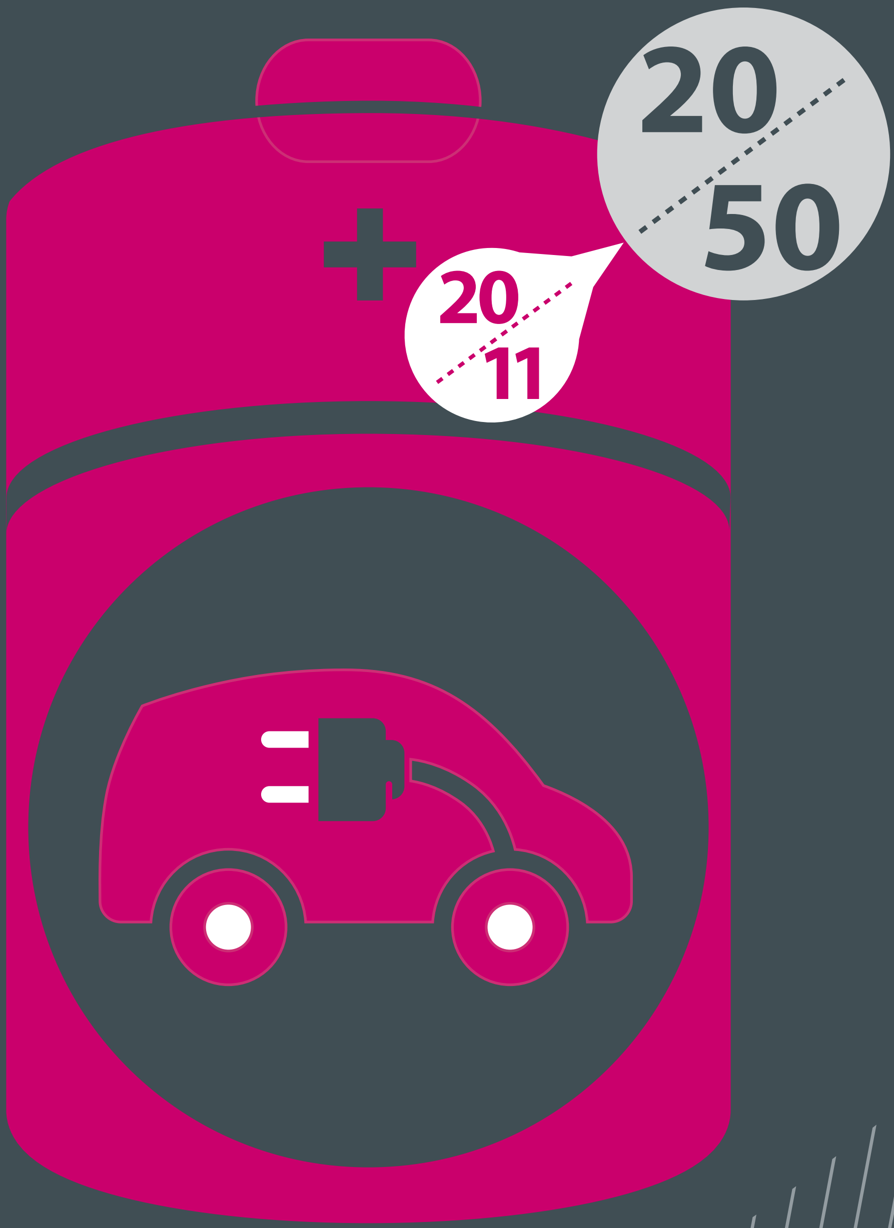
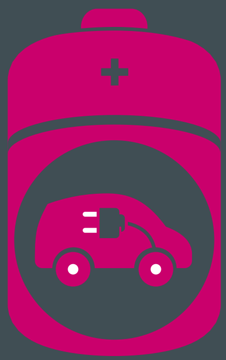
SUSTAINABLE ENERGY AUTHORITY OF IRELAND

ELECTRIC VEHICLES
Roadmap



Introduction to the Electric Vehicle Roadmap

Transport accounts for one third of Ireland's energy requirement and energy related CO_2 emissions and is almost entirely dependent on oil. Increasing oil scarcity, oil price volatility, and environmental concerns are driving a search for an alternative means of powering our transport system.



The transport sector has been the largest sectoral driver of energy demand in Ireland over the past two decades, increasing at twice the rate of increase in overall energy demand over the same period. Private road transport is the largest contributor to transport demand at 43%, with air transport and road freight contributing less than 20% each. In the context of an EU commitment to achieve an 80% reduction in carbon emissions by 2050, and concerns about future scarcity, alternatives to oil (particularly in private road transport) must be encouraged.

A number of alternative approaches are emerging, with different options being considered appropriate for different modes of transport. Biofuels are being promoted for all transport, but may be of most value for road freight and air transport, where length of journey will require higher density fuels. Options to address private road transport include modal shift towards public transport and cycling, and technology advancements, including more efficient internal combustion engines (ICE) and electric vehicles (EV). For Ireland, with access to large amounts of variable renewable wind and ocean energy, and with relatively short driving distances for most private vehicle users, electric vehicles offer the prospect of reducing energy consumption in transport, while at the same time reducing our import of fossil fuels, and providing an additional demand to balance the supply of variable renewable generation. The development of high energy density lithium batteries, the inherently high efficiencies of an electric drive train, and the current race between auto manufacturers to bring credible commercial electric vehicles to market is driving the cost of ownership towards parity with conventional vehicles. This means a transition to electric vehicles could provide economic benefits as well as energy diversity and reduced CO_2 emissions.

Achieving the potential benefits envisaged in a high electric vehicle deployment scenario assumes that a global high deployment scenario is achieved, driving technical innovation and providing scale economies, which Ireland's market cannot achieve on its own. In addition, it will require a strategic approach that integrates the deployment of electric vehicles and variable renewable generation with the development of smart grid technology, providing intelligence across the system and enabling communications between system operators, vehicle charging systems, and generators.

This roadmap provides scenarios for accelerated deployment of battery electric vehicles (BEVs) and plug in hybrid electric vehicles (PHEV) in the private vehicle fleet to 2050. It was developed alongside a wind energy roadmap and a smart grid roadmap, and key assumptions across all three are aligned. Our roadmap builds on the work of the International Energy Agency to present the potential impacts of accelerated electric vehicle deployment on energy demand, fossil fuel imports, and CO_2 emissions. The developments in policy, technology and infrastructure that will enable accelerated deployment are also identified. The delivery of an integrated low carbon energy strategy that facilitates electric vehicle deployment while increasing our use of zero carbon variable renewable resources is achievable by 2050. This roadmap highlights the substantial work required for its successful delivery and, along with the other roadmaps developed by SEAI, points to a possible low carbon future for Ireland.

I want to thank the many stakeholders who have contributed their time and their views to the development of this roadmap, and to invite comments from other interested parties to roadmaps@seai.ie.

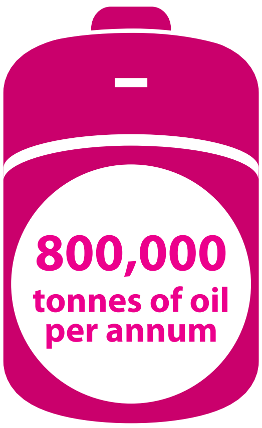
Prof. J Owen Lewis
Chief Executive, SEAI

Electric Vehicles Key Points

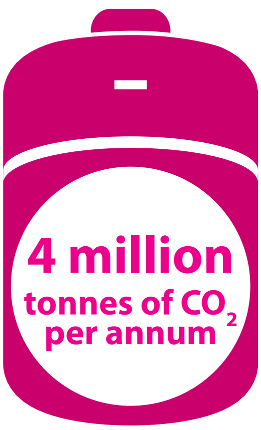
Electric vehicles within this roadmap include battery electric vehicles and plug-in hybrid electric vehicles in the Irish passenger car market up to 2050.

With an abundance of accessible wind and ocean energy and distances from the capital city to key neighbouring cities ranging from 170km to 260km, Ireland is well suited to become an early adopter of electric vehicle technology. This roadmap offers a vision of how the Irish market for electric vehicles could develop up to the year 2050 and models a number of EV deployment scenarios. The impact of EVs on energy efficiency, fossil fuel imports and CO_2 emissions is presented. Additional analysis results considering the impact of EVs on electricity demand and on critical peak load periods are shown.

Reduction in Fossil Fuel Imports by 2050



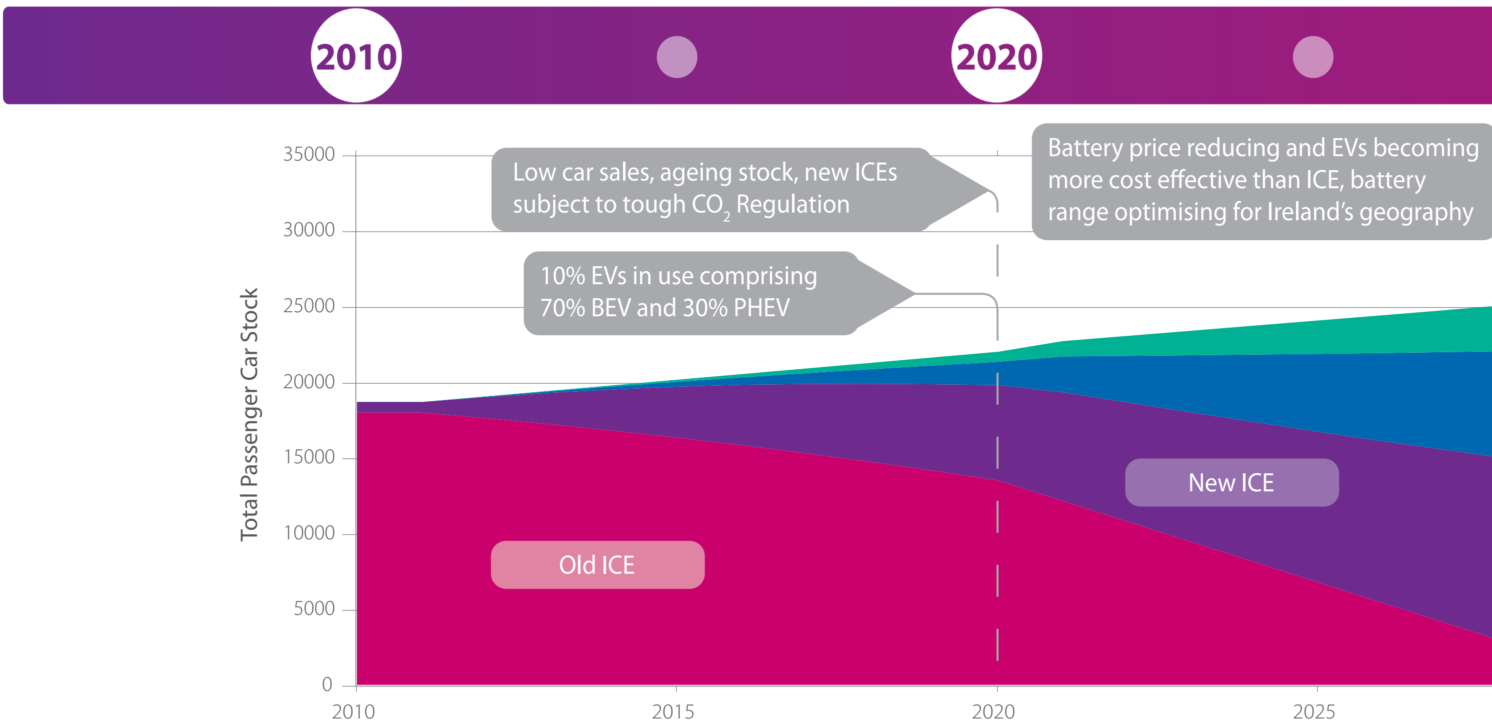
CO_2 Reduction from Passenger Car Fleet by 2050



Key Findings

- The Passenger Car Fleet increases by 57% from 2011 with 2.9 million vehicles on the road by 2050
- By 2020 the EV contribution to the passenger car segment is 10%, growing to 60% by 2050 in the medium scenario
- Transport fossil fuel imports reduce by up to 50% compared with 2011: this equates to a reduction in fossil fuel imports of 800,000toe per annum for the passenger car segment
- Renewable energy in the passenger vehicle segment increases by up to 50% by 2050
- CO_2 emissions for the passenger car fleet reduce by about 80% with respect to 2011 emissions, despite a significantly larger fleet size in 2050 (the energy sources are assumed to be wind and fossil fuels only)
- Based on projected cost reductions for battery production, EVs may offer cheaper 10 year cost of ownership than future ICE vehicles from the period 2019 to 2025 without financial incentives
- Comparing the Mean EV deployment scenario, including 60% EVs and 18% hydrogen vehicles, with a future fleet of only ICE vehicles, the cumulative savings to society could range from €2.3 billion to €12.4 billion by 2050
- EV deployment causes gross electricity consumption to grow by just 14%. Assuming EV energy is consumed during a 5 hour period at night time, there could be sufficient capacity available to supply an EV Fleet of up to 1.7 million vehicles with 2.7GW of electrical capacity required at night. Adjusting this window to an 8hr period reduces this capacity figure to 1.6GW. Therefore, some method of aggregating and managing the EV load will be required to minimise grid development costs and enable EVs' demand to assist in managing wind variability

EV Mean Deployment Scenario 2010 - 2050



POLICY & SUPPORT MEASURES

- Incentives to secure early adoption and acceptance of EV technology and operational characteristics
- Main policy support measures may include fiscal incentives along with soft incentives such as priority parking or congestion charge exemption
- EU CO_2 regulations encouraging more investment in battery production facilities resulting in greater variety of BEV & PHEV models from mainstream automotive ma
- Planning system regulations optimised for EV charging infrastructure development on private and public properties
- Electrical trading system rules optimised for sale of electrical energy and electrical services to and from EVs

TECHNOLOGY

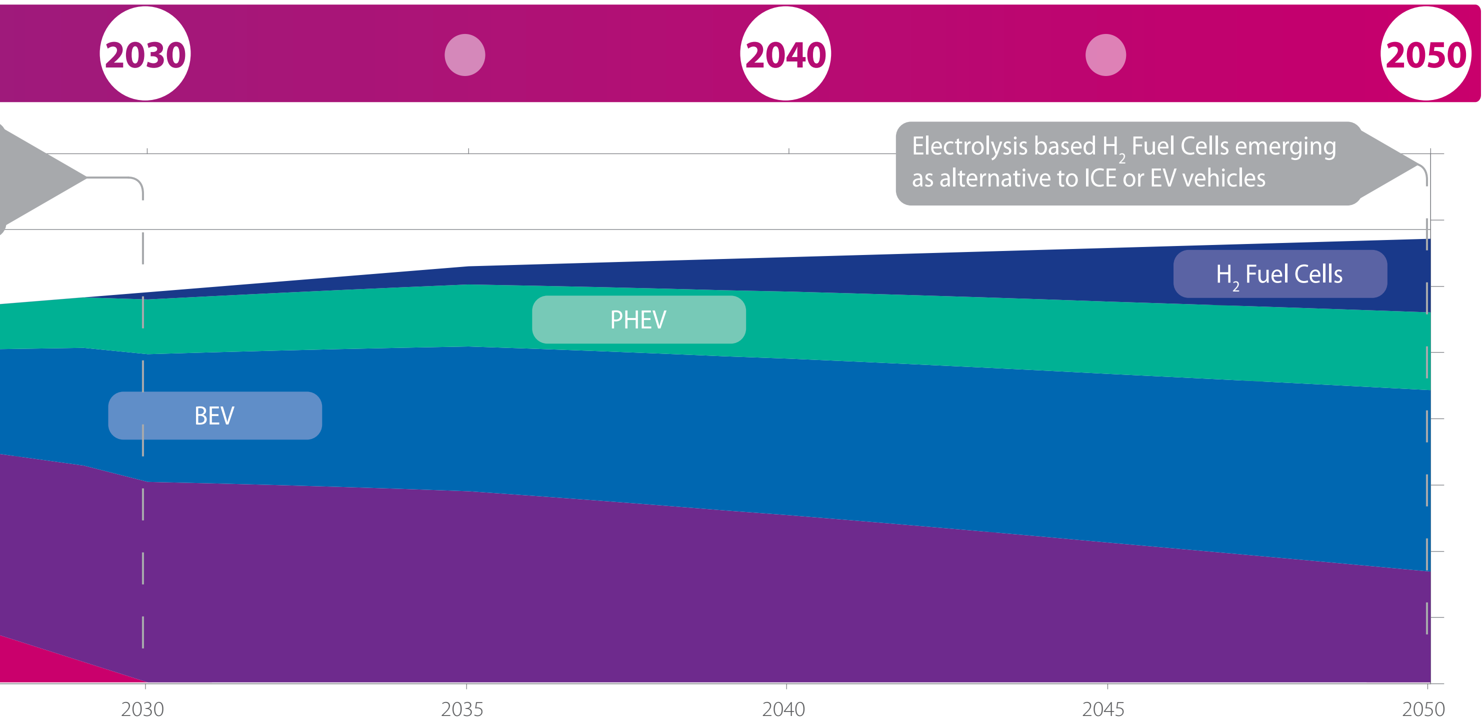
- Commercial ready Lithium Ion and Lithium Polymer battery technology resulting in energy densities of 100 to 150 Wh/kg with manufacturing process feedback to battery design leading to reduced battery costs
- High surface area and high ion current intercalation electrodes with advanced electrolyte providing energy densities of 150 to 300 Wh/kg which could also suit retrofit applications
- Lithium/carbon nano

CHARGING INFRASTRUCTURE

- Electrical trading system rules optimised for sale of electrical energy and electrical services to and from EVs
- EV Electricity Trading System enabled and updated
- 1500 charge points available to consumers
- 1500 to 9,000 charge points depending on battery range development rate
- First Generation Fast Charger Stations will facilitate inter-city journeys
- Second Generation Fast Charger Stations utilising second life batteries charge rates in order to avoid expensive day time prices
- Automated

GRID AND WIND DEVELOPMENT

- Maximum 60% wind energy penetration in annual energy demand reached
- Near Zero CO_2
- Demand Aggregation system to manage charging process.
- Energy arbitrage including wind balancing schedule of EV nigh
- Unidirectional control for On/Off charging enables sale of grid
- Bi-Directional
- Planning for grid expansion to include EVs and heat pumps



Vehicle Type

ICE - Internal Combustion Engine
PHEV - Plug-in Hybrid Electric Vehicle
BEV - Battery Electric Vehicle

KEY

- Government & governing bodies
- Industry
- Power systems & regulators

anufacturers

fibers and advanced chemistries allowing energy densities of 300 to 600 Wh/kg

Vehicle to Grid Operations enabled through better battery lives and higher current discharge rates with probable assistance from on board vehicle capacitors

from first generation EVs to store off-peak electricity may be required in order to meet the need for higher volumes of electricity delivered at higher

battery to grid connection systems such as induction plates infrastructure enabling greater grid to vehicle and vehicle to grid opportunities

emission power system to be achieved by 2025

t time demand

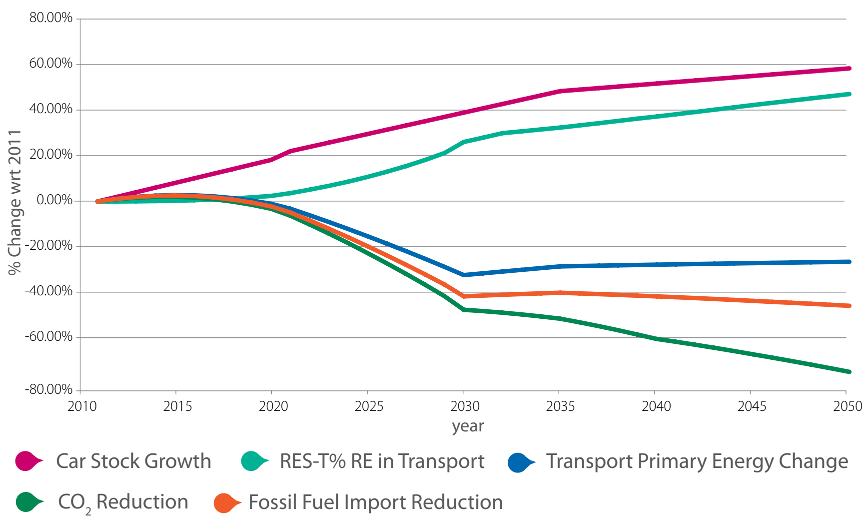
management services

control – Enhanced battery and control systems enable Vehicle to Grid sale of energy and service

Key Results

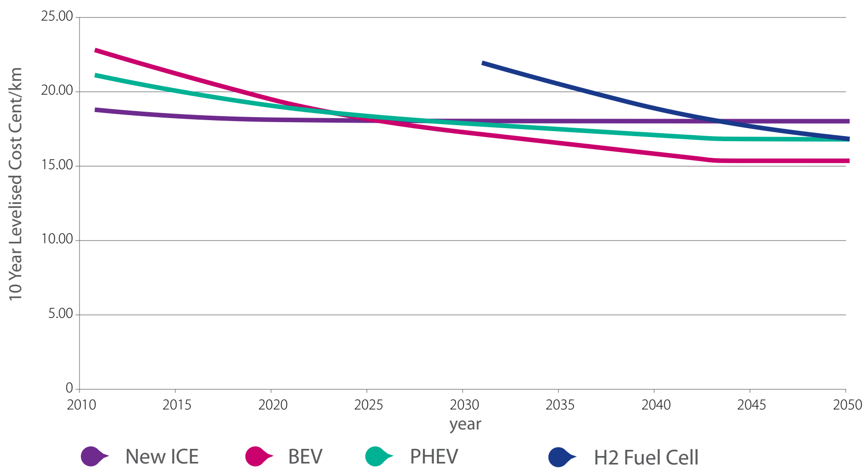
The key results are presented here for the Mean EV Deployment Scenario with 60% EV (BEV plus PHEV) and 18% H_2 Fuel Cells car sales by 2050. The High and Low Scenarios comprise the same overall car stock levels but differ by +/-20% from the Mean EV levels. Note that new ICE vehicles sold from 2011 onwards are subject to the EU prescribed CO_2 emission improvements to 95 gCO_2/km by 2020. The only form of renewable electricity included in the study is wind power. Alternative transport fuels such as liquid biofuels and natural gas are excluded, to focus exclusively on the effect of electricity in transport. This will lead to conservative estimates of CO_2 reduction and transport fuels consumption. Results for all scenarios are presented in table form.

EV Mean Deployment Impacts 2010 - 2050



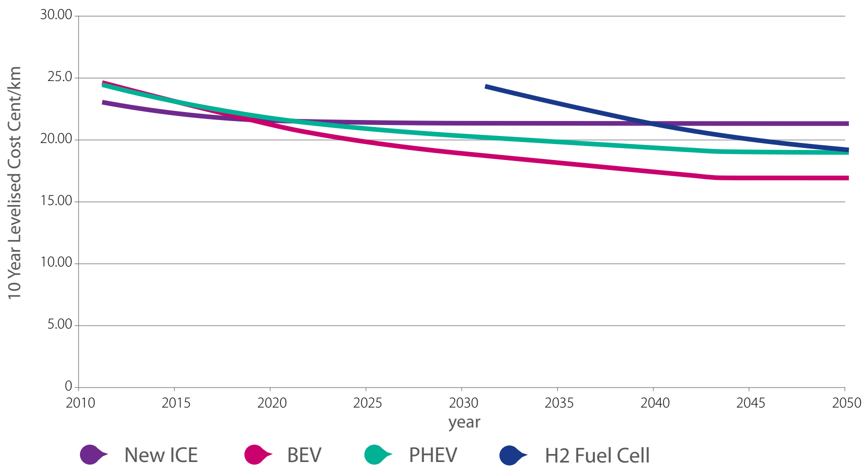
Key Point: With EVs comprising 60% of total car stock in 2050, the Mean Deployment Scenario indicates EVs will reduce fossil fuel imports by 45% and overall vehicle CO_2 emissions by 73%. 45% of Ireland's passenger car energy will be supplied from locally generated wind power.

Low Prices (Oil $110/bbl, Carbon €15/tonne) - 10 Year Levelised Cost of Ownership (cent/km)

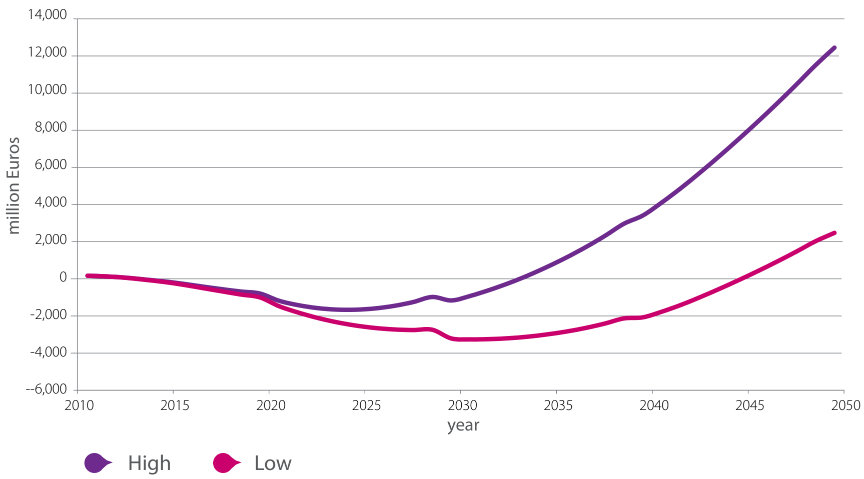


Key Point: Including all costs and km travelled for a 10 year period and in the absence of any supports, EVs will become a cost competitive choice for consumers by 2019 to 2025, as shown in this and the following graph. However, we would not become early adopters and beneficiaries of the technology. IEA World Energy Outlook 2011 indicates rapidly decreasing availability of oil from 2015 onwards so early adoption is necessary to mitigate risk to consumers.

High Prices (Oil $250/bbl, Carbon €35/tonne) - 10 Year Levelised Cost of Ownership (cent/km)

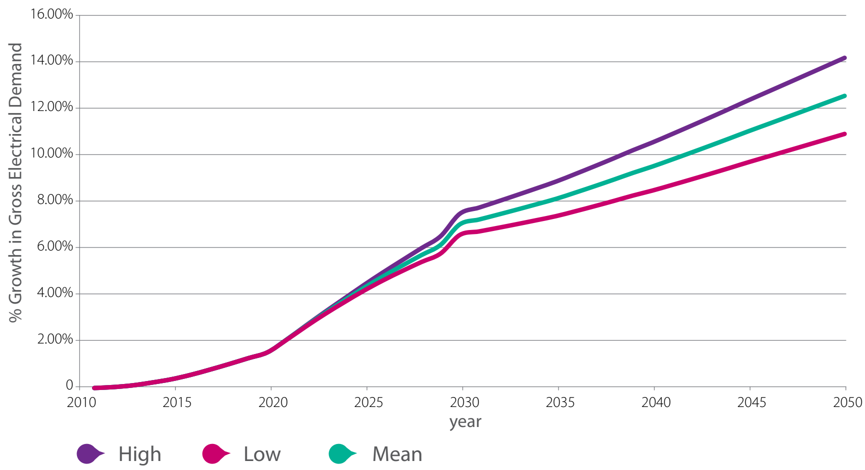


Fleet Cumulative Cost Benefit for Mean EV Deployment - High Prices ($250/bbl, €35/t CO_2) and Low Prices ($110/bbl, €15/t CO_2)



Key Point: The figure shows the cumulative cost of purchasing and operating annually the Mean EV Scenario fleet (i.e. BEV, PHEV, New ICE and H_2) with respect to the corresponding costs for new ICE vehicles only fleet. Results are shown for High and Low energy prices. Once EV capital costs become competitive, the operating costs for the EV fleet over time produces significant savings to society. An early uptake of EVs will provide protection for Irish consumers if exposed to high oil prices in the near to medium term.

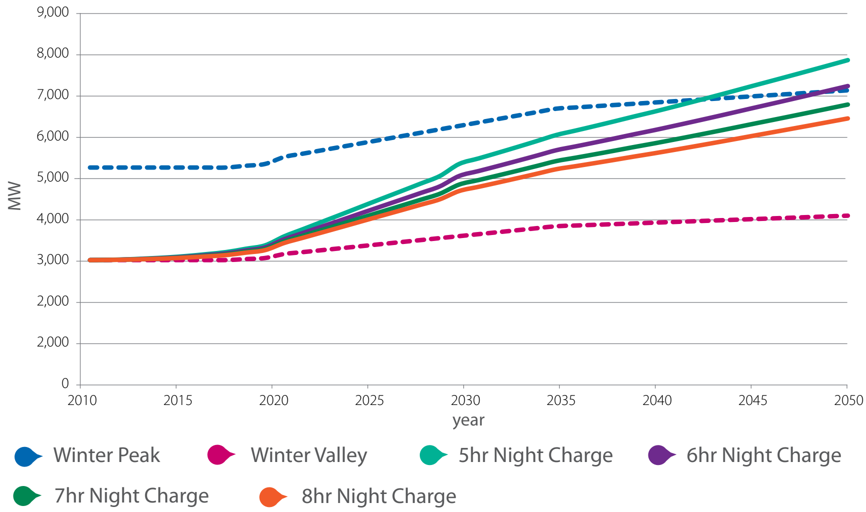
% Growth in Gross Electrical Demand in addition to Forecast Growth due to BEV/PHEV/H_2 Fuel Cells



Key Point: A modest increase in electricity volume sales occurs due to the high direct energy efficiency of the EVs. This will provide increased revenues to support any additional infrastructural demands due to the growing EV market.

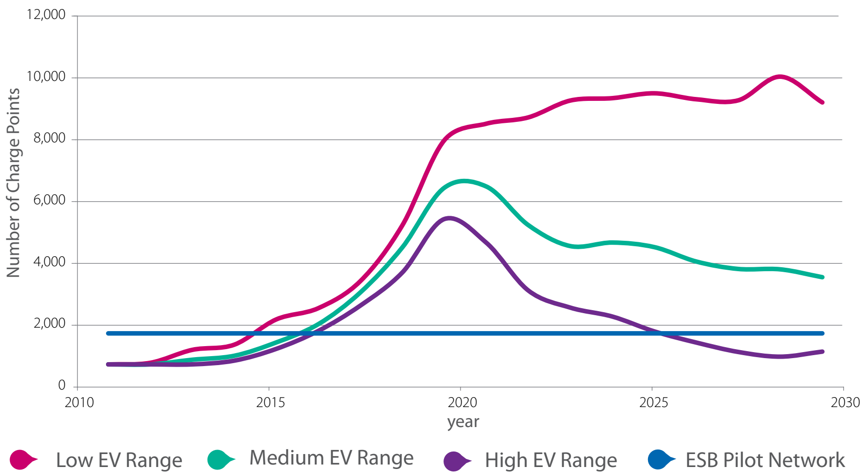
Key Results

High Scenario - Additional Winter Night MW Capacity Requirement for EV & H_2 Fleets for varying Night Charge Periods



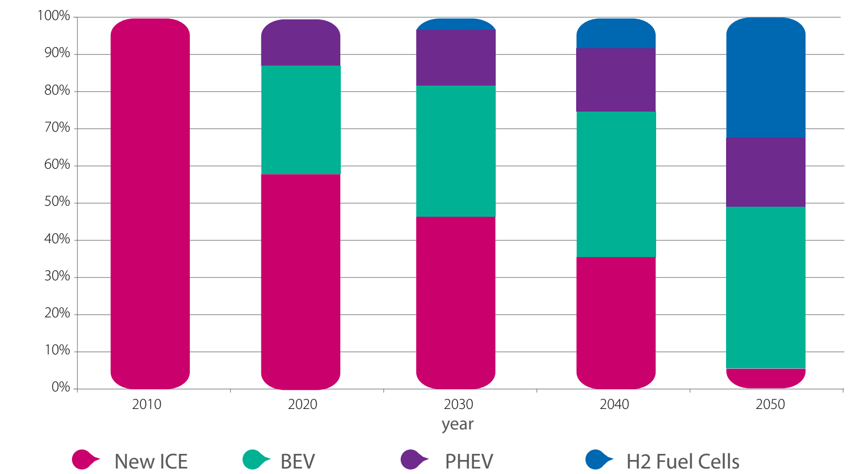
Key Point: Critical use of electrical grid occurs during winter peak demand. Assuming nominal grid development, significant capacity should exist for night time EV charging. Control of charging window during the night time period can be used to offset the requirement for any upgrade of network assets. This could change significantly should electrical heating systems also be encouraged on our energy system.

Number of Charge Points required as a function of Battery Range Development for the projected number of EVs[1]



Key Point: Public charging infrastructure re-assures motorist in the early days of EV deployment. As battery range and familiarity increases, reliance on public charge points will reduce. This measured approach will mitigate the risk of charging infrastructure overdeveloping.

Annual % Vehicle Sales for Mean Deployment



Key Point: EVs' share of annual sales grows to 42% by 2020, enabling Ireland to meet the 10% EV penetration target, and to 60% by 2050, resulting in 1.8m EVs in a total car stock of 2.9m vehicles.

1. (courtesy ESB Ecars)

Summary Results for Low, Mean and High % EV Deployment - ktoe

	Units	Baseline 2011	Low Scenario	Mean Scenario	High Scenario
Total Car Stock	Units	1,868,000	2,932,005	2,932,005	2,932,005
% EV in Car Stock	%	0%	48%	60%	70%
Number of EVs	Units	0	1,407,362	1,759,203	2,052,404
Primary Energy					
Fleet Primary Energy Consumption	kToe	1,598	1,231	1,186	1,141
% Reduction	%	N/A	23%	26%	29%
Energy Imports					
Energy Imports	kToe	1,598	969	885	801
% Reduction	%	N/A	39%	45%	50%
Final Consumption in Transport					
RES-T Fleet Final Consumption	kToe	1,598	1,625	1,638	1,651
RES-T RE Final Consumption	kToe	0	656	753	850
% Change	%	N/A	40%	46%	51%
CO_2 Emissions					
Fleet Emissions	kTonne CO2	4,930	1,756	1,336	917
% Change	%	N/A	64%	73%	81%
Primary Energy BAU Saving					
BAU (ICE only)	kToe	1,598	1,420	1,420	1,420
% Reduction wrt 2011	%	N/A	11%	11%	11%

Summary Results for Low, Mean and High % EV Deployment - GWh

	Units	Baseline 2011	Low Scenario	Mean Scenario	High Scenario
Total Car Stock	Units	1,868,000	2,932,005	2,932,005	2,932,005
% EV in Car Stock	%	0%	48%	60%	70%
Number of EVs	Units	0	1,407,362	1,759,203	2,052,404
Primary Energy					
Fleet Primary Energy Consumption	GWh	18,586	14,318	13,794	13,269
% Reduction	%	N/A	23%	26%	29%
Energy Imports					
Energy Imports	GWh	18,586	11,265	10,291	9,316
% Reduction	%	N/A	39%	45%	50%
Final Consumption in Transport					
RES-T Fleet Final Consumption	GWh	18,586	18,897	19,047	19,198
RES-T RE Final Consumption	GWh	0	7,631	8,757	9,882
% Reduction	%	N/A	40%	46%	51%
CO_2 Emissions					
Fleet Emissions	kTonne CO2	4,930	1,756	1,336	917
% Reduction	%	N/A	64%	73%	81%
Primary Energy BAU Saving					
BAU (ICE only)	GWh	18,586	16,510	16,510	16,510
BAU % Reduction wrt 2011	%	N/A	11%	11%	11%

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Ireland's EU Structural Funds
Programmes 2007 - 2013

Co-funded by the Irish Government
and the European Union

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STRUCTURAL FUNDS

The Sustainable Energy Authority of Ireland is partly financed by Ireland's EU Structural Funds Programme co-funded by the Irish Government and the European Union.

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