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National policymaking and the promotion of electric vehicles

by

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Abstract

This paper considers supply-side factors underpinning technology forcing by national policymakers in the low carbon vehicle sector. It focuses on five countries – France, Germany, Italy, Spain and the UK – and examines the driving imperatives for promoting alternative fuel vehicle and electric vehicle uptake. It does so by looking at four over-arching concerns for decision-makers; energy security, sustainable development, impact on the existing automotive sector and the pressure from sub-national actors such as city councils. The paper seeks to show that national policy in the five selected countries is heterogeneous in nature making consistent, standardised approaches to policy implementation a challenge, despite the similarity in ambition to advance instances of electromobility and to transition from conventional transport technology to alternatively fuel-sourced vehicles.

Keywords

Low carbon vehicle, lead markets, technology forcing, supply-side policy.

I. Introduction

Despite the presence of a tight, regulatory framework driving the demand for low emission vehicles and the existence of strong support from industry and from policy makers at various levels of government, the take up of these vehicles by European Union (EU) consumers remains sub-optimal. Why this is the case is of interest to both policy makers and stakeholders seeking to understand how demand can be increased in the context of challenging emission targets across the globe. This paper will focus on supply-side issues and the role of policymakers in agenda-setting and technology forcing. The aim of the article is to provide an analysis of policy initiatives introduced by five national actors, to understand the decision-making process underpinning the promotion of key technologies central to decarbonising their respective transport sectors. By doing so the discussion will offer improved understanding of the drivers of these policies and enable the identification of successful policy approaches that perhaps can be utilised by other national policy-making units facing similar challenges.

The focus will be placed on five EU member states; France, Germany, Italy, Spain and the UK. These five countries account for 72.8 % of total vehicle production in the EU and four of the five (France, Germany, the UK and Spain) are the largest EU motor manufacturers in terms of number of vehicles produced per annum (ACEA, 2016). The same countries also account for the vast majority of new vehicle registrations in the EU (75.6 %). All five are also legally bound by the same European manufacturing regulations that address carbon emission reduction in the European transport sector.[1] However, the policy response by these countries in terms of promoting carbon free motoring has been notably different, demonstrating the importance of national policy interpretations in technology-forcing. Such is the centrality of these actors that they have had the effect of creating lead markets for certain vehicle types such as, arguably, both hybrid and fully Electric Vehicles (EVs).[2] Yet all five have had varying experiences of low carbon vehicle uptake. By comparing and contrasting their respective approaches to decarbonising their networks an improved knowledge of the drivers of policy can be developed.

To address the issue of policy drivers, the paper utilises the following structure. Initially it considers the role of technological selection in the development of lead markets for key products. Having considered the factors that lead to policy makers preferring different forms of intervention, the

[1] A case could also be made for the inclusion of one of the Eastern European countries that accessed to the EU in 2004, the Czech Republic or Slovakia for example. However space prohibits such a discussion here.
[2] The term Electric Vehicles (EVs) refers to a wide range of technologies including; battery electric vehicles (BEV), extended range electric vehicles (EREV), plug-in hybrid electric vehicles (PHEV) and fuel cell electric vehicles (FCEV). Hybrid electric vehicles (HEV) that use an e-motor as their secondary rather than primary means of propulsion are not classified as EVs in this paper.

subsequent section details the federal regulations that establish the carbon emission rules for European automakers. Section IV then looks at Low Carbon Vehicle (LCV) and Alterative Fuel Vehicle (AFV) proliferation amongst the selected member states, with particular reference to electromobility and EVs. With this context established the remainder of the paper focuses on comparing and contrasting policy initiatives and identifying the key drivers of same, as well as considering the relative merits of these approaches.

II. Technology-forcing and lead markets

To rapidly decarbonise transport by technology-forcing requires a significant shift in policy-making. While there are opportunities for market expansion, export and employment growth through policy intervention in lead technologies, in the increasingly complex area of environmental policy, where decisions closely intersect with economic and societal concerns, the role of national institutions is more challenging than ever before (Loomis and Helfland, 2001; Brown and Ryan 2011; Annema et al, 2015). The need for practical considerations in policy formulation can lead policy makers to adopt only incremental changes, fearful that too rapid a transformation might bring about resistance that would lead to policy failure. Identifying optimal conditions for involvement by policy actors in the area of low carbon transport has encouraged a spate of academic analysis, including the development of Cost-Benefit models. For example, as part of the process of determining when intervention was warranted, Greene et al (2010) developed a Cost-Benefit analysis model of Zero-Emission mandates in the US that also incorporated concepts of net social value, network external benefits and adaptation to an uncertain future, offering guidance on intervention for policymakers. Masiani (2015) also considered the use of Cost-Benefit analysis for electric vehicle policy development in Germany. However, the conclusions reached were that existing models were still limited in their value due to the added complexity of factors such as policy response or integration with other transport sectors into existing Cost-Benefit models.

Intervention by policymakers in environmental, energy and transport sectors is frequently justified by whether it's stimulating industrial innovation, research and development (R&D), or if it is bringing about optimal levels of performance in a socially acceptable manner. Porter et al (1995) point to the role of environmental regulations as a driver of technological innovation, with the use of incentives and standards stimulating research in areas that would otherwise remain a low priority. This can lead to increased entrepreneurial competitiveness and may in turn induce the creation of lead markets in pioneering countries as the early adopter advantage, allied to regulatory constraints, can pressure competing firms to adopt the same technologies (Porter and Vander Linde, 1995; Beise and Renning, 2003; Wiesenthal et al, 2015). Authors such as Kiempe (2000), Beise (2003), Zubaryeva

(2012) and Massiani (2015) have focussed on the role of the state in the development of lead markets for emerging technologies. Prompted by marketing models of technology diffusion (such as the Bass diffusion model[3]), these authors identified a number of exogenous factors that served to influence technology take-up; national demographics, economic, political and social factors. However, in the case of environmental challenges and technological innovation, a double externality is incurred. Effectively the cost of innovation for the private company exceeds the social value of the innovation itself, since private companies are not motivated by positive spill over effects (EC, 2011). It is this gap between societal good and profitability that underpins the need for public policy engagement and drives national agendas which in turn translate into the development of lead markets by national policymakers, as will be discussed. While authors like Kiempe, Beise, Zubaryeva and Massiani took a top down approach to understand technological diffusion, work by authors such as Calef and Goble (2005) and Greene (2010) considered the role of local and regional factors in the process of promulgation. California provides one international example of how regulatory actions driven by social and economic concerns at a regional level can organically promote specific technologies at the national, a point that will be considered later in this paper, when the role of European cities in driving the decarbonisation agenda are examined (Calef & Goble, 2005; Greene et al, 2010).

However, in terms of low carbon transport policy the situation is complicated by a host of competing priorities of which environmental concerns are but one, if crucial, factor. As Van Geenhuizenet (2007) argues, transport is a highly involved sector involving a complex system incorporating a multitude of factors. In terms of low carbon transport policy, the importance of four broad categories of concern serve to influence decision-making; resource management and energy security, social concerns and sustainability, industrial impact and, finally, local and regional considerations. These competing priorities have served to influence policymakers in the selected countries and, in turn, are primarily a consequence of exogenous factors related to limited resources, environmental challenges and health concerns. It is the interplay of these factors that make decarbonising transport such a complex issue. Responses to this carbon challenge by national policymakers can, by and large, be categorised under two approaches. In the first instance through the use of incentive-based instruments such as emissions taxes, subsidies and tradable allowance systems. Secondly, through direct regulatory instruments, for example technology mandates and performance standards (Goulder and Parry, 2008). In the instance of the five selected countries, these decisions occur within a well-established and clearly demarcated federal legal structure.

[3] The Bass Diffusion Model dates back to 1969. It is a standard marketing model for explaining how technology diffuses through innovative adopters driving the popularity of a product and encouraging its uptake by offering proven knowledge, experience of use and, therefore, credibility to other consumers.

III. Federal legislation and its impact on European automotive manufacturing

The EU regulatory framework that sets CO_2 emission standards for motor manufacturers in the five selected countries has been in place for nearly a decade. Legislation was introduced in 2007 by the European Parliament and the European Council to bring about a reduction in vehicle emissions across all member states. The 2007 strategy for reducing CO_2 emissions for light duty road vehicles included a number of Regulations on new car and van CO_2 emissions. A short term target of 130 gCO_2/Km by 2015 and a longer term target of 95 gCO_2/Km by 2020 were established for cars. For vans these targets were 175 gCO_2/Km by 2017 and 147 gCO_2/Km by 2020 respectively (to be phased in by 2021). The key Regulations, (EC) No 443/2009 and (EU) No 510/2011, provided the core of CO_2 emission performance standards for EU road vehicles (with support from a variety of secondary legislative regulations). An integral component of these regulations was ensuring that manufacturers should have the flexibility to decide how to meet targets set. Producers were allowed to average emissions over their fleet - averaging across new vehicle registrations in the Community - rather than setting CO_2 for each individual vehicle. Further, the decision was made not to apply the same reduction targets to small-volume manufacturers (defined under Article 11 as a manufacturer responsible for fewer than 10,000 passenger cars registered per annum in the Community, or 22,000 light commercial vehicles). Instead these small-volume manufacturers could apply for a derogation from these specific emission targets and were allowed benefit from an alternative target; 25% lower than their average CO_2 emissions in 2007 ((EU) No 510/2011; EC No 443/2009).

The decision to offer derogations to small-volume manufacturers stemmed from the belief that alternative reduction targets should take into account the technological potential of a given manufacturers vehicle to reduce CO_2 emissions, as well as making them consistent with the market segments concerned. Such an approach was defensible as it offered automotive producers flexibility during a transitional period that would allow a smoother changeover, away from traditional, polluting technologies toward cleaner, environmentally responsible technologies. Large-volume manufacturers also benefitted from a degree of leniency during these transitional years; As noted, manufacturers were given allowance to form a fleet pool that measured average emissions from the pool as a whole for purposes of meeting emission reduction targets. Effectively this could be interpreted as allowing manufacturers to continue producing more polluting models as long as this was offset by the new registrations of low carbon emitting vehicles.

A further incentive was the introduction of super credits to promote the production of low emission vehicles. These credits allowed manufacturers of LCVs (below 50 gCO_2/Km) to count a single vehicle as multiple vehicles in their fleet. Starting in 2012, each of these vehicles counted as 3.5 vehicles above the 50 gCO_2/Km limit. Their value would then be gradually reduced until by 2016 they would only be considered as a single vehicle in the fleet once more. Another round of super credits is set to come online in 2020, when these LCVs (below 50 gCO_2/Km) will count as 2 vehicles in a fleet, gradually reducing back down to 1 by 2023. These super credits were used to encourage R&D as well as production of LCVs and ultra-low carbon vehicles.

This approach to both high and low volume manufacturers carried with it certain concerns. For example by allowing manufacturers to average emissions across fleets and pools of fleets, producers could choose to seek out strategic partnerships rather than pursue innovative, technological solutions. For small-volume manufacturers and niche producers, the allowances made in terms of emission targets might potentially discourage the expansion of production beyond the defined limits. Such compromises could feasibly sacrifice optimisation for flexibility. However, it does allow member states greater control over their own domestic automotive sectors. By offering over-arching supply-side interventions with a degree of leeway built-in to regulations, it has allowed member states control over their own policy initiatives with differing results.

IV. Promoting the decarbonisation of the transport fleet

Despite their importance in terms of producing these vehicles, four of the five selected countries have low levels of Alternative Fuel Vehicle (AFV) penetration of their respective fleets; France, Germany, Spain and the UK all record levels below the European Union average of 4.9 % (ACEA, 2016a).[4] Only Italy (9.6%) greatly exceeds the EU average and serves as an important comparator for the other nations.[5] In fact, the larger the vehicle manufacturing base, the likelier it will be that there will be lower instances of AFVs as a percentage of the vehicle fleet, as shown in Fig 1 below.

Fig 1: Vehicle production, new registrations and instances of AFVs; selected countries

Member state	Vehicle production	New registrations	AFVs as % of fleet
France	1,855,231	2,210,927	3.5
Germany	5,954,838	3,356,718	2.6
Italy	694,750	1,491,965	9.6
Spain	2,418,462	987,281	2.2
United Kingdom	1,597,892	2,843,030	4.7
European Union	**17,191,442**	**14,399,784**	**4.9**

Source: ACEA, the Automobile Pocket Guide 2016a

[4] An Alternative Fuel Vehicle is defined by the European Automotive Manufacturers' Association as being a motor that is powered by means other than an internal combustion engine and includes pure electric, liquefied petroleum gas vehicles, natural gas vehicles, ethanol (E85), biodiesel and plug-in hybrid vehicles.
[5] Italian motor manufacturers also specialise in small passenger car design, a natural fit for EVs and AFVs.

While the correlation is ambiguous and open to criticism, it does raise some interesting questions on AFV uptake in these countries. All five member states use a range of incentive-based instruments to address the issue of carbon emissions and encourage a move away from traditional internal combustion engine (ICE) technology toward AFVs, most notably EVs, as will be shown. This includes the use of CO_2 based motor-based vehicle taxes in some countries, which have been broadly welcomed by car manufacturing representative organisations such as the European Automobile Manufacturers Association (ACEA). However, the lack of uniformity in their implementation has caused ACEA some concern (ACEA, 2016b). Fig 2 below summarises these taxes.

Fig 2. Carbon emission based vehicle taxes in selected EU member states

France
Introduced in January 2008 the *bonus-malus* (good-bad) system is one of the key measures the French government is using to bring down carbon emissions. Vehicles below 130 gCO_2/Km are credited while those above this level are taxed on a varying scale up to as high as €8,000 for vehicles that emit more than 201 gCO_2/Km. Company cars also pay a range of charges.
Germany
Annual tax is set at a rate of €2 per 100 cc (petrol) and €9.50 per 100cc (diesel). A further carbon tax is then charged at €2 per gCO_2/Km emitted above 95 gCO_2/Km.
Italy
None
Spain
Has a variable tax rate for registrations based on carbon emissions of vehicles (4.75% for vehicle s between 121 gCO_2/Kmand 159 gCO_2/Km and 14.75% for vehicles of 200 gCO_2/Km and greater)
United Kingdom
Annual car tax is based on carbon emissions. Vehicles below 100 gCO_2/Km are exempt, those above this level taxed up to a maximum of £505 (for vehicles exceeding 255 gCO_2/Km). Additionally there is a first year fee; Vehicles below 100 gCO_2/Km are exempt, those above this level taxed up to a maximum of £1,100 (for vehicles exceeding 255 gCO_2/Km). Liability tax on company cars are also based on carbon emissions.

Source: Automotive Industry Data (AID); SMMT; National Automobile Manufacturers Associations (NAMA); ACEA

In addition to these penalties designed to discourage the use of ICE vehicles there are also a range of incentives to promote uptake of LCVs and AFVs by automotive users. Most notably within the wider classification of AFVs, electric vehicles (BEV, EREV, PHEV and FCEV) are heavily promoted by all five nations. Electric motor technology is perceived as central to the decarbonisation process; even though ownership numbers are still negligible, all five countries see enormous potential penetration rates of their respective fleets.

A range of incentives such as tax breaks and preferential parking complement the use of subsidies to promote purchases of EVs. France offers a premium under its bonus-malus system for green vehicles as well as a 'super bonus' for buying a green vehicle and scrapping an old one. Electric vehicles are also exempt from the company car tax. In addition to EVs being exempt from the annual circulation tax in the UK, there is also a one-time subsidy of 35% of the cost of a car, up to a maximum of either £2,500 or £4,500 depending on the model, while 20% of the cost of a commercial vehicle (up to a maximum of £8,000) will be paid by the government. Despite previous German opposition to subsidising EVs, Chancellor Angela Merkel recently announced a deal to supply a subsidy of up to €4,000 for these vehicles as part of a plan to have one million EVs on German roads by 2020 (Bloomberg, 2016). In Italy EVs are exempt from the annual circulation tax for a period of five years. The level is then set at 75% thereafter. Finally, Spain utilises a scrappage scheme, *Programa de Incentivos al Vehículo Eficiente* (PIVE), as well as a range of subsidies (up to €6,000 per vehicle) in its plans to promote the purchase of a targeted one million EVs. Despite efforts that include regional and local initiatives to support the charging and parking of EVs, penetration rates are a negligible share of national fleets as shown in Fig 3below.

Fig 3. European Sales of Pure Electric and Plug-in Hybrid Electric Vehicles 2014-2015

Country	**2014**	**2015**	**2015 Market Share**	**% Change**
Austria	1,718	2,787	0.9	62.2
Belgium	2,047	3,837	0.8	87.4
Denmark	1,616	4,643	2.2	187.3
France	*12,497*	*22,867*	*1.2*	*83.0*
Germany	*13,118*	*23,481*	*0.7*	*79.0*
Italy	*1,420*	*2,283*	*0.1*	*60.8*
Netherlands	14,805	43,441	9.7	193.4
Norway	19,771	33,721	22.3	70.6
Spain	*1,405*	*2,224*	*0.2*	*58.3*
Sweden	4,667	8,588	2.5	84.0
Switzerland	2,688	6,288	1.9	133.9
UK	*14,608*	*28,715*	*1.1*	*96.6*
Europe	**92,455**	**186,170**	**1.41**	**101.4**
European Union	**69,996**	**146,161**		**108.8**

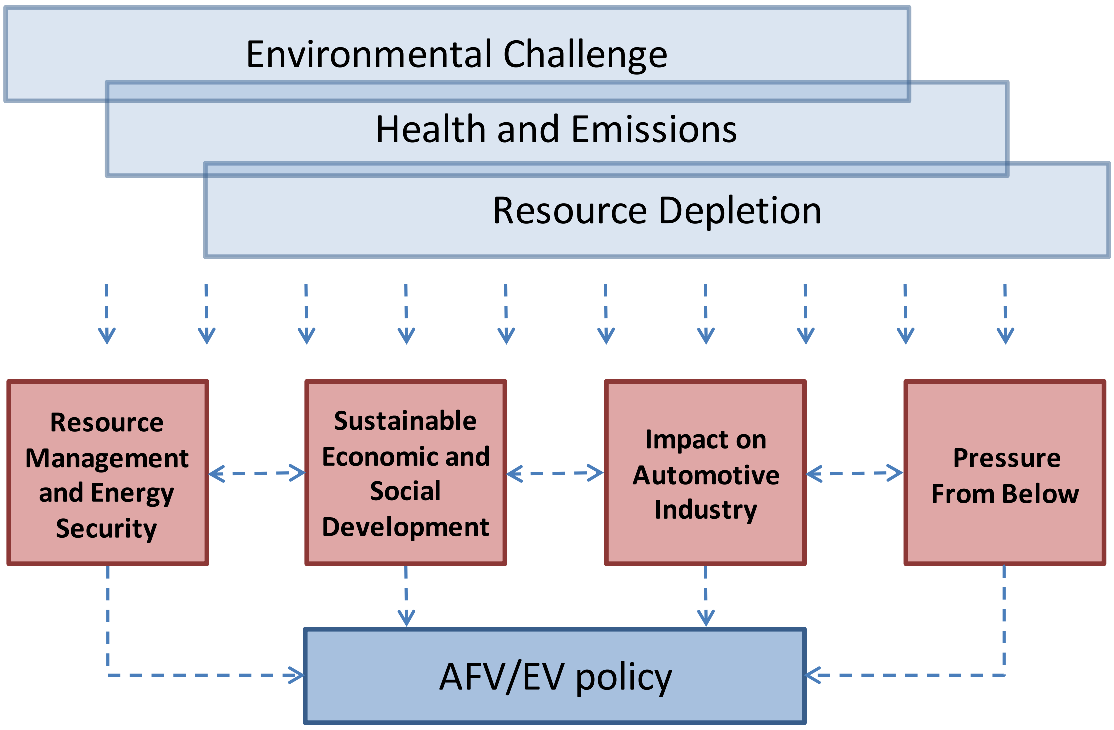
Source: Automotive Industry Data (AID); SMMT; National Automobile Manufacturers Associations (NAMA); ACEA

What is evident from the above is that all five countries have a number of far-reaching and important policy tools in place to promote the domestic consumption of AFVs, most notably EVs. Yet, even though the numbers remain small there is still significant variation in terms of penetration of their respective fleets. There are also significant differences in approaches to promoting AFV technologies. Understanding drivers of these policies in the respective countries and how these have translated into consumer uptake will be the focus of the remainder of the paper.

V. Factors underpinning policy-making decisions

Fig 4 below offers the authors' illustration of the key factors influencing the formation of policy impacting on the decarbonisation of transport in the five selected countries as identified in the literature above. The overarching concerns are environmental, wellbeing and resource scarcity. In turn these pressing, exogenous factors are considered by national actors from four standpoints; energy security, sustainable new development, impact on existing industry and interaction with regional and local agencies.

Fig. 3: Factors influencing the formulation of low carbon AFV/EV policy



The priority for policymakers is that they choose the right, future-proof technologies (as opposed to a developmental cul-de-sac) that don't create external resource dependency and are a suitable fit with existing industry, avoiding excessive structural change and economic upheaval. In addition the activities of sub-national actors, particularly around issues of noise and air pollution, have also served to influence national policy and determine responses. These four perspectives serve as a useful prism to understanding the differing priorities of the selected countries.

Resource management and energy security

The context to understanding the role of energy security in AFV/LCV uptake in the five selected states is the EU Directive 2009/28/EC (and before it Directive 2001/77/EC) as well as the *Europe 2020* strategy, which set ambitious energy goals and renewable energy targets for its members.[6] The promotion of renewable, clean energy neatly complements the decarbonisation of European transport networks. For example, the promotion of EV technology makes considerable sense from a French energy security perspective. Oil and natural gas are in very short abundance domestically, accounting for just 1.1 % of total energy production in 2014 (Eurostat, 2015).[7] The bulk of energy production is accounted for by nuclear power (80.9 %) and renewable energy (17.1 %). In fact France is a net exporter of energy to the rest of the EU and in 2010 was urged by the Energy Agency (IEA) take a more strategic role as provider of low-cost, low-carbon based energy for the whole of Europe, rather than continuing to focus on energy independence (IEA, 2010). The decision to pursue a nuclear energy policy stemmed from a 1974 decision to safeguard France's energy independence in the wake of a series of global oil shocks during the period. The result is a country with amongst the lowest cost electricity in Europe, with extremely low CO_2 emissions per capita from electricity generation (WNA, 2016). Little wonder French policymakers are keen to promote electric vehicle technology at the expense of conventional ICE automobiles; crude oil was the most imported good into France in 2013 (Eurostat, 2015; WNA, 2016).

Germany, in contrast, has been slower to embrace EV technology due in part to its commitment to biofuels. Germany is one of Europe's largest biofuels producers as a result of the decision to promote biofuels and bioenergy since the early 1990s (Bomb, 2007; IEA, 2012; UFOP, 2015). The country experienced rapid growth in production capacity between 2000 and 2007, incentivised by tax exemptions for pure biofuels (IEA, 2012). Bioenergy in particular is deemed strategically important in terms of energy security, but also as a way to support agricultural as well as regional development (Bomb, 2007; IEA, 2012; UFOP, 2015). Figures from the German Ministry of Food and Agriculture certainly indicate the importance of biofuels and biogas to the Agricultural sector. The value added by energy crops contributes approximately €2.6 billion to the German economy every year. The strategic import of biofuels is not only economic. A significant proportion of German

[6] The *Europe 2020* strategy set three targets for climate change and energy sustainability; the reduction of greenhouse gas emissions by 20% (or 30%, given optimal conditions) compared to 1990 levels, 20% of energy production to be derived from renewables and, finally, a 20% increase in energy efficiency.
[7] Latest available figures, though a new report is due from Eurostat in June 2016.

domestic energy production is in the form of renewable sources (including energy crops). However, these renewable energy sources do not offer the same stability, accessibility and low costs as nuclear power (Stuchtey and Below 2015). Unlike in France, Germany has no love affair with nuclear power. Up until 2011 about 25% of German total energy production came from nuclear plants. This came after nearly a decade of government attempts to phase out nuclear power, a policy first instigated mooted by the 1998 coalition government. This process was suspended in 2009, but restarted in 2011, a decision that Lovins attributes to the shock of the Fukushima disaster in 2011 and a choice supported by the vast majority of German people (Lovins, 2011; WNA, 2015). Nuclear power currently accounts for 20.8 % of German energy production, renewable energy 27.9 % and oil and natural gas reserves about 10.5 %. The remainder (37.4 %) is solid fuel (Eurostat, 2015). The result is that German electricity costs nearly double that of its French counterpart, with obvious consequences for EV uptake in particular.

In contrast to the above, the main concern for UK energy security is dwindling oil and gas reserves in the North Sea in addition to a number of power plant closures (Bird, 2007). In 2003 the UK had the highest level of primary energy production among the EU member states, almost double that of Germany. A decade later the UK went from being a net energy exporter to a major importer; the energy equivalent of 94,400 thousand tonnes of oil were imported in 2013 alone (Eurostat, 2015). Effectively the UK is moving from self-sufficiency to oil, gas and coal import dependence. Renewable energies have consequently become a key component of government policy as part of the environmental challenge, but also in an attempt to limit imports of energy; however penetration rates are still very low at 7. 7 %. Nuclear energy accounted for just 16.6 % in 2013, less in fact than Germany, with the rest of domestic energy production being derived from oil, gas and solid fuels (Eurostat, 2015). To date the response from the UK government has been to liberalise electricity markets and improve electrical production efficiency as well as usage through an improved smart grid. New capacity built by 2015 consisted mostly of gas and coal-fired stations, as well as wind farms, but longer term plans are less clear (DECC, 2015). An increased focus on options such as oil sands, extra-heavy oil, oil shale and coal-to-oil may be one solution, but would do little for carbon reduction.

Imported energy dependence is a major consideration for both of the remaining countries. Italy produces very little of its own consumed energy domestically, though what it does produce is largely from renewable sources such as hydropower. Italy is amongst Europe’s largest energy consumers, with transport accounting for the majority of this use, particularly imported oil and gas consumption (IEA, 2015a; WEC, 2013; energypost, 2014). It makes sense then for Italy to pursue the development of domestic renewable energy sources in keeping with the commission's *Europe 2020* strategy. Consequently the Italian target for renewable energy component of final energy consumption has been set at 17% and 10.06% of alternative fuels in the transport sector by 2020, as stated in the National Renewable Energy Action Plan (EEA, 2016). Since 2002 Italy has used Green Energy Certificates and a feed-in-tariff system to encourage the production of hydropower. The next largest source of renewable energy is derived from biomass (WEC, 2013). Ending dependency on strategic resources like oil and gas by encouraging transport technology substitution and increased use of advanced biofuels in existing petrol and diesel fuel mixes is important for the government.

Similarly Spain imports approximately 70% of its energy supply. Primarily these imports are oil and gas. However, Spain has seen significant reductions in its imports of energy over the last decade, reaching a new low in 2013 (Eurostat, 2015). Most of this reduction can be considered a result of the energy policies pursued by successive governments to diversify and increase domestic energy production (Eurostat, 2015; IEA, 2015b). During the same period the Spanish government has engaged in significant reform of the gas and electrical market. This has included progressive liberalisation and cross-border integration of energy networks with France (IEA, 2015b; Gomez, 2011). To complement this EVs have received significant support from the Spanish government in the form of subsidies and grants in an attempt to continue the downward trajectory of oil imports and encourage its substitution with cleaner energy.

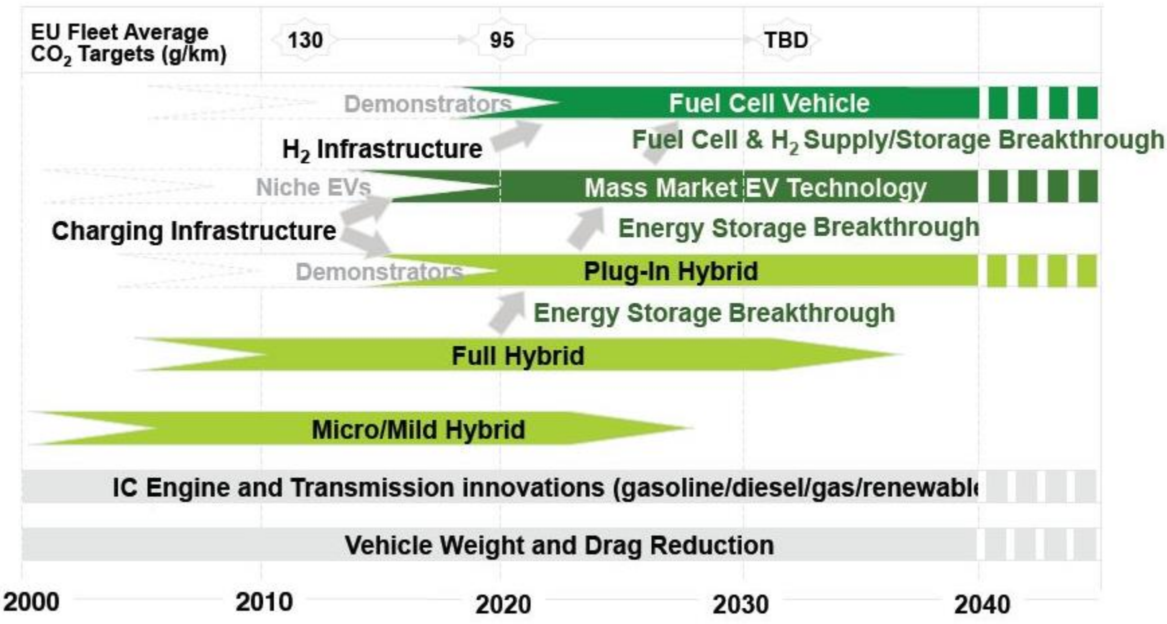
What emerges from the above is that Member States are heterogeneous when it comes to energy policy. This makes a common energy policy difficult to achieve, but also influences transport policy; countries might accept the broad strokes of EU regulation, but are influenced in their decision-making by their own energy production priorities. In turn transport technology choice is, arguably, subordinate to the strategic energy concerns of individual countries. The decision to pursue modal shifts to electric vehicle technology is determined as much by the need to end oil import dependency as by the value of EVs as a clean transport solution. In other areas too these five countries demonstrate pragmatic concerns when it comes to technology forcing.

Sustainable transport solutions

Complementing the question of energy security is the issue of sustainability. If energy security concerns are rooted in rational considerations about the present, sustainability focuses on longer term future-proofing of energy and transport sectors. The perceived economic benefits of early engagement with an emerging industrial sector are clear; entry into emerging markets will allow brand recognition, brand growth and development that late adopters will be forced to compete with. Furthermore, creating lines of communication and knowledge exchange will allow these pioneers to establish productive research networks. Little wonder then that states with a significant automotive sector have proven so eager to promote LCV technology and AFV consumption utilising a range of policy tools to take advantage of existing knowledge and industrial presence. However, the over-riding importance of the environmental aspect to the greening of the transport sector means that the economic development of the LCV sector and promotion of AFVs has incurred substantial regulation. To date policymakers in the selected state have favoured a sustainable developmental approach, incorporating aspects of social, economic and environmental policy into the development of the LCV sector (Streimikiene, 2009). Central to this developmental approach is ensuring that the LCV sector does not develop path dependencies around finite resources as has occurred with ICE technology and instead follows a technological roadmap that remains relevant in the medium to long-term, but is also in tune with socio-economic and environmental considerations.

The EU has framed the decarbonisation of European transport networks around the concept of sustainability. The Sustainable Urban Mobility Plan provides a major example of the commitment at supranational level to ensuring future transport networks are developed using long-term goals and objectives that balance and integrate all modes of transport by understanding and assessing current and future performance of urban transport systems (EC, 2016). National actors have been influenced in their own long-term thinking by these overarching objectives, but the complexity of the challenge has elicited a range of varying responses. In the UK, for example, the Automotive Council in the UK is the driving force behind technological change in the UK transport fleet. Its earlier, simplified developmental path of transport change in the UK passenger car market was updated in September 2013 to include a range of technological roadmaps for different vehicle types, such as passenger cars (Fig. 4).

Fig. 4: Automotive Council UK Passenger Car Low Carbon Technology Roadmap



Source: Automotive Council UK, 2016

The commitment to electromobility is predicated on the understanding that it will supply short-to-medium term carbon emission reduction solutions, while expected technology breakthrough will ensure sustainability and competiveness.

The adoption of long-term strategic plans is a common theme amongst all five countries. For example in August 2007 Germany adopted an energy and climate programme, consisting of 29 key elements, doubling Germany's previous climate protection targets (FME, 2007). The emphasis of the plan differed somewhat to its UK counterpart. For example it envisaged a much greater expansion in the use of advanced biofuels. As the German transport sector still lags behind stated carbon emission goals it is argued that the widespread use of biofuels offers a more immediate solution to the carbon challenge (REA, 2016). This would allow pressing climate-change objectives to be achieved while technologies such as electric and hydrogen continue to establish a market presence (Hockenos, 2016; REA, 2016; UFOP, 2015).

Electromobility has been deemed as the central component to these strategic plans, as well as to the future of the five selected countries transport sectors. In 2010 the German federal government and automotive industry jointly declared targets and measures to establish electric mobility through the German National Platform for Electric Mobility (NPE, 2016; GTAI, 2016). Both France and the UK have similarly developed road maps for the electrification of their respective transport fleets, but have done so from a much earlier date and are, arguably, further advanced in achieving their goals than their German counterparts. France, with its large capacity of cheap electric power allied to an automotive sector with small car technological skills and a desire for new markets, was an early engager and promoter of EVs. The 2008 the *Grenelle de l'environnement* law provided a framework for public support by offering a fiscal stimulus package to encourage electromobility. The following year the *Low Carbon Vehicle Plan* and offered a range of incentives to simultaneously tackle both supplyand demand issues, including generous subsidies and supporting semi-governmental companies fleet procurement of EVs (IFA, 2012; Altenburg et al, 2015).

Italy also enjoys considerable advantages in small-car technology that are beneficial to UV development. To date, however, it is gas-powered vehicles that have seen the most expansion in terms of AFVs. EVs are a negligible share of the market as shown previously in Fig 3. Instead gas powered vehicles dominate AFV penetration. Gas-fuelled cars first became popular in the 1970s and received a further fillip in the 1990s when small-to-medium sized models powered by compressed gas were released onto the Italian market. Since 2008 the government has supported their proliferation using natural gas subsidies and heavy investment in filling station infrastructure. These subsidies ended in 2010, slowing down the rate of consumer uptake, but these AFVs are still a substantial share of new vehicle purchases. Figures from the Italian Association of the Automotive Industry for 2015 show 11.6 % of new registrations are LGP or methane variants, compared to just 1.8 % of new registrations beings EVs or hybrids thereof (ANFIA, 2016). CNG does offer significant advantages over petrol and diesel; burning clean and releasing significantly lower emissions of NOx, CO and CO_2. It also possible to derive it from renewable sources; however, in Italy gas is primarily imported and from non-renewable sources.

This not only raises questions over energy security, exposing the country to potential external energy dependency, but also is problematic in the longer-term from a sustainable perspective. In the short-to-medium term there is scope for substantial expansion though, with representatives of the Italian natural gas industry (NGV) noting that only 12 of the country's 20 regions are well-served by filling stations (NGV, 2016). This may explain why Italy has been relatively slower in promoting electromobility, though it is on the national agenda (Ministry of Economic Development, 2013). In addition to tax cuts for EVs the national parliament is also considering further measures to encourage EV uptake. However, high energy prices and limited infrastructural support in the form of charging stations inhibit the efforts of Italian officials to promote EV use. The example of CNG demonstrates how the Italian market is responsive to government measures to promote key AFV technology; a similar argument can be made for the potential effectiveness of subsidising EVs.

Impact on the automotive industry

The global automotive industry remains the largest producer and employer in the global market (Dicken). Consequently any substantive changes to automotive legislation and policy that could result in major sectoral shifts that are liable to derail national economies and global markets unless carefully and gradually introduced. The carbon emission regulatory framework pursued by countries and organisations with a major automotive presence has, to date, been designed primarily to provide flexibility for the existing automotive industry, to help mitigate the high costs of emission reductions. Firms with extensive capital investments in ICE technology have been given a degree of latitude and time to make the move toward carbon free motoring. This holds true for the five selected countries focussed on in this paper and in actuality ties in closely with their aims for economic sustainability; if social, environmental and economic harmonisation are key factors for the future development of the automotive sector then a smooth transition for the existing industry, with limited disruption to the social and economic balance, also dovetails closely with these aims. However, the possibility does exist that by providing this flexibility targeted emission levels might lag behind stated objectives (Fontaras and Samaras, 2010).

The automotive sector responds well to a strong, regulatory environment and in fact welcomes clarity in certain areas (Wisenthal et al, 2010). ACEA, for example, argues that carbon taxes must be standardised across the European common market and should be technology neutral, budget neutral and linear, to allow automotive firms the opportunity to explore a range of technological solutions to offer the consumer (ACEA, 2016b). This supports the argument put forward by Ockwell et al that automotive manufacturers are not resistant to change, but are instead looking for a clear roadmap for carbon emission reduction; If manufacturers are to make large capital investments they must be assured that certainty of markets and regulation exists (Ockwell et al, 2008; Bastard, 2010). Bastard in fact concludes that economic instruments such as carbon taxes have effectively served to orient the market towards low carbon-emitting vehicles, raising awareness of new models amongst consumers and putting the issue of low carbon vehicles higher on the agenda of buyers. This has accelerated the trend toward purchasing new low emission vehicles and helped grow consumer awareness of the carbon challenge in conjunction with other drivers such as resource depletion and climate change (Bastard, 2010).

Arguably one outcome of increased regulator activity has been to create new market opportunities and encourage new investment models, such as battery leasing, for manufacturers. It is not just in terms of the environment and resources that sustainability has a role to play. Economically all five countries perceive the expansion of AFVs and EVs as crucial to the medium-to-long term well-being of industry. For example, despite the low numbers of registered EVs in Spain the country is the largest producers of EVs in Europe (Spanish News Today, 2015). Unsurprisingly the government has made their promotion a key pillar to its programme for sustainable transport and energy development as it attempts to increase domestic consumption and grow the manufacturing sector still further. In 2010 Prime Minister José Zapatero committed to having on million electric cars on the roads of Spain within four years. To support this €590 million was made available to promote and develop electric cars, including €80 million in subsidies (IT, 2010). Initially at least the scheme had little impact; in the first seven months of the year, only 16 electric cars were registered (Tremlett, 2010). By 2012 the figures were slowly improving, but were still below the targets set by Zapatero. In November 2015 the government announced Plan MOVEA, merging the previous Movele and PIMA Aire transport plans. MOVEA aims to promote the acquisition of vehicles that use alternative energy sources (including gas-powered vehicles) and has a budget of €16.6 million euros for 2016, including €7.7 million for EV subsidies and charging infrastructure (MOVEA, 2016). Spain's promotion of domestic consumption of EVs has only started to have an impact, possibly due to recent economic recession and the continued use of austerity measures, but the sector holds substantial potential for the Spanish car industry.

Similar initiatives taken in the other selected countries by government departments working closely with stakeholders and automotive representatives has resulted in sizable investment in R&D related to low carbon transport technologies. For example, the Advanced Propulsion Centre was established in the UK in 2013, a 10-year £1 billion joint partnership between government and the automotive industry to engage in low carbon vehicle R&D; this is comparable to the German federal government's plan for electromobility that has agreed with German motor maunfacturers to invest in the region of €1.5 billion in electric vehicle R&D. At the core then is the response of manufacturers to these promptings. While it is difficult estimate how much manufacturers are spending on low carbon vehicle technologies R&D due to the manner in which such spending is reported, research by Wisenthal et al (2010) shows patent applications relating to low carbon technologies taken by the European automotive industry have sharply increased since 2005, nearly quadrupling in number.

The well-being of the automotive manufacturing sector is clearly a key component to the sustainability of a decarbonised transport sector. Policy decisions on low carbon transport technologies must be taken in conjunction with these firms. The vision for the sector is best described by representatives of the McKinsey Global Institute at the United Nations Framework Convention on Climate Change. The belief of stakeholders and policymakers is that by adopting a careful mix of the right policies, incentives and new technologies, industry and government can oversee a transport transition that dramatically reduces greenhouse gases while also simultaneously promoting job growth and wealth creation (Beinhocker and Oppenheim, 2014). Whether it is possible to follow both these trajectories simultaneously, reducing carbon emissions in transport and creating new wealth opportunities, is still an open question.

Pressure from below

While the above three factors can largely be classed as macro in terms of their scale, growing pressure on national and federal policymakers has also become more evident from the meso and micro level, where concerned stakeholders in cities and regions have become increasingly active in their push toward decarbonising local economies and improving air quality in particular. This in turn has forced a response from not just policymakers but also automakers, as legislation and regulation has served to promote the adoption of AFVs, but also to discourage the uptake of traditional ICE vehicles. While federal regulation has offered a degree of flexibility as noted above, regions and cities have been more stringent in their attempts to overcome congestion and improve quality of life. In London, for example, the targeted use of a congestion charge has been used to encourage the uptake of AFVs, as well as to increase revenue. In Germany, the large number of cities exceeding the EU PM10 threshold (Particulate Matter associated with emissions that harm health) has seen some cities, such as Bonn, Dresden and Hannover, introduce Low Emission Zones (LEZs), banning certain categories and classes of vehicles from entering these designated areas. Though this has generated a negative reaction from the German public and served to give automakers considerable difficulties in meeting these requirements, research by Wolff suggests that these zones may have had the effect of increasing the take up of low emission vehicles (Wolff, 2014). This has included vehicles using ICE technology, but points to a possible means of encouraging AFV consumption and the role regional authorities can have in this process.

In France these Low Emission Zones are still in their investigative phase, though they are currently being trialled in eight cities; Lyon, Grenoble, Clermont-Ferrand, Aix-en-Provence, St Denis, Paris, Nice and Bordeaux. However, the move towards the use of punitive LEZs was driven by central authorities. Regional pressures in France are weaker than, for example, in Federal Germany, due to the strong central control of the *dirigiste* state (Transport and Environment, April 2011; EC, 2016). More tellingly, Paris has long been a positive driver of electric vehicle uptake. EVs have been entitled to free parking in the city since 1993. Additionally EVs are supported by local government commitment to providing numerous public charge points. The *Autolib'* car scheme introduced in 2011 helped normalise EV use by providing an electric car share service in the city. It also acted as a catalyst to electromobility throughout the rest of France (OECD, 2015; Autolib, 2016). In part the decision was made to promote the use of EVs due to air pollution concerns (OECD, 2015). Reasons notwithstanding, the case of Paris demonstrates how positive incentives can be as effective as more restrictive regulations limiting entry to urban areas used in LEZs.

Auto manufacturers are taking advantage of the opportunities presented by local government in major urban areas to engage in demonstrator trials of a range of AFVS, including EVs. In recent years, for example, SEAT electromobility has joined with local officials in Barcelona and Madrid to make available fleets of their latest EV models. These trials not only provide real world data to help improve these products technically, they also serve to iron out technological challenges, normalise AFV and EV engagement and effectively advertise the value of the vehicles. Similar demonstrator trials have been in evidence across all five selected countries. While government policy is strategically determined by external factors such as economic concerns, environmental challenges and access to key resources, these actions by regional policy units, often in conjunction with industrial stakeholders, serves to guide their decision-making and often reinforces decisions already made at the macro level, ensuring continued commitment to overarching policy over time. What is evident from the above is how regional influences can alter and change consumer behaviour, as well as the response of national policymakers, as well as the automotive producers' actions. The challenge presented to federal and national policymakers, as well as automotive manufacturers is the unpredictable and unregulated nature of this pressure from below. With many urban centres acting without consultation, LEZs in particular can serve to dissatisfy consumers and frustrate attempts by policymakers to coordinate activities.

VI. Concluding remarks

This paper has focussed on understanding why leading nations promote key technologies, identifying the factors that serve to influence their decision-making. A range of priorities inform policy-makers thinking; exogenous factors that create the need for decarbonisation of the transport fleet and how they intersect with other competing socio-economic priorities. While the responses by the five selected countries have been broadly similar, the challenges unique to each country have served to alter individual national approaches. Policymakers, forced to navigate a hazardous route forward while remaining cognisant of the needs of the most impacted stakeholders have adopted measures that are simultaneously aspirational and pragmatic.

France, with its excess capacity of electrical power and comparatively cheap energy prices has heavily promoted EV usage, with the support of major French automotive manufacturers such as Renault. Spain, too, has pushed for greater electromobility but has been hindered by economic hardship in promoting uptake; however, the Spanish automotive industry has greatly benefitted from these efforts as it has become a leading producer of EVs. In the UK, energy constraints of a dwindling pool of domestic oil reserves has similarly promoted a desire to electrify the vehicle fleet; however, the need to expand the national grid has created some concern amongst policymakers and contributes to a more technology neutral approach to carbon emission reduction. Additionally, the dominance of component manufacture in the UK motor industry means the sector is more flexible and less impacted by technology forcing than other countries with greater volume manufacturing of vehicles in evidence. Germany in particular is mindful of the need for a smooth transition from vehicles using ICE technology to AFVs and it is this thinking that also underpins their promotion of the use biofuel and biodiesel as a means to graduate the process of change. Italy too is concerned with protecting its automotive sector. Although energy security is also a major consideration for Italy as it tries to end its oil and gas import dependence, the widespread use of CNG and LPG powered cars in Italy must also be factored in to the decarbonisation process in this country.

What is evident is the heterogeneous nature of decarbonisation of transport across the selected EU member states. Further complicating this process is the organic pressure of urban centres driven by concerns over congestion, pollution and parking, engaging in largely unregulated activities to discourage conventional vehicles from accessing city spaces. This has also led some cities to actively promote the use of certain LCV technologies at the expense of conventional automobiles, further influencing the transition from ICE vehicles top AFVs. The response by policymakers has been necessarily circumspect, encouraging a wide range of actions. Whether this approach is optimal remains to be seen. While a gradual transition that makes allowances for existing socio-economic conditions including industrial presence, consumer preference and strategic resource usage, it may inadvertently slow the pace of change. The fact that all the countries under examination, countries that account for the greatest share of new vehicle registrations in the EU, have such low levels of AFV penetration is a concern for policymakers and stakeholders. In particular, the negligible sales of EVs in these countries after so much emphasis was placed on electromobility suggest that achievements are lagging behind policy goals. Whether these were realistic goals in the first place is a question worth asking, but it cannot be doubted that some review of policy must occur.

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