emissions more (7% and 3%) compared with CNGV (1.5%). For renewable energy demand, the CNGV scenario achieves 0.9%, better than the ‘pessimistic’ EV scenario (0.7%) but not as good as the ‘optimistic’ EV scenario (1.5%).

When considering contribution to RES-T renewables from electricity are given a 2.5 weighting, while biofuels from second generation biofuels (from residues, non-food cellulosic material and lingo-cellulosic materials) receive a double weighting. It has not been established yet whether biomethane from grass will count for this weighting.

4.2 Biofuel Mixing
The 2010 Biofuels Obligation Bill requires each fuel supplier to include a 4% mix of biofuels by volume in road fuels by July 2010. We assume that this is met by a 4% mix of bioethanol in petrol and a 4% mix of biodiesel in diesel. The share of biofuel by energy content is calculated using the energy content by volume of each fuel as defined by Annex III of Directive 2009/28/EC and the overall petrol and diesel share as projected in the baseline scenario.

5 CONCLUSION: MEETING 10% RES-T
Figure 4 compares four scenarios: Biofuel mixing, EV(A) (BEV High/Stock Average), EV(B) (BEV High/Petrol<1.5L) and CNG, and several mixed scenarios, for their contribution towards renewable energy demand in private cars (without weightings), and for their contribution towards RES-T (with weightings). It shows that with an optimistic scenario for EVs, with a target for CNGV similar to the EV target, with 40% RES-E and 7.5% renewable natural gas in the pipeline and with the Biofuel Obligation Bill, an estimated 5.2% of the RES-T target will be met from private cars.

Almost entirely fuelled by fossil oil, the issue of energy security and carbon abatement is especially pertinent to private car transportation. The purpose if this study is to determine the effects of purely technological and fuel-switching policies on the energy profile of cars. This paper has used a detailed bottom-up stock model to quantify the possible emissions and renewable energy demand as a result of several policies and targets relating to private car energy demand.

ACKNOWLEDGEMENTS
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THE USE OF HYDROGEN AS A FOSSIL FUEL EXTENDER FOR INTERNAL COMBUSTION ENGINES

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ABSTRACT

This study aims to firstly investigate the production of hydrogen from green renewable energy sources and secondly to determine the criteria necessary for adapting conventional internal combustion engines for the efficient burning of same.

International reports have highlighted Ireland’s over-dependence on crude oil supplies – electricity generation and transportation are cited as the two main reasons. In 2009, the Minister for Energy, Mr. Eamon Ryan commented that: “Ireland relied on oil for almost 60 per cent of its energy needs, all of which was imported.”

Experts predict that we will reach the maximum rate of global oil extraction (peak oil) in the next 10 to 15 years, after which the rate of production will go into decline. In the near future, it is reasonable to predict that Ireland will face significant economic challenges due to global demands for dwindling oil supplies. Therefore, as a matter of urgency, it is essential that we begin to search for a secure form of energy for Ireland’s future transportation requirements.

Hydrogen is an excellent fuel because it has a very high specific energy when compared to an equivalent amount of fossil fuel – one kilogram (kg) of hydrogen has three times the energy content of one kilogram of petroleum spirit. Hydrogen is the most abundant element on our planet but it does not exist by itself in nature. Energy must be expended to separate it from other, more complex materials and to store it so it can be used as a fuel.

While hydrogen can be used as a fuel it is not an energy source. Instead, hydrogen is only an energy carrier, i.e. energy must be expended to generate the hydrogen and store it so it can be used as a fuel. Electrolysis is the electrochemical process whereby electrical current is passed through water in order to break it into its constituent components, hydrogen and oxygen. Energy is required to bring about electrolysis; this same energy can be retrieved by burning hydrogen in an internal combustion engine or by allowing it to reunite with oxygen in a fuel cell.

Hydrogen emits almost no pollution when it burns so its environmental impact is determined by the way in which it is produced. Environmental impact and dependability of supply are maximised if a selection of renewable energy sources such as wind and wave are used provide the required energy.

Keywords: Transport, alternative-fuel technologies, internal combustion engines, hydrogen.
1 INTRODUCTION
The internal combustion (IC) engine has been the power unit of choice for generating motive power for the automobile for nearly 100 years. During this time engine designers have experimented with a number of different fuel types. However, fossil fuels, like petroleum spirit and diesel oil, have for many years been the fuels of choice – this was in essence due to their previous abundance and cheapness.

It is predicted that in the next ten years the number of automobiles on our planet’s roads will exceed one billion. One can appreciate the negative environmental effects associated with the burning of fossil fuels – toxic exhaust emissions and global warming to name but a few.

It is also recognized that in the near future we will reach peak oil production. A global energy crisis seems inevitable as the world’s fossil fuel reserves run low. According to Plesch (2002), “No country could survive economically if its goods and people could not move from place to place”. Naturally, this shortage of oil and the ensuing demand for same will cause oil prices to soar exponentially – the potential for global conflict over oil will be greater than before.

Automobile manufacturers currently have to reconsider the fuels used to power their vehicles and to assess the practicalities of various alternatives. Their main criteria are as follows:

- Readily available,
- Sustainability,
- Cost effectiveness, and
- Reduced environmental impact.

1.1 Alternative Fuel Sources
Alternative fuels typically fall into two categories:\n1. Those that are self renewing in nature (e.g. rape seed oil, methane, methyl and ethyl alcohol), and
2. Those that are more plentiful (natural gas, coal derived liquids and hydrogen).

2 HYDROGEN: THE HOLY GRAIL OF FUEL
Imagine a source of energy that is plentiful supply, renewable, non-polluting and generates no nuclear radiation. Hydrogen (H2) is one such fuel and just happens to be the most widely available element in the universe.

Ideally, hydrogen should be burnt only with pure oxygen in the combustion process as the exhaust will be pollution-free, consisting only of water vapour (H2O).

3 HYDROGEN SUSTAINABILITY
H2 is not available as a direct energy source on planet Earth – as it does not occur naturally. It is however contained in many compounds such as water, which covers ¾ of our planet’s surface.

At present, H2 is made from fossil fuels – such as natural gas. However, it can be produced from a wide range of renewable sources – e.g. nuclear, methane, tidal, solar, or wind.

3.1 Wind-to-Hydrogen Production
According to Buckley, “Ireland and Scotland have the best wind resources in Europe”. Global climate change will see that resource only gets better!

H2 can be extracted from water by electrolysis. The power provided is far in excess of any input of power needed to produce it.

Wind farms can be adapted to produce H2 in environmentally friendly, cost-effective, sustainable, and practically limitless quantities.

4 CONVENTIONAL ENGINE ADAPTION
The possibilities of hydrogen as an automotive vehicle fuel have been extensively investigated since the 1960s.

Conventional IC engines can be adapted to run on hydrogen. IC engines are also cheaper, lighter and have a greater range than their equivalent fuel cell technologies.

H2 has a higher flame speed during combustion than its fossil fuel contemporaries – resulting in greater efficiencies and energy consumption.

For the driver, a conventional power unit means that there is no need for a lifestyle change – the vehicle operates performs, and has the range of a conventional automobile.

4.1 Bivalent Use of IC Engines
Another crucial advantage for IC power units is their scope for multi-fuel systems – i.e. they can run on both hydrogen and petrol. This is an important factor in view of the fact that H2 filling stations are still rather scarce.

Should one fuel source be depleted, the system automatically switches to the other fuel type – thus extending the maximum range of the vehicle.
4.2 Construction and Operation

Exhaust Emissions

Studies carried out by the University of Melbourne, Australia show that ideally, a hydrogen engine should be run with pure oxygen as the oxidant in the combustion process, in which case the exhaust is pollution-free, consisting only of water.5

Because of the problems of storing oxygen, however, air is the more viable alternative. As air contains 77% Nitrogen (N₂) by mass, and because hydrogen burns hotter than petrol/diesel, the hydrogen combustion process results in higher engine temperatures and the undesirable production of oxides of nitrogen (NOₓ).5

Hydrogen fuel is virtually sulphur-free and its combustion produces no soot particulates. Hazardous substances like carbon monoxide (CO), carbon dioxide (CO₂), hydrocarbons (HC), and other health-and environment-harming exhaust gas components are negligible. Their presence is mainly due to the small amounts of engine lubricating oil, that is used to seal the gaps in the piston rings and to provide upper cylinder lubrication, that are burnt in the combustion process.

However, exhaust emissions produced by hydrogen powered IC engines are amongst the lowest that can be achieved with this type of power unit.

To further reduce toxic exhaust emissions, BMW recommend that the engine-starting phase should always take place in hydrogen mode – the driver then has the option of manually selecting petrol mode or staying with hydrogen.

Hydrogen Operation Mode

A fuel line transports hydrogen gas from the fuel tank to the engine. The cylinders receive their metered supply via the hydrogen intake manifold and injection valves. At the injection valves, the hydrogen is roughly at ambient temperature. Via suitable solenoid valves, precisely metered quantities of hydrogen are blown into the air induction pipe, at a pressure of about 1 bar above atmospheric, to mix with the air (external mixture formation). This air/hydrogen mixture then enters the combustion chamber and is ignited.

Petrol Operation Mode

In petrol operation, the engine uses direct injection: unlike the hydrogen supply, petrol is not mixed with air in the air intake system (external mixture formation), but is injected directly into the combustion chamber (mixture formation in the combustion chamber). Otherwise, the combustion process in the cylinder is the same as for H₂.

4.3 Storage and Delivery

Hydrogen can be stored and transported either in gaseous (H₂) or liquid form (LH₂). The storage, distribution and handling of is more difficult than conventional liquid-based fuels (petrol and diesel).

Gaseous H₂ storage is heavy and bulky, and the liquid LH₂ form is very expensive and has an undesirably high accident potential. Early attempts to overcome these problems adopted a method of vehicle storage in a metal hydrde form. H₂ gas was then released by heating. In this form, hydrogen fuelling would provide an acceptable range without the problem of undue bulk or weight encountered with other systems.5

Modern methods store and transport H₂ in liquid form, as the density of liquid hydrogen is much higher than that of hydrogen gas. As hydrogen only liquefies at extremely low temperatures (about –250 °C), the use of specially insulated storage containers are required to keep the hydrogen at a constant temperature of approximately –250 °C.

To keep the hydrogen at a constant –250 °C, the fuel tank utilizes a twin-wall design (like a thermos flask), with a special super-insulation between the two walls.

The Thermos Flask Principle

The super-insulated LH₂ tank is comprised of an inner and an outer tank, each made of 2 mm stainless steel panels. To achieve the required level of insulation, there is a 30 mm vacuum super-insulation space with 75 layers of aluminium and fibreglass foil between the two walls. In addition, the inner tank is suspended within the outer tank in such a way that thermal bridges and the resulting heat conduction are minimised. The suspension elements are made of a low-conducting material (CFRP bands).

BMW claim that if this specially insulated tank were filled with hot (80 °C) coffee, it would take around 500 days for the coffee to cool down to about 40 °C!

Refuelling

Refuelling a hydrogen vehicle is very similar to a conventional automobile. To refuel, a specially insulated hose with a liquid hydrogen (LH₂)
The tank coupling engages automatically, and the vehicle’s fuel management system signals the filling station, via an electronic contact, that refuelling can begin. Refuelling then starts automatically, and the extremely cold LH₂ flows into the hydrogen tank. Once refuelling is complete, the tank coupling is automatically disengaged.

Safety
The risks associated with hydrogen usage in automobiles are generally overestimated. Hydrogen offers the same levels of safety as petroleum spirit. The only difference being the way the fuel is handled.

The components of the hydrogen system were designed and tested in accordance to the most rigorous safety requirements – crash, fire and vacuum breakage tests for example have established the safety of the special fuel tank.

Various sensors are used to monitor the vehicle’s hydrogen system on a continuous basis. Should a fault be detected, the vehicle’s fuel management system automatically closes all valves to ensure safety.

Hydrogen is safely discharged from the vehicle via a boil-off valve. The gas is then passed through a catalyst were it is oxidised and transformed into harmless water vapour.

The Fuel Storage System
In conjunction with a conventional petrol tank, a Hydrogen vehicle is also equipped with a hydrogen storage system.

The hydrogen is stored, in a separate fuel tank, in liquid form (LH₂) at a temperature of –250°C and a pressure of between 3 - 5 bars. The main advantage of storing hydrogen as a liquid, as opposed to gas, is its higher energy density.

As well as the liquid hydrogen, there is always a cushion of gaseous H₂ in the LH₂ tank. This cushion of gas is needed because the hydrogen is always drawn off from the tank in gas form. As the hydrogen is still extremely cold at this stage, it has to be heated up before it can be combusted in the engine. This is achieved by passing it through a heat exchanger heated by the engine’s coolant.

5 IN SUMMARY
The pending fuel crisis and various environmental problems have little prospect of being resolved until well after the end of the 21st century. Automotive designers and engineers need to be stimulated by the challenges presented.

With more and more nations expressing a greater environmental awareness, it looks increasingly likely that the course of automotive design will be predominately influenced by legislation.

Historically, the transition to new vehicle concepts has been slow. In the short term (25 years), it will be important to develop the internal combustion engine to its highest possible efficiency. Hydrogen burns cleanly and is thus amongst the latest of energy fuels. Consequently, is in a prime position to take the place of conventional fuels once mineral oil reserves finally start to run out.

Hydrogen therefore offers us an amazing opportunity to improve the environmental and ethical performance of the automobile. An important milestone on this path is also the ongoing development of hybrid technology.

In the long term (50 years +), electrically-powered vehicles, running on fuel cell technology, may dominate.

As Charles Darwin said, “It is not the strongest of the species that survives, nor the most intelligent, but the one most adaptable to change.”

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ABSTRACT
Energy storage in electrical vehicles is of importance in the energy management of electric vehicles. A fully or partly powered electrical vehicle could be developed that utilised renewable energy sources such as solar, wind and wave for its energy supply. The paper reports proposed research into methods to optimise energy storage for an electric vehicle. To provide focus, the system is designed for a section of one particular motor bike racing track. The aim is to determine that combination of energy storage that, together with the engine, would provide the motor bike sufficient power, in terms of distance and acceleration requirements, to part-take in a competitive racing event. The minimum energy storage requirements will be determined.

Keywords: Transport, alternative-fuel technologies, energy storage, electric vehicles.

1 INTRODUCTION
The purpose of this paper is to outline the direction of our research and to explain the thinking behind the limits that we are imposing on that research. The basic target is to design renewable energy micro-generator fuelling stations for the supply of electric vehicles. To quantify the fuel requirement a specific load type is considered. The demand is defined as a number of simplified stages of the Isle-of-Man Mountain Electric Bike race. Restricting the load type simplifies initial calculations and enables a basic simulation to be developed.

2 CONTEXT
International reports have highlighted Ireland’s over-dependence on crude oil supplies. Electricity generation and transportation are cited¹ as the two main areas that need to be weaned-off oil. Hence, electric vehicles that depend on non-renewable energy sources are not sustainable. A fully or partly powered electrical vehicle could be developed that utilised renewable energy sources such as solar, wind and wave for its energy supply. These are transient forms of energy and will require support, by energy storage, to form viable fuel stations. Electric vehicles also require on-board energy storage. The paper reports plans for research into methods to optimise energy storage for electric vehicles. To provide focus, the system is designed for one particular motor bike racing track. The aim is to determine that combination of energy storage that, together with the engine, would provide the motor bike with sufficient power, in terms of distance and acceleration requirements, to part-take in a competitive racing event. The initial step is to determine the minimum energy storage requirements.

3 TRADITIONAL LIMITATIONS OF ELECTRIC VEHICLES RELATIVE TO COMBUSTION ENGINES.
Once rechargeable batteries were developed, at the end of the 19th century [2], electric vehicles took-off. At the start of the 20th century electric vehicles were well positioned to dominate road transport. By 1920 700,000 electric vehicles had been produced [3]. The other contenders were the internal combustion engine which was unreliable, smelly and needed to be manually cranked and the steam engine which had relatively low thermal efficiency. Both of these needed an electric source for lighting. The reasons for the subsequent dominance of combustion engines seem to be [2][3] & [4]:
- Invention of the electric starting motor.
- Cost of electric vehicle relative to combustion.
- Easier access to fossil fuel.
- Lower cost of fossil fuel.
- The distance that could be travelled by the combustion engine.
- The maximum speed of electric vehicles.

The rise in the cost and the future limits on the availability of combustion fuels put the electric vehicle back in play. For electric vehicles to compete they also need to address the questions of cost, distance and speed. Central to these issues is the cost, capacity and weight of energy storage.
4 BATTERIES
In terms of weight lithium is the lightest metal. The tradition vehicle battery is the Lead-Acid but lead is a very heavy metal.
A comparison of the weight of selected batteries is given in Table 1. It is see that the Lithium Ion and Nickel-Cadmium are lighter than the Lead Acid.

Table 1. Weight of selected batteries [5]

<table>
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<tr>
<th>Type</th>
<th>Weight per Amp-Hour (Kg)</th>
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<tbody>
<tr>
<td>Sealed lead acid</td>
<td>0.33 to 0.49</td>
</tr>
<tr>
<td>Lithium ion high capacity</td>
<td>0.028 to 0.04</td>
</tr>
<tr>
<td>Nickel-Cadmium</td>
<td>0.022 to 0.35</td>
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</table>

Recharge time is an issue but an option is to replace spent batteries with fully-charged batteries at refuelling stations. This is the technique that would be used for racing vehicles. It is an approach that would match the characteristics of typical renewable micro-generators.

Lithium ion has a higher power density than nickel cadmium as shown in figure 1.

5 ULTRA-CAPACITORS
Batteries perform best when supplying steady loads. They are very inefficient during periods of deceleration. Capacitors are ideal for delivering short bursts of energy. With the development of ultra-capacitors their energy ratings have improved to useful values. Their voltage rating is very low, typically 2.6v. The option of connecting a number of them in series has the disadvantage that this will reduce their energy capacity. Hence, they need to be connected in parallel with a dc/dc converted to step-up the output voltage.

6 LOAD
The demand is defined as three simplified stages of the Isle-of-Man Mountain electric bike race. The actual race involves 38 stages involving hills and turns. Only three equal length racing stages will be considered and these will be simplified to straight level sections. There is a starting stage; steady acceleration. A constant speed stage. And a half deceleration half acceleration stage. A fourth stopping stage will also be considered to determine the remnant energy. The load is a bike weight of 200 kg including a single rider and no luggage. All four stages are 1.5 km. Maximum speed is 100 km/hour. The limits of the variable speed stage are 100 km/hr and 50 km/hr.

7 CONCLUSION
An initial literature review is underway, as is testing of individual components. This will provide the base for system testing. A simulation will be developed and the results verified by practical system tests. It is intended that this project will provide a context for a series of student project over the next few years. The results can then be reported to a future ITRN conference.

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