Ea Energy Analyses

Promotion of electric vehicles

EU INCENTIVES & MEASURES SEEN IN A DANISH CONTEXT

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Ea Energy Analyses
Frederiksholms Kanal 4, 3. th.
1220 Copenhagen K
Denmark
T: +45 88 70 70 83
F: +45 33 32 16 61
Email: info@eaea.dk
Web: www.eaea.dk

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1 Executive Summary

Ambitious Danish climate targets

Denmark has very ambitious climate targets, as exemplified by the Danish government's target of becoming independent of fossil fuels by 2050 – including in the transport sector. Due to their high level of energy efficiency, and ability to utilise electricity produced from renewable sources, electric drive vehicles[1] are likely to play a prominent role in achieving this long-term goal. However, Denmark is a small country with no automotive industry, and therefore the potential for reducing energy consumption and CO_2 emissions within the transport sector depends on international trends, both in terms of the availability and affordability of transport technologies, and the development of policies to promote these technologies.

Goal is to affect change at EU level

Given that Danish national electric vehicle (EV) related initiatives and incentive schemes will have a limited effect on overall EV development and market penetration, the primary objective of this report is to identify and provide recommendations *regarding EU level measures and incentives* that can promote EV diffusion. As the EU policies towards 2020 have already been decided, the focus of the study is the post 2020 period.

EU climate targets & policy - 2020

In order to reduce greenhouse gas emissions and promote renewable energy within the transport sector up till 2020, the EU utilises two primary tools. The first is the EU renewable energy directive, which includes an agreement that the member states shall reach a target of 10% of transport fuel coming from renewables by 2020. Options to comply with this target include biofuels and EVs. At this point in time though, it is unclear what will happen after 2020, i.e. whether the directive will be extended, increased, etc.

The second main tool consists of CO_2 requirements for new passenger cars. In 2011, average emissions for all new EU cars was 135.7 g CO_2/km. Under what is referred to as the "Cars Regulation" the 2015 figure is to be lowered to 130 g CO_2/km, and by 2021 to 95 g CO_2/km. These 130 and 95 g/km figures are fleet averages and individual manufacturers can meet these targets by reducing emissions from standard gasoline and diesel vehicles, and/or receiving credit for producing vehicles with extremely low emissions, i.e. below 50g/km, where EVs qualify (European Commission, 2009a).

[1] Throughout this report the term electric drive vehicles includes electric vehicles (EVs), plug-in hybrids (PHEVs) and hydrogen vehicles (HEVs).

EU climate targets & policy - 2050

The EU has also set long-term targets for total greenhouse gas emissions, namely an 80-95% reduction by 2050 compared to 1990. The Commission 'Roadmap for moving to a competitive low carbon economy in 2050', sets out how to meet the 2050 target of reducing domestic emissions by 80% in the most cost-effective way. Depending on the scenario, compared to 1990, transport emissions need to decrease in the range of 54%-67% by 2050. (European Commission, 2011a). In line with this, the 'Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system' from March 2011 sets out a transport strategy aimed at achieving a 60% emissions reduction in the transport sector.

EU Scenarios - 2050

In order to estimate how both the 2020 and 2050 EU targets could be met in the most cost-effective fashion, scenarios were developed for new passenger vehicles in the EU covering both timeframes. The scenarios indicate that if the various targets were to be met without relying too heavily on biofuels, in 2020 between 5-10% of new passenger vehicles sold in the EU would have to be EVs or PHEVs, with this figure growing to 45% in 2030, and 85% in 2050. However, the scenario analysis also highlights the fact that it is quite possible to reach the EU 2020 targets without EVs. The RE targets can be met largely with biofuels, which according to the respective EU country National Renewable Energy Action Plans (NREAPs), is precisely how this target will primarily be met. Meanwhile, the 2020 CO_2 emission requirements can largely be met via improvements to internal combustion engine (ICE) vehicles. Meeting the longer term targets however, i.e. in 2050 (and other potential intermediary targets in the years 2030-2050), would likely prove to be very difficult without EVs, plug-in hybrid electric vehicles (PHEVs) or hydrogen vehicles (HEV).

Disconnect between current EU policy and future requirements

There appears to be a disconnect between what current EU policy encourages (i.e. CO_2 reductions almost solely via improvements in the ICE engine, and use of biofuels), and what is required in the long-term (i.e. large-scale deployment of electric drive vehicles). Given the lifetime of a personal vehicle, a transition to such a large proportion of electrical drivetrains will take time, and even more importantly, will require technology advancement and cost reductions. The above-mentioned scenarios, and their underlying cost assumptions, indicate that in the absence of taxes, EVs and PHEVs would be competitive with ICE vehicles by 2030 when looked at from a total cost of ownership perspective. These scenarios are predicated on the assumption that EV costs will continue to fall due to R&D and increased production levels. However, as current EU policy does not send clear signals to automotive manufacturers, nor ensure that investments in this transformation are taking place, this analysis has focused on identifying EU policies enabling a gradually increasing EV deployment.

Policy options

The current analysis reviewed a number of initiatives and policies that could potentially be used to increase EV diffusion over both the short and longer term within the EU. In doing so, information was gathered regarding policy measures from different countries including Norway, Germany, the USA, and China as well as the state of California.

Generally speaking, EVs could be promoted in the EU through EU wide measures or via obligations on member states. Both approaches have been applied recently. The “Cars regulation” and the EU Emissions Trading Scheme (ETS) are examples of EU wide measures, targeting car manufacturers and the large emitters of greenhouse gasses, whereas for example the renewable energy directive set mandatory targets on the member states.

One could imagine EU legislation similar to that of the renewable energy directive - or an addendum to the existing 10% renewable energy target in the transport - where the EU sets mandatory minimum EV targets for EU countries, and allows them to meet these targets as they see fit. One positive aspect of such an approach is that member states are free to select national policies.

On the other hand, national targets may lead to a sub-optimal dispersal of EVs (I.e. EVs may be better suited to some countries rather than others), and thus also lead to serious negotiations on how this effort should be shared among members states. Due to the fact that it may be difficult to enforce, this approach also involves a significant risk that the overall target will not be reached. Moreover, it may be difficult for member states to identify cost-efficient policy measures providing the desirable penetration of EVs in their individual market. Some countries would be able to support EVs through tax reductions on the registration and circulations fees, whereas other countries, which do not impose vehicle taxes on a large scale, would likely have to provide direct support to EV purchasers.

As the case of Norway illustrates, it is possible to enable a large-scale market breakthrough for EVs, but currently very strong incentives are required (see text box below). In this respect, Norway is likely in a rather unique situation in that the country can afford to absorb these additional costs, even as EV penetration levels increase. However, it is unlikely that financial incentives of this magnitude can be implemented broadly among EU member states.

The Norwegian case

In recent years, the country with the highest % of new EV sales has been Norway, as it had EV sales totalling approximately 5.5% of all new vehicles sales in 2013, and for the month of March 2014 this figure was a staggering 20% (Clean Technica, 2014) (Gronne bil, 2014). Numerous studies have been undertaken to investigate the barriers towards a wide adaption of electric vehicles in the mass market, and the vast majority come to the same conclusion, namely that it is the purchase price that is paramount. As such, it is not surprising that the primary tools utilised by the Norwegian government address the purchase price. EVs in Norway are not subject to registration taxes or VAT (ICEs are taxed heavily), and are subject to lower annual fees as well. In addition, EVs are not subject to road tolls, have access to free parking in municipal parking lots, and can also charge free in some locations (cars21.com, 2013). Coupled with the much lower fuel prices (electricity vs. gasoline or diesel), the total cost of ownership (TCO) in Norway for the majority of car segments is lower for EVs than its diesel or gasoline counterparts.

In reviewing what has worked for Norway, it is important to note that other than allowing EVs to drive in bus lanes, all of the above named measures result in forgone revenues and/or additional costs to the

Industry mandated targets

Rather than placing the economic burden on governments, another option is to mandate targets on the automotive industry. This form of policy is already in place in the EU via the CO_2 requirements for new passenger vehicles. While this specific policy does allow for EVs to assist in fulfilling the CO_2 target via “supercredits”, EV production and sales are by no means a requirement.

Another region that has implemented industry mandates is California in the United States. California also has relatively ambitious CO_2 emission reduction goals, with legal requirements of reducing emissions to 1990 levels by 2020, and emissions in 2050 to be 80% below 1990 levels (California Council on Science and Technology, 2011). The state has a long history of EV promotion, and as part of its plan to reduce emissions from transport, in 1990 the California Air Resources Board (CARB) adopted the Zero-Emission Vehicle

(ZEV) mandate. The ZEV program dictated that ZEVS[2] constitute a share of each large-volume automobile manufactures vehicle sales.

The ZEV program evolved over time and today is part of the larger Advanced Clean Cars program, which coordinates the goals of the Clean Fuels Outlet, Low-Emission Vehicle, and Zero Emission Vehicle programs. The ZEV program is based on a credit system where vehicle manufactures must present credits based on the number of total vehicles sold. The amount of credits earned per vehicle varies depending on the vehicle technology (EV, PHEV, etc.) and the all-electric range. Generally speaking, pure EVs receive more credits than PHEVs, and credits increase with the all-electric range of the vehicle. If a vehicle manufacturer does not earn enough credits from the sale of its own vehicles, it must purchase credits from another manufacturer that has excess credits (Tesla and Nissan have for example been the largest suppliers of credits). If a manufacturer does not produce and/or purchase the required amount of credits then it can be fined $5,000 per missing credit, and it must still acquire the remaining credits in upcoming years.

The table below roughly translates the required credits into anticipated vehicle sales figures for the years 2018-2025. By 2018, 4.5% of the manufacturer's sales in California must be either ZEVs or a mixture of ZEVs and plug-in hybrids, with this figure growing to 22% by 2025. (US Department of Energy, 2013b). For a point of comparison, the recent historic EV and PHEV sales are also included in the table.

[2] ZEVs - Vehicles deemed to meet a specified emission standard. At this time EVs were the only vehicle to meet the standard. (Bedsworth & Taylor, 2007)

Year	Transitional ZEVs (Plug-In Hybrids)	ZEVs (EV and/or Hydrogen Fuel Cell)	Total ZEV Sales/ Requirements
2010*	97	300	0.0%
2011*	1,682	5,302	0.5%
2012*	14,701	6,197	1.4%
2013*	20,235	21,963	2.5%
2018	61,000	17,000	4.5%
2019	75,000	33,000	7.0%
2020	89,000	49,000	9.5%
2021	102,000	61,000	12.0%
2022	116,000	75,000	14.5%
2023	131,000	87,000	17.0%
2024	147,000	99,000	19.5%
2025	162,000	109,000	22.0%

*Table 1: Historic California sales of PHEVs and EVS for the years 2010-2013 (CNCDA, 2014) and estimated future California Zero-Emission Vehicle (ZEV) sales, as mandated by the 2012 Amendments to the California Zero-Emission Vehicle Regulation (US Department of Energy, 2013b). *Figures are solely for PHEVs and EVs. The credit system is somewhat complicated, particularly for the years up to 2017, therefore estimated figures for these years are not included.*

As can be seen from Table 1, the 2018 target for pure EVs was already surpassed in 2013, and even with slowed growth, the total ZEV sales target for 2018 appears to be quite achievable.

Seen from the viewpoint of a government, the strength of such a system is that the economic burden lies with the automobile manufacturers. In order for manufactures to achieve the required EV and PHEV sales targets they may have to reduce the price of these vehicles, with the result being little or even negative short-term profit from the sale of EVs and/or PHEVs. In order to maintain their overall profits in such a situation, manufactures could be expected to pass these additional costs onto their other vehicles, thus spreading the additional costs associated with EVs and PHEVs over a wide consumer base.

If a similar system were to be implemented in the EU, it would be prudent to look at some of the lessons learned from the early experiences in California, for example avoiding the production of ‘compliance cars’ (i.e. low quality EVs produced solely to meet EV targets) and ensuring the credit system is established in such a way that it promotes electric vehicles with varying all-electric ranges, while at the same time not overcompensating specific manufactures. It should be noted that with respect to the risk of manufacturers producing so-called 'compliance cars', minimum technical standards, and the much larger EV product range found today, make it less likely that this will be a significant risk going forward.

Public procurement

Public procurement of EVs, for example facilitated through mandatory EU policies, may provide a powerful tool, particularly in a start-up phase. However, it is worth bearing in mind that with respect to the passenger car segment, the share of vehicles that are publicly procured makes up less than 1% of all cars. Within the van/lorry and bus segment, public procurement policies favouring electric vehicles would be a significant and positive driver for EV sales.

Findings and conclusions

Given the long-term EU goals and targets, of the options reviewed above, the most attractive systems appears to be the adoption of an EU industry mandated EV/PHEV/HEV credit system similar to that in place in California. This electric drive credit system could run in parallel with the current CO_2 emissions target system, (it would however likely be advisable to remove the current super credit system, as it would be overly burdensome to have two credit systems in place). Having both a mandated electric drive credit system and a CO_2 emissions target system in place would allow the EU to continue to control the level of CO_2 emissions from new vehicles (thus reducing short/medium term CO_2 emissions dominated by ICEs), while at the same time also ensuring that a growing amount of electric drive vehicles are being developed and brought to market. While these two systems would be running in parallel, they would also be linked due to the fact that the electric drive vehicles will also count toward the CO_2 emission requirements.

The primary reasons for selecting this particular policy tool rather than some of the others reviewed are:

- The system would not confer a significant economic burden on the EU country governments.
- The system has proven to be effective in promoting EV diffusion and meeting specific targets in other regions.
- The system allows for EVs to be sold in those countries where it is most attractive for the automobile manufacturers to do so.
- Notwithstanding potential resistance from the automobile industry, it would be relatively straight forward to implement on an EU level.
- Individual countries with more aggressive EV targets can still utilise more specific tools such as public procurement, or economic incentives such as those in Norway.

Preferably, the industry mandated EV targets should be developed in accordance with a new overall EU transport technology roadmap, where the requirement and the role of EVs in the future transport system is assessed in conjunction with other transport measures and alternative technologies and fuels. In this respect, the current white paper on transport from 2011 is not deemed to provide sufficient guidance. Inspiration for a more detailed roadmap along with technology targets could for example be found in the United States EV Everywhere Challenge.

Danish viewpoint

Seen from a Danish viewpoint, the establishment of EU-wide industry mandates for electric drive vehicles would increase the number of EVs on the market, as well as encourage additional R&D in vehicle and battery technology. The scheme should yield lower vehicle costs, both in the short-term, as manufacturers would need to reduce prices of EVs to gain a market share, but also in the longer term through learning effects. Similarly, the system should also encourage increased all-electric driving ranges, thereby addressing the two most important customer concerns regarding EVs. This would be of utmost importance for Denmark's prospects of complying with the long-term target of a fossil free transport sector.

2 Introduction

2.1 Backdrop

CO_2 emissions from transport represent one of the most difficult challenges related to climate change mitigation both in Denmark and on the EU level. Electric vehicles (EVs) are anticipated to play a significant role in reducing transport emissions, and as such, a number of initiatives and incentive schemes in both Denmark and at the EU level have been implemented to promote the sale of EVs. While these initiatives have been effective in promoting the sale of more efficient conventional ICE vehicles, EV growth is not on pace to reach a number of targets set for the EU.

Denmark

Historic energy use and CO_2 emissions from transport

In Denmark, over the last 30 years the transport sector's energy consumption has increased from roughly 145 PJ in 1980, to 220 PJ in 2008. However, 2009 saw a slight decrease in this figure, which is most likely the result of the financial crisis. As such, in 2011 the Danish transport sector's final energy consumption stood at 211 PJ, which is just under 1/3 of Danish annual final energy consumption. In terms of CO_2 emissions, the transport sector stood for just under 15 Mt in 2011, which is also roughly one third of Denmark's total CO_2 emissions.

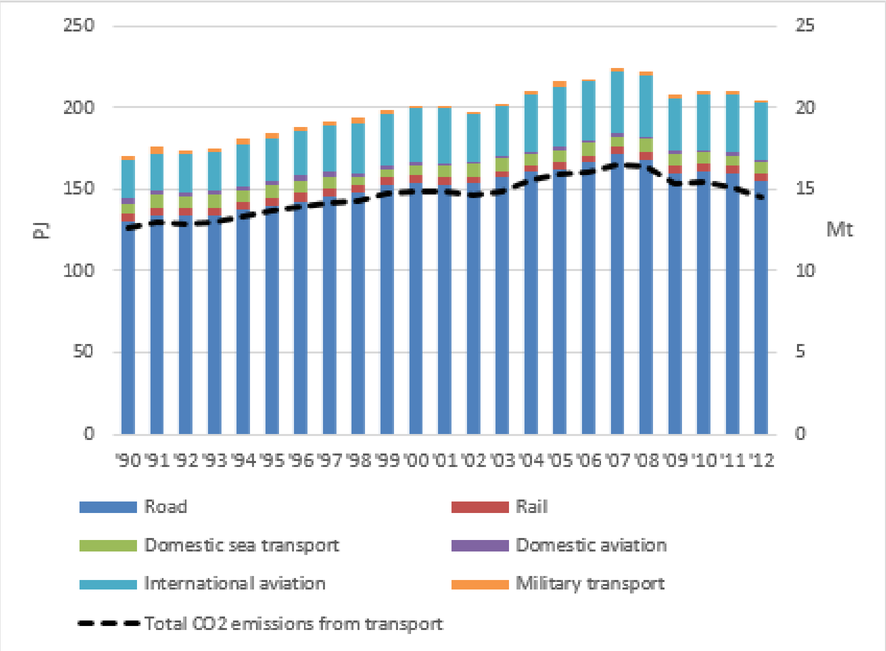


Figure 1: Danish transport energy use by mode – left vertical axis (PJ), and total CO_2 transport emissions – right vertical axis (Mt) since 1990 (Danish Energy Agency, 2013).

Figure 1 illustrates the fact that Danish CO_2 emissions from transport have historically been directly correlated to energy use, at roughly 73-74 kg CO_2/GJ. Given the dominance of gasoline (73 kg CO_2/GJ) and fuel oil (74 kg CO_2/GJ) in the Danish transport fuel mix, this is of course not surprising. This correlation highlights why the electrification of the transport sector is so important if Danish transport related CO_2 emissions are to be reduced.

Future plans

By 2050, the Danish government's target is to become independent of fossil fuels – including in the transport sector. EVs are likely to become one of the cornerstone technologies as they enable a very high level of energy efficiency and may use electricity produced from renewable energy sources. However, to a higher extent than other sectors, the possibilities to reduce energy consumption and CO_2 emissions within the transport sector depend on international trends, both in terms of the availability and affordability of transport technologies, and the development of policies to promote these technologies.

European Union

At the EU level, the long-term emissions target is an 80-95% reduction in greenhouse gases by 2050 compared to 1990 (in the context of the necessary reductions by developed countries as a group). The Commission 'Roadmap for moving to a competitive low carbon economy in 2050', sets out how to meet the 2050 target of reducing domestic emissions by 80% in the most cost effective way. Depending on the scenario, compared to 1990, transport emissions need to be between +20% and -9% by 2030, and decrease by 54% to 67% by 2050. (European Commission, 2011a).

In October 2014 the European Council endorsed a binding EU target of an at least 40% domestic reduction in greenhouse gas emissions by 2030 compared to 1990. The reductions in the ETS and non-ETS sectors, which include the transport sector[3], should amount to 43% and 30% by 2030 compared to 2005, respectively. The EU has not specified a specific 2030 target for the transport sector, but the European Council has asked to EU Commission to further examine instruments and measures for a "comprehensive and technology neutral approach for the promotion of emissions reduction and energy efficiency in transport, for electric transportation and for renewable energy sources in transport also after 2020" (Council, 2014).

[3] A Member State may opt to include the transport sector within the framework of the ETS.

The 'Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system' from March 2011 sets out a transport strategy within a frame of achieving a 60% reduction in transport GHG emissions by 2050 (European Commission, 2011b).

10% renewable energy by 2020

In addition, member states have committed to the EU renewable energy directive, which includes an agreement that the member states shall reach a target of 10% of transport fuel coming from renewables by 2020. According to a proposal by the Commission from October of 2012, the share of energy from biofuels produced from cereal and other starch rich crops, sugars and oil crops shall be no more than 5%, and at the same time advanced biofuels should be considered to be four times their energy content (European Commission, 2012b). However, due to intense lobbying from the biofuel and agricultural sectors, the suggested 5% target was first raised to 6%, and as of December 2013, a 7% cap was being discussed. Largely due to a deep divide between countries favouring a lower cap (e.g. Denmark and Belgium), and those in favour of a high cap (e.g. Poland and Hungary), the EU was unable to reach a consensus, and no new limit has been implemented (EurActiv, 2013). Finally, according to a June 13th ministerial decree, a 7% cap was agreed on, with the compromise including a non-binding provision that 0.5 of the 10 percent points (i.e. 5% of the biofuel) to come from next-generation biofuels (Todays Zaman, 2014).

CO_2 requirements for new vehicles

The EU Commission has recently strengthened requirements for CO_2 emissions from new passenger cars. In 2011, the average emissions for all new cars on the market was 135.7 g CO_2/km. Under what is referred to as the "Cars Regulation" the 2015 figure is to be lowered to 130 g CO_2/km, and by 2021 to 95 g CO_2/km. These 130 and 95 g/km figures are fleet averages and individual manufacturer targets are set according to their vehicle fleet weights. As such, heavier vehicles can emit more, and lighter vehicles must emit less than the overall fleet average. (European Commission, 2014a).

These EU fleet average targets of 130 and 95 g CO_2/km are to be phased in over time. For example, in 2013, an average of 75% of each manufactures' newly registered cars had to comply, with this growing to 80% in 2014, and 100% in 2015. Similarly, in 2020 95% of each manufactures' newly registered cars must comply with the 95 g CO_2/km limit, with this rising to 100% in 2021. (European Commission, 2014a).

The EU regulation concerning mandatory emissions reduction targets for new cars provides additional incentives for manufacturers to produce vehicles with extremely low emissions, i.e. below 50 g CO_2/km (European Commission, 2009a). Each low-emitting car counts as: 3.5 vehicles in 2012 and 2013; 2.5 in 2014; 1.5 in 2015; and then one vehicle from 2016 onwards. For the 95 g CO_2/km target, each low-emitting car will count as 2 vehicles in 2020, 1.67 in 2021, and 1.33 in 2022. However, the total reduction that that can be achieved under this incentive scheme will be capped at 7.5 g CO_2/km per manufacturer over the three years. These so-called "super credits" enable manufacturers to further reduce the average emissions of their new passenger vehicle fleet. Apart from this regulation, the EU has not provided a detailed policy framework to create demand for EVs among European consumers. (European Commission, 2014a).

In addition to super credits, vehicle manufacturers can also employ CO_2 reducing 'eco-innovations'. If proven to be innovative and resulting in reduced CO_2 emissions in a manner generally not taken into account when calculating vehicle emissions, vehicle manufacturers are then granted emissions credits up to a maximum of 7 g CO_2/km per year for their fleet (European Commission, 2014a). The first approved eco-innovation was by Audi, and involved the use of LEDs in the low and high beam headlamps, as well as the licence plate lamp. As such, each version of the vehicle that employs this technology will have it count towards Audi's annual CO2 emission target (European Commission, 2013b). Another example is Valeo, which has demonstrated that its Valeo Efficient Generation Alternator reduces emissions by at least 1 g CO_2/km (European Commission, 2013c).[4]

When looking beyond 2021, there have been discussions of further strengthening this emissions requirement to 70 g CO_2/km by 2025.

European automotive industry

Another relevant factor in EV development and promotion is the health of European automotive industry. At the EU level, the automotive industry is incredibly important. The recent communication from the EU Commission entitled 'CARS 2020: Action Plan for a competitive and sustainable automotive industry in Europe' detailed a number of challenges facing the EU automotive industry, as well as key actions the Commission is planning in order to deal with these challenges (European Commission, 2012a). The report stresses that developing tomorrow's technological solutions to enable sustainable mobility is a key long-term goal, and EVs can play a major role in this endeavour.

[4] The Cars Regulation also allows for manufactures to group together and pool their emissions, sets targets for smaller manufacturers, and outlines the monitoring processes and penalties for excess emissions (European Commission, 2014a).

Globally

On a global level, there has also been a growing focus on EVs as a future transport solution, and an increasing awareness that the progress in the upcoming years is important. For example, in the IEA's Energy Technology Perspectives (ETP) report from 2012 it stated that:

> *"Deployment of electric vehicles has already started, with major producers selling about 40,000 during 2011. The next few years will be critical to build markets and promote customer acceptance of this innovative technology, especially in regions that are heavily car-dependent."*

Since then, global sales of EVs and PHEVs have grown substantially, as indicated in Table 2, which highlights the fact that 2013 sales of pure EVs were estimated to be over 110,000 (EV Obsession, 2014). Up to this point, the majority of cumulative PHEV and EV sales have taken place in the United States and Japan. However, in terms of EV sales as a % of total passenger vehicle sales, both countries have sales under 1%, whereas Norway, which is the clear global leader, had EV sales equal to roughly 2.5% of all new vehicles sales in 2012, 5.5% in 2013, and for the month of March 2014 this figure was roughly 20% (Clean Technica, 2014) (Gronne bil, 2014).

Vehicle	Global 2013 Sales
EV	**111,718**
Nissan Leaf	47,484
Tesla Model S	22,186
Renault Zoe	8,869
Renault Kangoo ZE	5,886
Chery QQ3	5,007
Mitsubishi i	4,769
Smart Fortwo ED	4,130
Renault Twizy	3,062
Jac J3 EV	2,500
Ford Focus Electric	1,894
BYD e6	1,684
VW e-Up!	1,465
Mitsubishi Minicab MiEV	1,464
BMW i3	1,318
PHEV with range > 50 km	**31,409**
Chevy Volt PHEV	28,252
Opel Ampera PHEV	3,157
PHEV with range ≤ 50 km	**62,515**
Toyota Prius PHEV	23,075
Mitsubishi Outlander PHEV	18,444
Volvo V60 PHEV	7,437
Ford C-Max Energi PHEV	7,353
Ford Fusion Energi PHEV	6,206
Grand total	**205,642**

Table 2: Estimated global EV and PHEV sales for 2013. (EV Obsession, 2014)

2.2 Report objective

Since Denmark is a relatively small country, national EV related initiatives and incentive schemes will have a limited effect on overall EV development and market penetration. The primary objective of the current report is therefore to identify and provide recommendations *regarding EU level measures and incentives* that can promote EV diffusion. The secondary objective is then the examination of how these measures will affect the promotion of EVs in Denmark.

2.3 Project methodology

The project is split into a number of work packages as outlined below:

- WP 1 - Fulfilment of EU goals – Why are EVs relevant?
    - EV requirements in 2020/2050 to meet EU targets
- WP 2 - State of the art

- Review of EV related EU policies
- Review of other EV related polices
- Review of non-EV related EU policies

- WP 3 - Selection of measures for the analysis
    - Selection of screening criteria
    - Application of screening
- WP 4 - Review & analysis of selected policies and measures + Conclusions

3 EVs' role in fulfilment of EU goals

The purpose of this chapter is to answer the question, "Why are EVs relevant for passenger vehicle transport; Why not focus on improving existing ICE vehicles, and/or develop other technologies?" The first portion of the chapter will therefore investigate whether EVs need to play a role prior to 2020 in order to comply with existing CO_2 emission requirements and the 10% renewable energy from transport targets outlined in section 2.1. Thereafter, EV deployment related to CO_2 emission targets from transport beyond 2020, and through to 2050, will be examined. This examination will involve the establishment of simplified passenger transport scenarios and their related CO_2 emissions. The last portion of the chapter will then present some of the cost aspects that were utilised as inputs to the passenger transport scenarios.

3.1 EV requirements in 2020 to meet CO_2 and renewable targets

CO_2 requirements for new vehicles - 2020

Since 2000, the average CO_2 emissions from new passenger vehicles according to official tests has fallen greatly, particularly after 2007 (about the same time that mandatory CO_2 emissions targets were being developed - please see discussion in section 4.1). These emission reductions have taken place despite the fact that the average weight of gasoline vehicles has remained largely unchanged, and diesel vehicles have become heavier (see figure below).

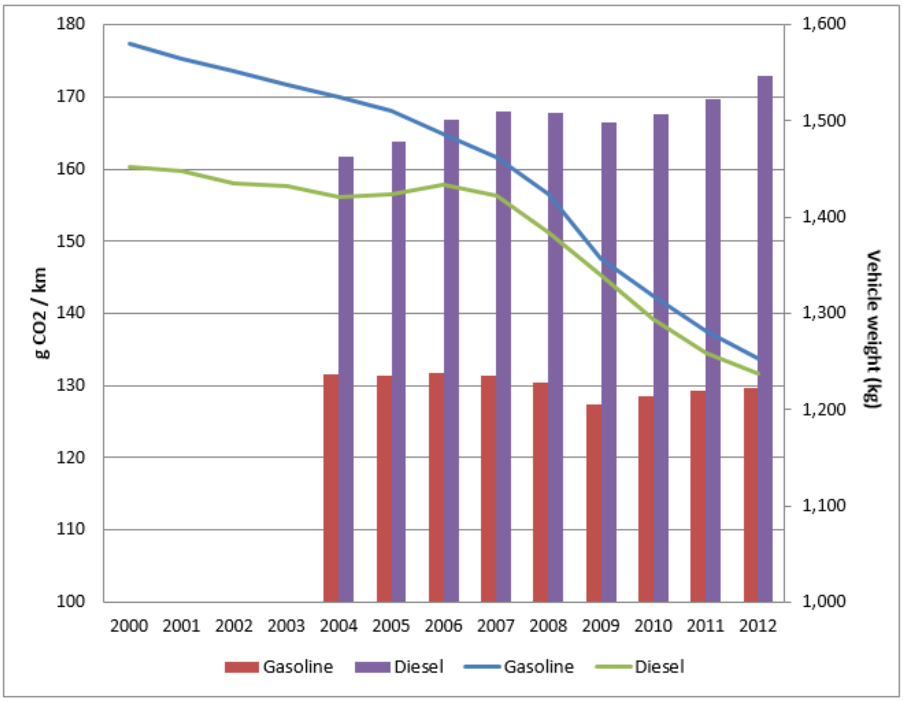


Figure 2: Average CO_2 emissions (left axis) and vehicle weights (right axis) for new gasoline and diesel passenger vehicles in the EU. Please note that the left axis starts at 100 g CO_2 /km, and the right axis starts at 1,000 kg. (European Environment Agency, 2013)

Based on the assumption that improvements in vehicle efficiencies and improved performance at vehicle CO_2 emission testing will continue towards 2020, it is forecasted that vehicle manufacturers can likely reach a fleet average of 95 g CO_2 with little (ca. 1.5% of production), or no, contribution from EV sales.

10% of transport fuel from renewables in 2020

With respect to the renewable energy transport portion of the 20-20-20 targets, it appears as though many of the EU countries will utilise biofuels to fulfil the majority of this target 10%, and therefore it is not deemed to be a major driver of EV deployment.

3.2 EV requirements beyond 2020 to meet CO_2 targets

CO_2 requirements for new vehicles - 2050

There are currently no mandatory targets for car manufactures beyond 2021. However, as highlighted in the previous chapter, at the EU level there is an overall target of 80-95% reduction in greenhouse gases by 2050 compared to 1990, and the Commission's 'Roadmap for moving to a competitive low carbon economy in 2050' scenario work indicated that compared to 1990, transport emissions need to be between +20 and -9% by 2030 and decrease by 54% to 67% by 2050 (European Commission, 2011a). These transport emission reductions are in line with the abovementioned Whitepaper, which calls for CO_2 emission reductions of at least 60% from the transport sector relative to 1990 levels. This equates to a roughly 70% reduction relative to 2012.

Future personal transport scenarios

Based on this long-term 70% reduction target for all transport emissions, some simplified future scenarios were created to focus solely on CO_2 emission reductions from new passenger vehicles. In determining the scenario targets, one of the first things taken into consideration is that relative to other transport sectors (i.e. aviation, shipping, heavy goods transport), it is generally accepted that is easier to make significant CO_2 emission reductions within the passenger transport sector. In addition, while the whitepaper target involves comparing the entire vehicle fleet (new and used vehicles) in 2012 with the vehicle fleet in 2050, as a proxy it has been elected to compare new vehicles in 2012 with new vehicles in 2050. As such it was assumed that an ***85%*** reduction in CO_2 emissions from ***new*** passenger vehicles in 2050 would be required if the transport sector as a whole is to reach a *70%* reduction. The types of vehicles included in the scenario analysis were conventional Internal Combustion Engines (ICEs) that utilise gasoline, diesel, bioethanol, or biodiesel, Battery electric vehicles (EVs), series Plug-in hybrids (PHEV), and Fuel cell electric vehicles (FCEVs). The scenarios were designed with the objective of meeting the 2050 CO_2 emission reduction target in the most socio-economic cost-effective manner.[5]

High EV scenario

For the purpose of this study two scenarios were developed. The first is a High EV scenario, where battery costs and performance develop according to, or better than expected, and as a result there is a high EV penetration. In this scenario, breakthroughs in battery energy density and cost allow for EVs and PHEVs to compete with traditional vehicles by 2030, and dominate the new passenger market by 2050. In order to take advantage of a greater vehicle range, it is anticipated that by 2050 there will still be more PHEVs than pure EVs. Due to their significantly higher energy use and cost, hydrogen vehicles do not play a role in this scenario.

Meanwhile, natural gas, biogas, bioethanol and biodiesel all play minor roles as the successful roll out of EVs allows these resources to be used in other transport areas, for example in aviation, shipping, or heavy duty vehicles, and also the electricity generation sector, where they can be utilised more efficiently to produce the required additional electricity for EVs and PHEVs.

Lastly, there are still some conventional ICE vehicles present in the scenario, as it is assumed that some consumers will prefer vehicles with a longer driving range (over 900 km) than PHEVs (ca. 650-700 km) can provide. Lastly, some luxury vehicles, SUVs and trucks are still anticipated to be powered by ICEs.

Vehicle distribution according to km driven by new vehicles (%)	2013	2020	2030	2050
Gasoline	**44.1**	**41.0**	**25.0**	**9.0**
Bioethanol % of gasoline	5.0	5.0	5.0	5.0
Diesel	**55.0**	**48.0**	**29.0**	**5.0**
Biodiesel % of diesel	5.0	5.0	5.0	5.0
Natural gas	**0.5**	**1.0**	**1.0**	**1.0**
Biogas	**0.0**	**0.0**	**0.0**	**0.0**
Plug-in hybrid	**0.1**	**5.0**	**25.0**	**45.0**
EV	**0.3**	**5.0**	**20.0**	**40.0**
Hydrogen	**0.0**	**0.0**	**0.0**	**0.0**

Table 3: New passenger vehicle distribution according to vehicle type in the High EV scenario. (Ea Energy Analyses, 2014)

No breakthrough scenario

The No Breakthrough scenario reflects a situation where battery breakthroughs are not achieved, and as a result, substantial amount of

[5] As a result, a large number of assumptions were made regarding technology development, costs, km driven, vehicle size biofuel development, CO_2 content of electricity, range requirements, etc. Costs are without taxes, subsides, etc.

biofuels (bioethanol, biodiesel, and biogas) are required if the 2050 target of 85% CO_2 emissions reduction is to be met. Vehicle weights as a whole are also reduced, as car manufactures have limited alternatives with which to otherwise reduce emissions. In addition, EVs, and particularly PHEVs, despite still being more expensive than gasoline and diesel vehicles are relied on. Natural gas vehicles also serve as a cost-effective alternative to gasoline and diesel vehicles with slightly lower CO_2 emissions.

Vehicle distribution according to km driven by new vehicles (%)	**2013**	**2020**	**2030**	**2050**
Gasoline	**44.1**	**46.0**	**39.0**	**18.0**
Bioethanol % of gasoline	5.0	10.0	25.0	60.0
Diesel	**55.0**	**48.0**	**38.0**	**16.0**
Biodiesel % of diesel	5.0	10.0	25.0	60.0
Natural gas	**0.5**	**2.0**	**5.0**	**10.0**
Biogas	**0.0**	**1.0**	**4.0**	**15.0**
Plug-in hybrid	**0.1**	**2.0**	**10.0**	**31.0**
EV	**0.3**	**1.0**	**4.0**	**10.0**
Hydrogen	**0.0**	**0.0**	**0.0**	**0.0**

Table 4: New passenger vehicle distribution according to vehicle type in the no breakthrough scenario. (Ea Energy Analyses, 2014)

Scenario findings

While both of the above two scenarios allow for the overall CO_2 emission target to be met, in the 'No Breakthrough' scenario this however requires a great deal of biofuels + biogas, perhaps an amount that is unrealistically high as these limited resources are likely to be prioritised in the heavy duty vehicle and/or aviation sectors. In addition, the scenario also requires that traditional ICEs become increasingly efficient. Given the current difference between real-world fuel usage and new vehicle testing (please see discussion in chapter 4), this raises the question of whether the efficiency gains required are realistic. Lastly, the scenario also relies on an assumption regarding consumer preferences, in that it assumes that customers will be willing to select smaller vehicles.

The High EV scenario requires battery cost reductions within the average ranges of cited studies, and to a lesser extent, the scenario also requires battery density increasing as anticipated.[6] As a result, the scenario analysis points to the conclusion that if battery development proceeds roughly as it is

[6] It is worth noting that breakthroughs regarding battery technologies and EVs have been forecasted before, and optimistic forecasts from for example 10-20 years ago have yet to come to fruition. Therefore, while the High EV scenario may appear to have realistic barriers to overcome, these required technology advancements are by no means a certainty.

forecasted to, then EVs and PHEVs represent the most cost effective technologies for reducing passenger vehicle emissions in the long term.

3.3 EV economics

For the above scenarios, a per km transport cost was calculated for each of the drivetrains and fuel types investigated. The main categories of costs were the vehicle cost (with and without battery), operations and maintenance of the vehicle, the fuel wholesale costs, and the fuel distribution costs. All of the costs in the analysis were compiled without taxes.[7]

High EV

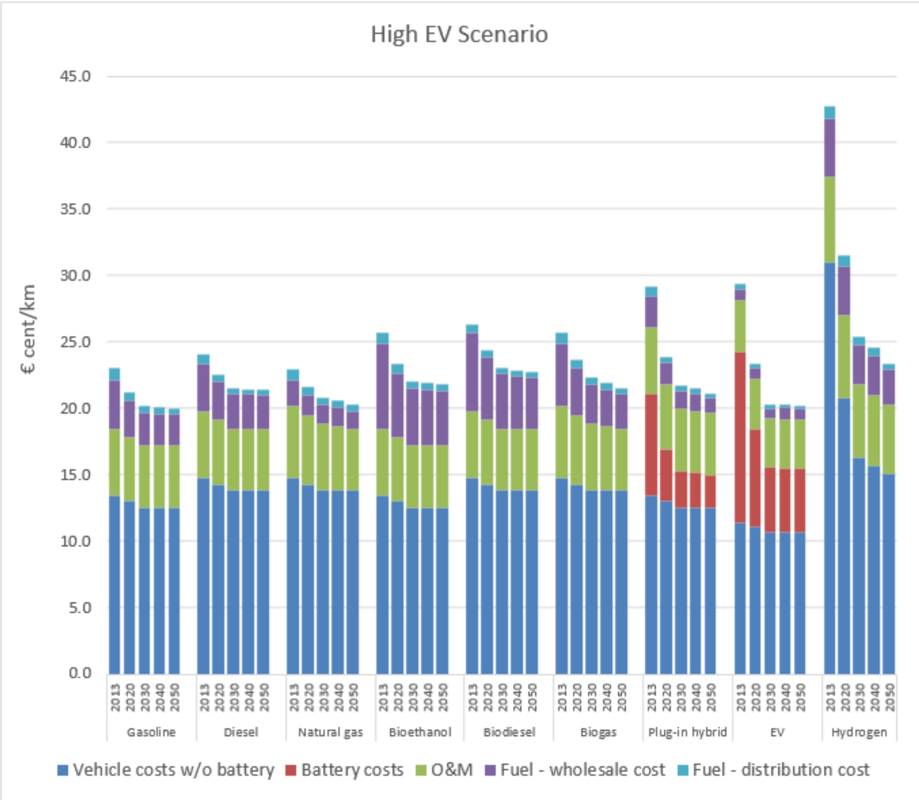


Figure 3: Personal vehicle economics (cost per km excluding taxes) – High EV scenario (Ea Energy Analyses, 2014)

In the High EV scenario, PHEVs and EVs see a large drop in the cost per km driven from 2013 to 2020, and in 2030, EVs are the lowest cost option. From 2030 to 2050, the cost of driving EVs does not fall in this scenario, which on

[7] The per km vehicle costs were based on the vehicle and battery purchase price, the km driven per year, lifetime of the vehicle and battery, and interest rate. In both scenarios each vehicle was assumed to drive 14,000 km per year in 2013, with this figure growing gradually to 15,000 km per year by 2050. The new vehicle lifetime for all vehicle types in both scenarios was assumed to be 15 years, while batteries produced in 2013 were assumed to have a lifetime of 7 years, with this growing to 11 years by 2050. Lastly, the discount rate used for vehicles and batteries was 5%. The operation and maintenance for a standard gasoline vehicle was assumed to be roughly 700 €/year (COWI, 2013). This figure was assumed to be roughly 20% higher for Hydrogen, and roughly 25% less for EVs due to them having less moving parts in the engine.

first glance may be surprising. The reason for this is the assumption that as the per kWh cost of batteries fall, and the energy density increases, the kWh capacity of batteries will increase, thereby allowing for a longer driving range. Meanwhile, the cost of driving a hydrogen vehicle falls quite substantially from 2013 to 2050, but it is still not competitive with the other vehicle categories.

No Breakthrough

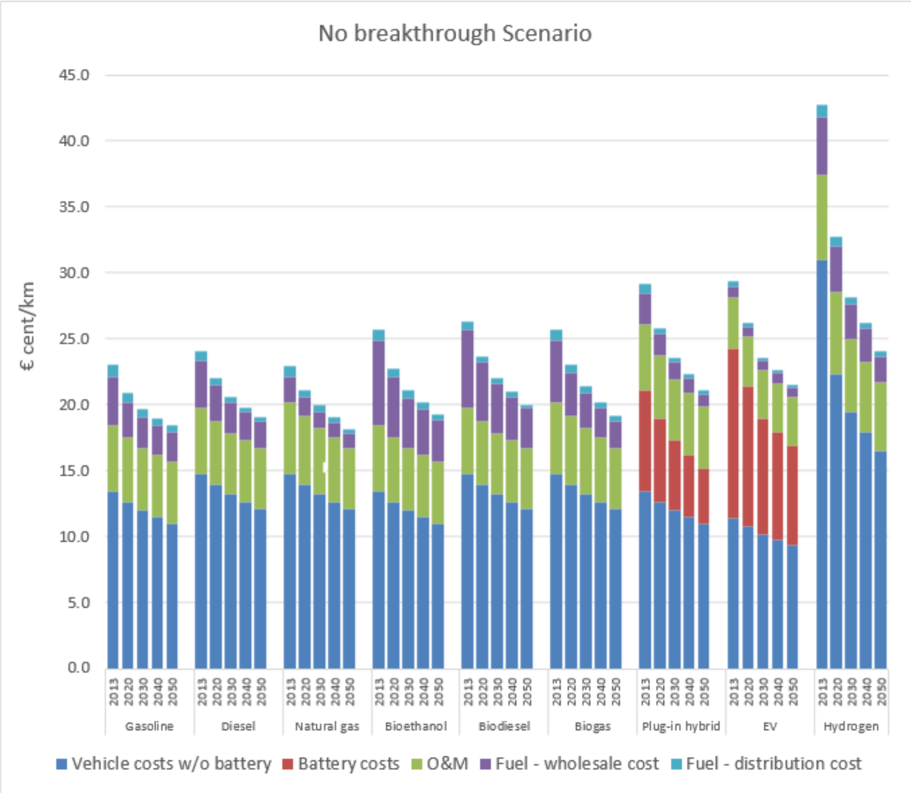


Figure 4: Personal vehicle economics (cost per km excluding taxes) – No Breakthrough scenario (Ea Energy Analyses, 2014)

In the No Breakthrough scenario, hydrogen vehicle costs still fall substantially, and EV and PHEV costs also fall considerably, but they are still more expensive alternatives than their traditional ICE counterparts.

Relevance of taxes

It is worth restating that these assessments are done without taxes, and as such the fuel costs above represent a smaller portion of the overall cost relative to real world situation. Due to the high efficiency of EVs and PHEVs, the energy usage is lower for these vehicles than others, and therefore when taxes are added to the picture, EVs and PHEVs fair better than their ICE and hydrogen counterparts. As such, in a real-world situation, and particularly from an end-user viewpoint, EVs would be more favourable than indicated in the above figures.

3.4 Key assumptions and parameters

In any scenario study there are always a number of assumptions and parameter selections that must be undertaken that are critical to the outcome. This is particularly the case when the timeframe of the analysis spans nearly 40 years. Table 5 displays some of the key assumptions utilised in the scenario analysis, while Table 6 displays some of the key parameters.

Element	Value/Description
Passenger vehicle km driven in the EU	Assumed to grow from 3,400 billion km in 2013 to 4,700 billion km in 2050.[8]
Biofuel availability	Capped at a value equal to 25% of the total energy from new passenger vehicles in 2013.[9]
CO_2 emissions from biofuels	Biofuels are assumed to be CO_2 neutral, and will increasingly come from 2nd generation production methods.
CO_2 emissions from electricity	CO_2 emissions associated with electricity utilised in EVs and PHEVS, and for hydrogen production are those from marginal EU electricity production. In terms of g CO_2 /kWh, emission factors were assumed to decline linearly from 840 g/kWh (marginal emission of coal fired power plants) in 2013, to 0 g/kWh by 2050, under the assumption that the power sector will be fully decarbonised by 2050.
Revised testing cycle	It is assumed that a new test will be implemented within the next 5-10 years, and as a result car manufactures will have a greater incentive to reduce the weight of their vehicle fleets.
Vehicle range	A maximum of 25% of all new vehicles can have a range below 150 km, and an additional maximum 25% of all new vehicles can have a range below 500 km.

Table 5: Key assumptions in the passenger vehicle scenario analysis.

			High EV			No Breakthrough		
Scenario parameter	**Unit**	**2013**	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**
Battery cost*	€/kWh	414	211	136	120	369	313	263
Battery density*	Wh/kg	140	250	294	375	150	165	180
Gasoline vehicle weight**	kg	1,220	1,281	1,210	1,250	1,159	1,001	750
Hydrogen vehicle cost***	€	44,988	31,296	25,428	23,472	34,426	31,785	29,340
Gasoline vehicle cost***	€	19,560	19,560	19,560	19,560	19,071	18,680	17,115
Plug-in hybrid battery size	kWh	15.0	17.6	21.6	25.0	16.0	18.0	20.0
EV battery size	kWh	25.0	33.0	38.5	49.5	27.0	29.8	36.0
Bioethanol in gasoline	%	5.0	5.0	5.0	5.0	10.0	25.0	60.0
Biodiesel in diesel	%	5.0	5.0	5.0	5.0	10.0	25.0	60.0
Biogas in transport	%	0.0	0.0	0.0	0.0	1.0	4.0	15.0

*Table 6: Scenario parameters. Note that all cost figures are in EUR 2013, without taxes and are EU averages. *The battery cost and density is for the battery cells alone.[10] **Vehicle weights*

[8] The future passenger km driven figures were based on estimates from a European Commission report, 'EU trends to 2030' (Capros, Mantzos, Tasios, De Vita, & Kouvaritakis, 2010) which forecasted total EU personal km travelled in 5 year periods up till 2030. For the years beyond 2030, a similar trajectory was extrapolated. These *personal km driven* figures were then converted to *passenger vehicle km driven* by assuming roughly 1.5 persons per vehicle per km.

[9] Due to the various issues and uncertainties cited with biofuels, as well as a recognition that biofuels are likely to be a limited resource, and those that are available are likely to be prioritised in the heavy duty vehicles and/or aviation sectors, this hard cap on total biomass for use in transport was implemented.

*based on EEA data (European Environment Agency, 2013). ***Vehicle costs based on "Alternative drivmidler". (COWI, 2013).*

3.5 Chapter summary

The scenario analysis highlights the fact that it is quite possible to reach the EU 2020 targets without EVs. Meeting the longer term targets however, i.e. in 2050 (and likely intermediary targets from 2030-2050), would prove to be very difficult without EVs, and given the massive biofuel requirements, perhaps even impossible. Hydrogen based personal vehicles could form part of the solution, but at this point in time it would appear that EVs and PHEVs will be a more cost-effective solution. In addition, the production and on-board conversion of hydrogen also involves additional processes that increase the overall energy use for hydrogen vehicles relative to EVs.

The scenarios demonstrate the likely future importance of EVs and PHEVs in the EU passenger vehicle segment. Given the lifetime of a personal vehicle, a transition to such a large segment of electrical drivetrains will take time, and equally important, will require technology advancement and cost reductions. To spur this technology advancement and cost reduction it is important that EV production and utilisation rates are increased in the upcoming years. The primary objective of the remainder of this report is therefore to identify and provide recommendations *regarding EU level measures and incentives* that can promote EV diffusion.

[10] Current and future battery costs were based on a number of sources (Element Energy, 2012) (McKinsey & Company, 2011), (International Energy Agency, 2012) (COWI, 2013) and cover the battery cells alone. Including the battery cell costs alone in the battery costs, and allocating the rest of the battery back in the cost of the EV or plug-in hybrid, was done to allow for scaling up and down of the battery size in different scenarios and years.

4 State of the art

4.1 Current and proposed EV related EU policies

The following subsection will review current and proposed EU policies in order to determine the extent that these policies can encourage EV sales.

CO_2 requirements for new vehicles

While not solely an EV policy, the EU Commission requirements on CO_2 emissions from new passenger cars (as outlined above in the preceding chapter) is currently the primary motivator in the EU for the reduction of emissions from vehicles.

EC White Paper

The 'Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system' from March 2011 sets out a transport strategy within a framework of achieving a 60% reduction in transport GHG emissions by 2050 (European Commission, 2011b).

Motivation

In reviewing the EC White Paper a number of motivations behind the vision of a 'competitive and resource efficient transport system' are mentioned. The most prominent and EV relevant of these factors include:

- Transport being an enabler in economic growth and job creation
- Oil dependence - oil will in the future become scarcer, and increasingly sourced from 'uncertain' suppliers
    - In 2010 the EU oil import bill was €210 billion
    - The EU still relies on oil and its by-products for 96% of its transport related energy needs, a figure that will only fall to 90% by 2020 under the current BAU approach
- A desire for a GHG reduction of at least 60% by 2050 relative to 1990 emissions
- Maintain a competitive position in the transport area
- Reduction of noise and local air pollution
- More efficient forms and usage of transport.

Issues related to oil dependency, both directly and indirectly, are a reoccurring theme in the White Paper, and coupled with transport related employment and GDP (which are in particular focus during the current financial crisis) appear to be the major driving factors behind the vision of a transport system that can achieve 60% emission reductions.

Other notes

The White Paper covers a number of transport related aspects, and another particularly interesting on-road observation relates to freight transport. The paper for example highlights the fact that on a weight basis, half of all goods transported via road are transported less than 50 km, and more than ¾ are transported less than 150 km (European Commission, 2011b). If these ICE trucks could be replaced by electric vehicles capable of transporting goods shorter distances, thus would reduce oil dependency, GHG emissions, local emissions, but also noise, which would have the positive side effect of allowing more deliveries at night, thus resulting in less congestion during the day (European Commission, 2011b).

Another interesting observation is that urban transport is responsible for roughly 25% of CO_2 emissions from transport (European Commission, 2011b). Given that people in cities generally have lower daily transport range requirements, and local pollution from vehicles is more of an urban issue, the replacement of ICE vehicles with EVs in cities would both be easier, and have a greater environmental effect, relative to replacing ICE vehicles with EVs in rural areas.

Goals

The White Paper outlined 10 goals for achieving the vision, and the most relevant for EVs were (European Commission, 2011b):

- 'Develop and deploy new and sustainable fuels and propulsion systems, hereunder:
    - Halve the use of 'conventionally-fuelled' cars in urban transport by 2030; phase them out in cities by 2050; achieve essentially CO_2 free city logistics in major urban centres by 2030'
- 'Increase the efficiency of transport and of infrastructure use with information systems and market-based incentives, hereunder:
    - Move towards full application of "user pays" and "polluter pays" principles and private sector engagement to eliminate distortions, including harmful subsidies, generate revenues and ensure financing for future transport investments'

The primary divers behind the EC future transport vision appear to be reduction of GHG emissions, reduction of oil dependency, and fostering economic growth and jobs. Associated benefits that will likely be derived from achieving these goals include reduction of local air and noise pollution, and reduced urban congestion.

In terms of how the above goals are to be achieved, overarching suggested guidelines are utilisation of: sustainable fuel propulsion systems, market-based incentives that incorporate externalities, and increased efficiency. Focus will be on urban areas, both in terms of the phasing out of 'conventionally-fuelled' cars, but also in terms of short distance freight transport. With the reference to use of market-based incentives and the elimination of market distortions comes the implication of technology neutrality, i.e. that the market shall choose the winners.

Potential to impact EV sales

With respect to EVs, the White Paper's vision is relevant because a number of its goals are well suited to EV implementation, i.e. reduction of oil dependence, GHGs, and local pollution, and utilising a sustainable and efficient technology to do so. On the other hand, the technology neutrality implication indicates that it is not necessarily EVs that will provide the solution, but that other technologies, if able to meet the goals in a more cost-effective manner, that will be utilised.

EU Clean Fuel Strategy

The EU Clean Fuel Strategy, which was announced in January of 2013, establishes a framework for an alternative future fuel infrastructure. The strategy aims at overcoming some of the obstacles that currently exist for the extension of alternative fuel stations with common standards and designs. The idea is that member states will have the ability to implement these changes by altering regulation of local and private actors so that the incentive framework is favourable. It should not be necessary to involve further public investments nationally and the EU already supports development through Connecting Europe Facility (formerly TEN-T) funds and cohesion and structural funds. The strategy includes objectives related to EVs, biofuels, hydrogen, LNG, CNG and LPG.

The Directive on the Deployment Alternative Fuels Infrastructure, which was adopted 22 October 2014 requires Member States to establish a charging infrastructure with adequate coverage in densely populated areas. As an indication – but not a requirement in the directive - the average number of recharging points should be equivalent to at least one recharging point per 10 cars. Since it is important to have a standardised plug, according to the directive charging points are required to have a "Type 2" plug for AC charging, and a "Combo 2" for DC charging (EC/94, 2014).

Potential to impact EV sales

With respect to the impact on sales of EVs, ensuring minimum standards for charging stations, as well reaching agreement on a standardised plug, are both beneficial and/or perhaps pre-conditions for a large-scale roll out of EVs. However, the extent to which the strategy is likely to influence the sale of EVs in the short and medium term is perhaps more uncertain.

Public Procurement

In 2009, the EU-Commission published a directive on the promotion of clean and energy-efficient road transport vehicles (European Commission, 2009b). The directive set out requirements for public procurement in relation to road transport vehicles, including EVs.

The main purpose of the directive is to affect the market for road vehicles (in terms of personal vehicles, busses and trucks) by securing demand for clean and energy efficient vehicles, and thereby motivating vehicle producers to produce and develop such vehicles. The directive includes an attempt to include externality costs related to environmental issues in the public procurement of vehicles.

Through the directive, the ‘contracting authorities, contracting entities, as well as certain operators’ are obliged to consider the energy and environmental impacts during the entire operation lifetime when they are purchasing vehicles. This means that energy consumption and environmental impacts (as a minimum CO_2 emissions, NO_x, NMHC and particles) shall be considered in all decisions regarding the purchase of road vehicles.

Two methods are prescribed to include environmental impacts in the procurement decisions:

1) Setting technical specifications for the vehicle’s energy and environmental performance
2) By including energy and environmental impacts as award criteria in the purchasing procedure.[11]

The directive gives the EU member states the possibility to choose freely between the two methods. The EU Commission performs an evaluation of the impacts of the directive every second year, starting in December of 2012. Evaluation reports shall include the progress in the member states by addressing questions related to what they have done to support the

[11] If the impacts are monetised for inclusion in the purchasing decision, common rules shall be followed, as defined in the Directive for calculating the lifetime costs linked to the operation of vehicles.

procurement of clean vehicles, what have been the effects of the methods set out in the directive. The results of evaluations can be adjustments of the methods to fulfil the purpose of the directive.

Implementation in Denmark

The clean vehicles directive is implemented in Danish law secondary law no. 1394 from December 14th 2010 (Ministry of the Environment, 2010). The act is almost a direct translation of the EU directive and repeats the possibility of selecting between the two methods mentioned in the directive to fulfil the objective of including energy and environmental impacts in public procurement of vehicles. The Danish Environmental Protection Agency has published a guide for the act on its homepage that states the possibility to combine the two methods – in this case the award criteria in method 2 shall be set in addition to the minimum criteria set in method 1.

Potential concerns

Upon being implemented, a few concerns were raised in connection to the directive. One such concern is as there is no minimum level for the technical specifications for the vehicle's energy and environmental performance in method 1; it appears to be up to the member states to decide on a level. In the case of Denmark the implementation act repeats the freedom to choose between the two methods for public procurement, but does not set a minimum level for the environmental impacts in method 1. Hence, it is left to the individual public institutions to set these levels, which then might end up depending on other considerations, i.e. economy, comfort etc. A possible solution to this would be to establish minimum levels for method 1.

First evaluation report

The first evaluation report from the EU Commission on the progress in the member states was published in April of 2013 (European Commission, 2013b), however the report stated that:

> Belated transposition of the Clean Vehicle Directive by most Member States has limited the experience with this Directive to date and has therefore provided challenges for the assessment of its impacts within the scope of this monitoring report. This situation is further aggravated by the absence of reporting obligations for Member States.

However, the report did indicate that "additional guidance appears necessary for the application of the different options of the Directive in order to take into account energy consumption, CO_2 and pollutant emissions when procuring vehicles". Lastly, with regards to the Clean Vehicle Portal, it was assessed to be a useful tool, and as such the Commission will upgrade the

Portal in accordance with procurer expectations. (European Commission, 2013b).

Potential to impact EV sales

The total annual purchase of vehicles by public authorities has been estimated to be in the order of 110,000 passenger cars, 110,000 light-duty vehicles, 35,000 lorries and 17,000 buses for the EU-25. Compared to the overall sales in the EU-25 this corresponds to a share of slightly below 1% for cars, around 6% for vans and lorries, and around 30% for buses (Environment, 2011).

Given the above evaluation it is difficult to ascertain with certainty the potential impact of this particular policy on EV sales. However, it would appear that public procurement in general, particularly if they include specific EV targets, can be a positive driver for EV sales particularly within the van and bus segments.

Fuel taxation

While not a direct EV related measure, the taxation of fuels can play a large contributing role in a purchaser's personal vehicle selection. The energy taxation Directive (2003/96/EC – "energy Directive") from 2003 defines the minimum levels of taxation to be imposed on energy products and electricity. The minimum for unleaded petrol used as a propellant is 359 EUR per 1000 litres (10.9 EUR/GJ, 33 GJ/l) and 330 EUR per 1,000 litres for diesel (9.2 EUR/GJ, 36 GJ/l). Many countries within the EU apply higher rates than the minimum level, as illustrated in the graph on the following page.

For example, the tax rate for unleaded petrol is higher than 700 EUR/1,000 litres in Italy and the Netherlands, and in a number of other countries it is more than 600 EUR/1,000 litres.

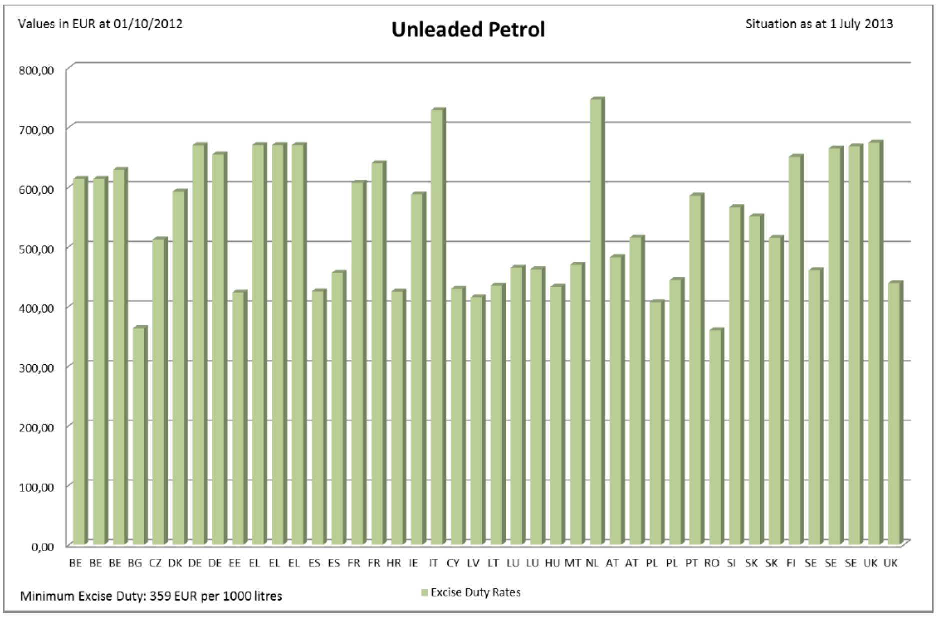


Figure 5: Excise duty rates for unleaded petrol for EU countries in Euro per 1000 litres. Note that the EU minimum is 359 Euro per 1000 litres, which is equivalent to 10.9 EUR/GJ (European Commission - Directorate-General Taxation and Customs Union, 2013).

For electricity, the minimum excise duty is only 1.0 EUR/MWh (0.28 EUR/GJ) for 'business use' and 0.5 EUR/MWh (0.14 EUR/GJ) for 'non business use'. A few countries also have relatively high taxes on electricity – much higher than the minimum levels – but in general electricity taxes are quite low compared to the taxes on diesel and petrol. This is reflected in the figure below.

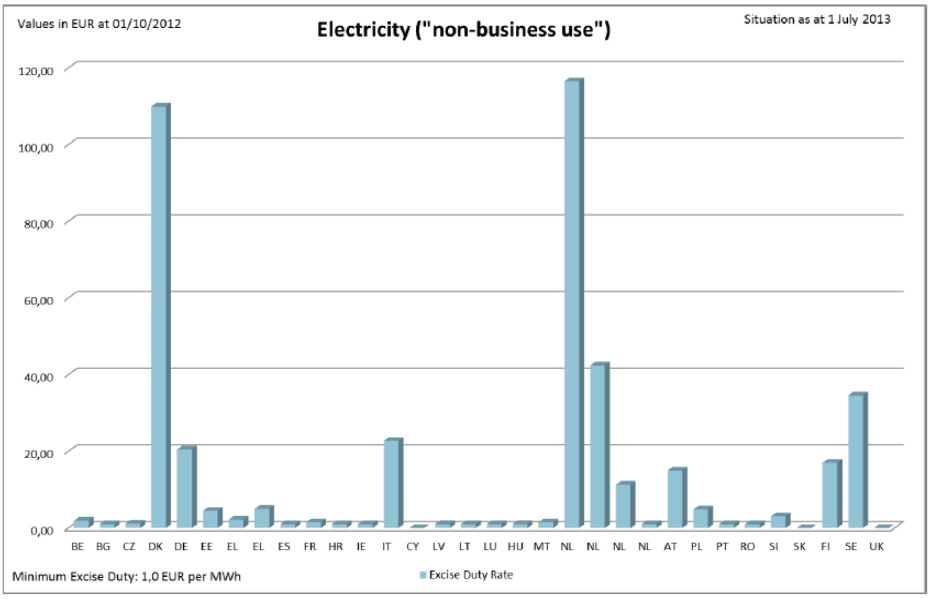


Figure 6: Excise duty rates for electricity in EUR per MWh. Note that the EU minimum is 1.0 EUR per MWh (0.28 EUR/GJ) for 'non-business use', and half as much for 'business use' (European Commission - Directorate-General Taxation and Customs Union, 2013).

Figure 6 highlights the fact that in certain countries (i.e. Denmark and the Netherlands) end-users face extremely high excise duties on electricity. However, in some of these high duty countries (i.e. Denmark), there are currently electricity tax reductions in place so that EV drivers see tax rates much lower than illustrated above.

Using Germany as a proxy for the EU, it is possible to compare the minimum and EU proxy per GJ costs of electricity vs. gasoline and diesel.

	Minimum			EU Proxy		
	€/litre	€/MWh	€/GJ	€/litre	€/MWh	€/GJ
EU petrol excise duty	0.36		10.9	0.67		**20.3**
EU diesel excise duty	0.33		9.2	0.48		**13.5**
EU electricity excise duty*		1.0	0.28		20	**5.6**

*Table 7: EU minimum excise duties on petrol, diesel, and electricity for 'non-business' use. Proxies are German values as these values are close to the median and represent a large % of the EU population. *Non-business.*

As indicated in Table 7, the minimum excise duty is currently significantly lower for electricity relative to petrol and diesel. Meanwhile, in practice, the excise duty is roughly 2.5-3.5 times higher for diesel and petrol on a per GJ basis. Due to the extremely efficient electric motor in an EV, on a per km basis a diesel or gasoline vehicle uses 3-4 times more energy than an EV. As a result, depending on the specific car and using the EU proxy values, an ICE vehicle owner in the EU will pay roughly 10 times more in fuel excise duties per km driven.

Potential to impact EV sales

In the long term, if a large shift to personal vehicle electrification does take place, this will pose a challenge to governments as these revenues will have to recouped via extremely high electricity tariffs, or, more likely, from alternative sectors. In the short term however, fuel excise duties represent a potential lever to further encourage a shift to electrification. This could for example be via increasing the minimum excise duty on gasoline and diesel, and/or by encouraging countries with high electricity duties to exempt EV users from these duties (i.e. as is done in Demark today[12]).

Revised testing cycle

The aforementioned white paper identified the need for a revised test cycle so that CO_2 emissions are reduced under real-world driving conditions. A 2012

[12] It should be noted that in Denmark EV users are not directly exempt from taxes on electricity. Suppliers of EV charging receive a significant reduction in electricity taxes, which they in turn can elect to pass on to their customers.

report (Transport and Environment, 2012), based on fuel consumption data for 28,000 German car users highlighted the fact that there is a growing gap between official test CO_2 test figures, and 'real life' driving figures. What is particularly interesting is that this gap has grown steadily from roughly 7% in 2001 to over 23% in 2011 (see figure below), and that a very dramatic drop starts in 2007, about the same time that mandatory CO_2 emissions targets were being developed (Transport and Environment, 2012).

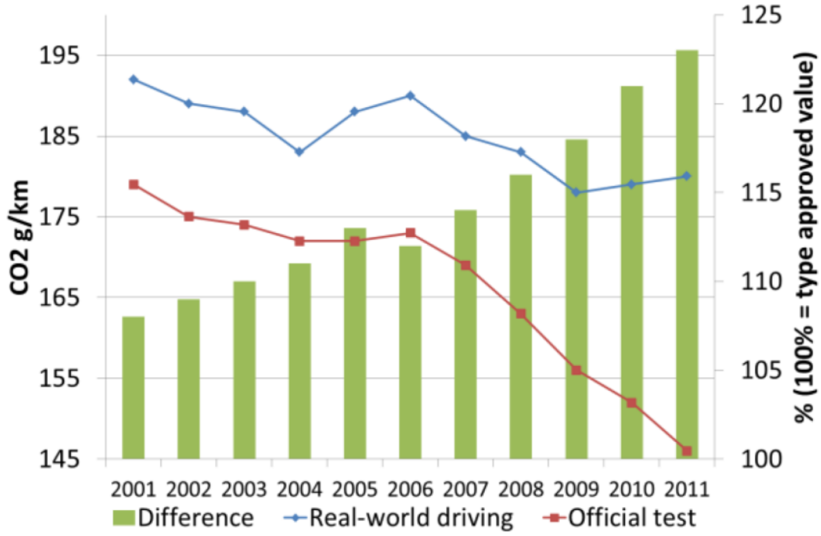


Figure 7: Gap between tested and 'real life' CO_2 emissions (Transport and Enviornemnt, 2013)

The result of this gap is that end-users do not attain the fuel savings they anticipate to realise (losses here are estimated to be around €1,300 over the course of the car's lifetime), and actual CO_2 emissions reductions from new passenger vehicles are much less than reported[13].

The report concludes that "the only realistic explanation for this gap is that carmakers go to ever greater lengths to 'optimise' their test vehicles for the official fuel consumption test" (Transport and Environment, 2012). Given the competitiveness of the automotive market, and the money at stake, automakers cannot be faulted for bending the rules to their favour in order to gain a competitive advantage.

The fact that manufacturers have exploited weaknesses in the current procedure, thus leading to official consumption and emission figures that are dramatically different from those achieved in everyday driving conditions, has

[13] The NGO ICCT (International Council on Clean Transportation) has analysed the gap between official and real-world fuel consumption and CO2 emissions for passenger cars in Europe. The report "From Laboratory to Road" (ICCT et al, 2014) can be downloaded from the ICCT's website: http://www.theicct.org/laboratory-road-2014-update.

not gone unnoticed by the European parliament. In the text involving the aforementioned 95 g/km target that was approved by the European Parliament in February of 2014, it is also stated that the new UN-defined World Light Duty Test Procedure (WLTP) should come into force at the earliest opportunity. The European Commission indicated that the WLTP better reflects real-world driving conditions and supports a 2017 deadline for its implementation. (European Parliament, 2014).

Historically speaking, the EU automobile industry lobby has been quite effective in postponing and/or weakening CO_2 emission legislation. As such, it is perhaps unlikely that a new testing cycle will be implemented by 2017, particularly with respect to the targets currently in place. However, a new test cycle and testing procedures that eliminate many of the above mentioned loopholes is likely to be implemented in the years to come.

Potential to impact EV sales

A new and effective test cycle could help to promote EVs due to the fact that once this loophole is closed, car manufactures would have to find other ways of lowering their overall fleet emissions. As such, for a small country such as Denmark, pushing for an effective new test cycle could prove to be a low-cost method of promoting EV diffusion.

4.2 Experiences with other EV related polices

With a focus on what can be implemented at the EU level, this subsection will review what other selected countries and regions are doing with respect to promotion of EVs. While a handful of countries will be reviewed briefly, California, with its relatively successful EV adoption, will be looked at in greater detail.

California

There were a number of reasons why California was selected as one of the primary regions for review. Firstly, California also has relatively ambitious CO_2 emission reduction goals, with legal requirements of reducing emissions back to 1990 levels by 2020, and emissions in 2050 to be 80% below 1990 levels (California Council on Science and Technology, 2011). In addition, the state has a relatively long history of EV promotion, and is also a front runner today. Lastly, California is also a rather large vehicle market, and thus represents a region where implementation of EV policies can result in a significant demand for EVs.

To put the size of the California car market into perspective, according to State of California's department of motor vehicles, as of December 31st, 2013, there were over 23 million automobiles alone registered, with an additional 10 million other types of vehicles registered (motorcycles, trucks, busses, etc.) (State of California department of motor vehicles, 2014). Meanwhile, when looking solely at new vehicle registrations, 2013 saw over a million new cars registered in California, and another nearly 650,000 light trucks (CNCDA, 2014).

Early ZEV

As part of its plan to reduce emissions from transport, in 1990 the California Air Resources Board (CARB) adopted the Zero-Emission Vehicle (ZEV) mandate. The ZEV program dictated that ZEVS[14] constitute a share of each large-volume automobile manufactures vehicle sales. The initial target was 2% of annul new vehicle sales for the years 1998 through 2000, 5% for the years 2001 and 2002, and 10% for the years 2003 and thereafter. After a 1995 review found that battery technology was not evolving as anticipated, as well as pressure from automobile manufactures, in 1996 CARB removed the requirements for the initial ramp up years (1998-2002), but maintained the 10% requirement for 2003. Over the following few years, technology reviews, litigation, and settlements resulted in three new vehicle categories being introduced that counted towards the 10% requirement:

- Partial-zero-emission vehicle (PZEV): Partial credits for ultra-clean ICE vehicles that met the most stringent tailpipe standards were initially allowed to count for up to 6 of the 10% target (1998).
- Advanced technology partial-zero-emission vehicle (AT-PZEV): Vehicles that met the PZEV requirements and incorporated advanced technology such as energy storage or electric motors, i.e. Toyota Prius, could count for up to 2 of the 10% target (2001).
- Fuel cell vehicle (FCV): credits were given under the alternative compliance path (ACP) introduced in 2003. (Bedsworth & Taylor, 2007).

CARB has continually adjusted the ZEV mandate to include new technologies (i.e. plug-in hybrids), as well as developed a system to earn, bank, and trade the credits required to meet the mandate. The result is the relatively complex system in place today, embodied by the adoption of a new package of standards referred to as Advanced Clean Cars, which will be described in part below.

[14] ZEVs - Vehicles deemed to meet a specified emission standard. At this time BEVs were the only vehicle to meet the standard (Bedsworth & Taylor, 2007).

Early ZEV - critiques

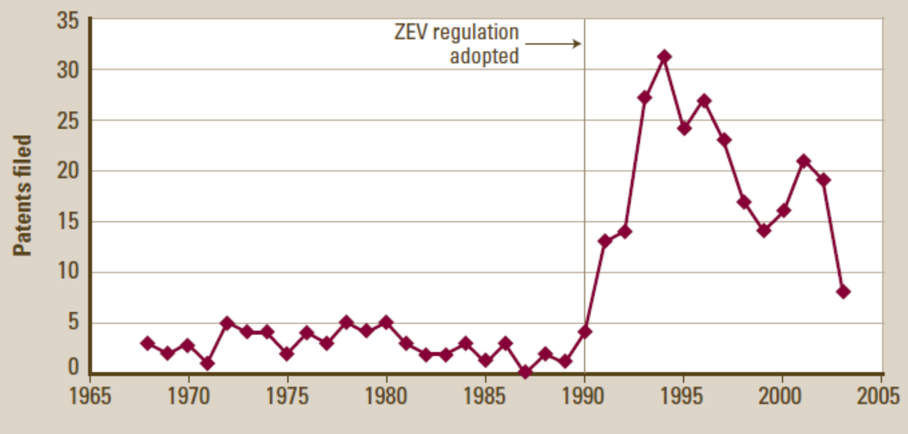
There were a number of criticisms raised regarding the early ZEV program, particularly towards the automotive and oil industries, which lobbied and brought lawsuits against the ZEV mandate. One of the chief complaints was that automobile manufacturers were producing electric vehicles simply to comply with their requirements in California, so that they could continue to sell ICE vehicles to the large and lucrative California market. As a result, these EVs were dubbed 'compliance vehicles'. It was argued that these vehicles were largely only made available in California, and were not eagerly promoted, so that the automobile manufactures could later claim that the public had little interest in EVs. This story, with a focus on GM's EV1 electric vehicle inspired the documentary 'Who Killed the Electric Car', which told the story of numerous EV1 lessors, who to their great disappointment were not allowed to purchase their vehicle at the end of the lease period, but instead had to return them to GM, only to have GM crush the vehicles. (Paine, 2006).

Early ZEV – Lessons learned

A 2007 study by the Public Policy Institute of California, a self-described "non-profit, nonpartisan think tank dedicated to informing and improving public policy in California through independent, objective, nonpartisan research", reviewed the early ZEV program in order to garner lessons learned (Bedsworth & Taylor, 2007).

Technology innovation

One of the aspects that the report examined was the effect the ZEV program had on technology innovation. Amongst other methods, it did so by looking at the number of patents filed before and after the implementation of the program.



Source: U.S. Patent and Trademark Office.
Note: This figure accounts for patenting by all sources, including automakers and component suppliers as well as other firms and individuals.

Figure 8: BEV related patents filed in the US from 1968-2003 (Bedsworth & Taylor, 2007)

Figure 8 reflects the fact that the EV was the only passenger vehicle technology anticipated to meet the original ZEV standard, and as such the adoption of the regulation resulted in a significant increase in EV related research. Not revealed in the graph, but of interest, is the dispersal of patents according to country of origin. The largest increase in patents came from Japanese firms, despite the fact that American federal government R&D support was only available to domestic automakers. (Bedsworth & Taylor, 2007). This is interesting, and particularly potentially relevant from an EU standpoint, as it reveals how a regulation in one jurisdiction can lead to foreign manufactures increasing their R&D efforts in the technology selected by the regulating jurisdiction.

The report also reviewed the technological spill overs of the early ZEV program and found that despite the fact that the program largely shifted away from pure EVs, hybrid electric vehicles benefited greatly from the EV related R&D efforts. These benefits were related primarily to battery evolution, but also high voltage controllers and electric motors. (Bedsworth & Taylor, 2007).

Climate change

With respect to developing climate change programs in the transport sector, the report found that lessons learned from the ZEV program included (Bedsworth & Taylor, 2007):

- *Actions that the state undertakes to reduce GHG emissions can provide strong market demand signals for new technology.*
- *Technology neutrality can prevent a regulation from being tied to the fate of a single technology—vehicle batteries in the case of the ZEV program. Neutrality can also reduce volatility, preserve a stable demand signal, and reduce the risks to consumers by avoiding a commitment to suboptimal technology.*
- *Performance standards have been largely responsible for the successful reduction of vehicle emissions to date. These standards have maintained flexibility while maintaining aggressive environmental goals.*
- *Climate policies need to consider full life-cycle emissions*

Lessons learned - conclusions

Based on the above, it can be concluded that if the aim is to promote a specific technology, then a technology specific mandate can be effective. However, it is also inherently risky as this requires an estimate from the regulator regarding the anticipated development of the technology. The risk lies in the fact that if the specified technology develops slower than anticipated, and/or an alternative technology advances quicker than anticipated, then the implementation of the specified technology will become overly costly. This is particularly the case if an alternative strategy proves to be much more cost-effective, thereby resulting in large sums of R&D funds being allocated in a sub-optimal manner.

On the other hand, if the aim is to meet overall transport related environmental goals, then it is likely favourable to adopt a technologically neutral approach. This approach allows individual automobile manufactures to determine how best to meet the targets. The setting of the overall target still requires an estimate regarding technology advancement, however an incorrect estimate is less likely because there are now a number of technologies that can potentially contribute to meeting the target, and adjusting this target underway is also less problematic. In addition, responsibility for sub-optimal allocation of R&D funds will not lie with the regulator, but instead with the individual automobile manufacturer.

ZEV program today

Today the ZEV program is part of the larger Advanced Clean Cars program, which coordinates the goals of the Clean Fuels Outlet, Low-Emission Vehicle, and Zero Emission Vehicle programs. The ZEV program is still based on a credit system where vehicle manufactures must produce credits based on the number of vehicles sold. If a manufacturer does not produce and/or purchase the required amount of credits then it can be fined $5,000 per missing credit, and it must still acquire the remaining credits in upcoming years. The number of credits earned per vehicle varies depending on the vehicle technology (EV, PHEV, etc.), all-electric range, and year. The credits received for pure EVs are displayed below in Table 8.

	Range (miles)[15]	Fast charging	Credits	
			2009 - 2017	2018+
Type 0	< 50	No	1	1
Type 1	50 - 75	No	2	2
Type 1.5	75 - 100	No	2.5	2.5
Type 2	100 - 200	No	3	3
Type 3	200+	No	4	3
Type 3	100 - 200	Yes	4	3
Type 4	200+	Yes	5	3
Type 5	300+	Yes	7	3

Table 8: ZEV credits according to EV vehicle range, charging ability and year of implementation (CEPA Air Resources Board, 2014).

As can be seen from the table, the major difference from 2017 to 2018 is that the 'fast refuelling capability' bonus has been removed. This particular aspect has been rather controversial, because Tesla in particular has generated substantial additional credits from its Tesla S after demonstrating that its battery packs could be swapped in a matter of minutes. Large purchasers of ZEV credits from Tesla and Nissan included General Motors and Chrysler, who could not meet their ZEV requirements based on their own vehicle sales alone.

From Table 8 it also becomes apparent that there is little incentive (at least from a ZEV credit perspective) to produce an EV with a range much greater than the minimum for each category (e.g. 40 miles for a type 0, 70 miles for a type 1, 150 miles for a type 2, etc.). As such, there is incentive for manufactures to produce EVs with ranges in a number of steps, i.e. just over 50 miles, 75 miles, 100 miles, and 200 miles, but nothing in between. These steps may however not correspond with customer demand, with the jump from 100 to 200 miles (160 km) representing a particularly large increase, and thereby perhaps overlooking a customer segment which could for example be satisfied with a driving range of roughly 150 miles (240 km). These considerations should be kept in mind when shaping new incentive schemes.

Lastly, there has also been some criticism regarding manufactures still producing 'compliance vehicles', a critique that may be valid for some vehicles, for example the Chevrolet Spark EV, the Honda Fit EV, the Ford Focus Electric, and the Toyota Rav4 (Shepard, 2012). However, as more states join the program (over 10 states are participating today, representing roughly 30%

[15] Please note that 1 mile = 1.6 km

of the American light duty vehicle market), and an increasing amount of production scale EVs are introduced (i.e. Tesla, Nissan, Renault,, BMW and Volkswagen all have all released full sized EVs) it is apparent that the ZEV program is contributing to the advancement and rollout of EVs.

ZEV program in the future

Under the Advanced Clean Cars program, changes to the ZEV program have been implemented so that vehicle manufacturers will be required to produce increasing numbers of ZEVs and plug-in hybrid electric vehicles in the 2018-2025 model years (California Air Resources Board).

The 2012 amended ZEV mandate, which was allowed via a waiver granted by the Environmental Protection Agency, stipulates that electric and fuel cell vehicle sales get full ZEV credits, while plug-in hybrids only get partial credits based on their all-electric range. In addition, a cap has been placed on the share of plug-in hybrid sales that can be used to meet the mandate.

The credit system is somewhat complicated, particularly for the years up to 2017. However, the figure below roughly translates the required credits into anticipated vehicle sales figures for the years 2018-2025. Starting in 2018, 4.5% of the manufacturer's sales in California must be either ZEVs or a mixture of ZEVs and plug-in hybrids, with this figure growing to 22% by 2025. (US Department of Energy, 2013b).

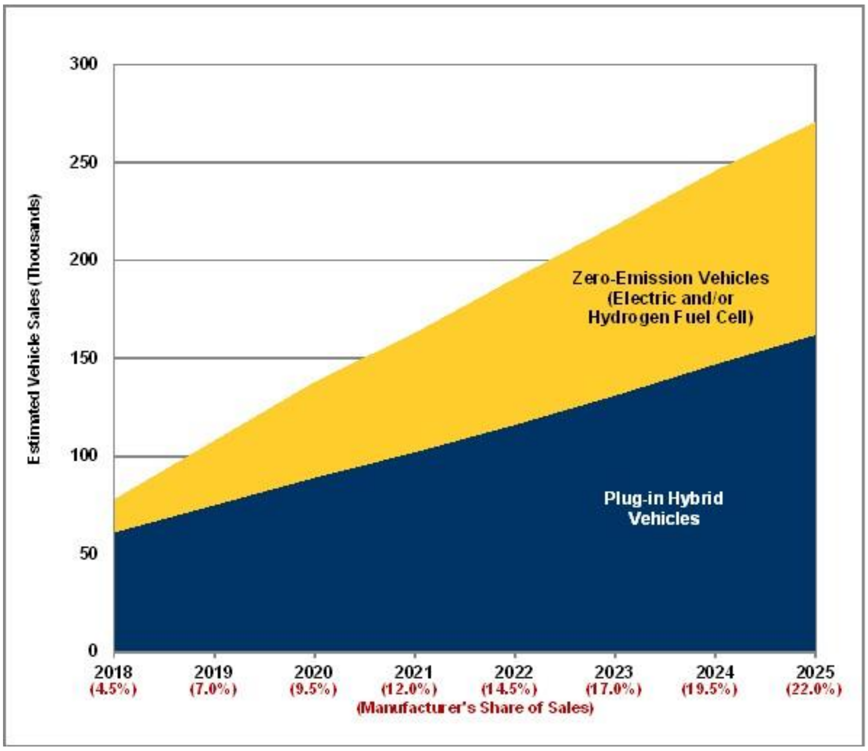


Figure 9: Anticipated compliance figures from the ZEV program for new vehicle purchases in California for the period 2018-2025 (US Department of Energy, 2013b).

For a point of comparison, Table 9 below displays the values from Figure 9, and also includes the historic EV and PHEV sales for the years 2010-2013.

Year	Transitional ZEVs (Plug-In Hybrids)	ZEVs (EV and/or Hydrogen Fuel Cell)	Total ZEV Sales/ Requirements
2010*	97	300	0.0%
2011*	1,682	5,302	0.5%
2012*	14,701	6,197	1.4%
2013*	20,235	21,963	2.5%
2018	61,000	17,000	4.5%
2019	75,000	33,000	7.0%
2020	89,000	49,000	9.5%
2021	102,000	61,000	12.0%
2022	116,000	75,000	14.5%
2023	131,000	87,000	17.0%
2024	147,000	99,000	19.5%
2025	162,000	109,000	22.0%

*Table 9: Historic California sales of PHEVs and EVS for the years 2010-2013 (CNCDA, 2014) and estimated future California Zero-Emission Vehicle (ZEV) sales, as mandated by the 2012 Amendments to the California Zero-Emission Vehicle Regulation (US Department of Energy, 2013b). *Figures are solely for PHEVs and EVs.*

The estimated requirements for the years 2009-2017 are not included as they are calculated differently from the 2018-2025 requirements. As can be seen from the table, the 2018 target for pure EVs was already surpassed in 2013, and even with slowed growth, the total ZEV sales target for 2018 appears to be quite achievable.

Other programs and projects in California

While the Advanced Clean Cars program, with the ZEV program as focal point, is the primary EV driver in California, there are also a number of other projects and programs that aid in the promotion of EVs. Many of these projects are administered by the CCSE (California Center for Sustainable Energy, 2013):

- The Clean Vehicle Rebate project
    - Which provides rebates of up to $2,500 for the purchase or lease of zero-emission and plug-in hybrid light-duty vehicles.
- Regional Plug-in Electric Vehicle Planning
    - The goal of which is to develop a regionally accepted, comprehensive plug-in electric vehicle (PEV) readiness plan for the San Diego region and San Joaquin Valley.
- San Diego International Airport – Clean vehicle conversion program
    - Under this program 'non-clean air vehicles' pay more for the required permits allowing them to service the airport.
- Clean cab partnership
    - Works toward clean vehicle advancement.
- Fleet consulting
    - Provides expertise and options that help municipal fleet managers evaluate changes in fleet composition and operations.
- Utility Customer Education Program
    - Connects PEV drivers and utilities to promote utility notification, special utility rate options and other PEV programs offered.
- Two R&D projects:
    - Plug-in Electric Vehicle Battery Pack Standardization Study.
        - To determine the benefits of establishing standardised EV battery packs to facilitate secondary use and recommend a strategy to implement standardization based on the study.
    - Secondary Use Applications of PHEV Lithium-Ion Batteries
        - To identify alternative uses of electric car batteries at the end of their useful life in automobiles.

Closing note on California

When comparing California to the EU it is worth noting that one of the driving forces in California is local air quality, as California has been noted as having the worst air quality in the nation. While this has been a driving factor in some European cities, i.e. Amsterdam, on the EU level as a whole, it is likely not as strong a driver.

United States *EV Everywhere Grand Challenge*

In March of 2012 President Obama announced a goal of being the first country in the world to produce plug-in electric vehicles[16] (PEVs) that are as affordable as today's gasoline-powered vehicles, and that this should occur within 10 years. Known as the EV Everywhere Grand Challenge, the goal is accompanied with a blueprint that outlines three main elements (US Department of Energy, 2013a):

1) Technology push (R&D) in order to reduce the cost of electric drives.
2) Charging infrastructure development to enable fuelling convenience.
3) Market pull through consumer acceptance via incentives and activities.

Figure 10: Key elements in the DOE's EV Everywhere Challenge (US Department of Energy, 2013a)

Technical targets

In order to reduce EV costs, the DOE developed a number of "stretch targets", i.e. targets that they acknowledge are ambitious, but at the say time are deemed to be achievable with collaborative efforts. These targets generally fell under three technical areas: Battery, electric drive system, and vehicle weight reduction. (US Department of Energy, 2013a). The specific targets for batteries and the electric drive system are indicated in the figures below.

Figure 11: Battery advancement targets in the DOE's EV Everywhere Grand Challenge Blueprint (US Department of Energy, 2013a).

[16] The DOE uses the term plug-in electric vehicles (PEVs) to include EVs and PHEVs.

Figure 12: Electric drive system advancement targets in the DOE's EV Everywhere Grand Challenge Blueprint (US Department of Energy, 2013a).

With respect to vehicle lightweighting, the 2020 targets call for a 35% reduction in the weight of the vehicle body, a 25% reduction to the chassis/suspension, and a 5% reduction to interior. Combined with weight reductions to the battery and electric drive system, the overall target is to reduce the vehicle weight by 30%. (US Department of Energy, 2013a).

Charging related R&D

Other R&D efforts without specific targets include developing more efficient climate control strategies, as well as investing in a number of charging related issues, such as charging infrastructure siting, standardisation, permitting, grid integration, etc. (US Department of Energy, 2013a).

Market pull

The third primary element, market pull or consumer acceptance, is to be addressed via education and policy intiatives. In terms of financial incentives, taxpayers receive a federal tax credit between $2,500 and $7,500 for qualified PEVs. (US Department of Energy, 2013a). A number of states also provide financial incentives in addition to the federal tax credit, with the aforementioned Clean Vehicle Rebate project in California being one prominent example.

2014 update

In January of 2014 the DOE released an update regarding the progress of various aspects of the EV Everywhere program. The report started by highlighting the fact that total PEV sales were almost 100,000 in 2013, thereby nearly doubling the sales figure for 2012. Other highlights from the report included (U.S. Department of Energy, 2014):

- Significant progress regarding the cost and energy density of electric batteries. Costs were now estimated at $325/kWh of useable energy, while energy density was now estimated at 150 Wh/liter. Improvements in the areas of electric drive systems, vehicle lightweighting, and efficient climate control technologies were also reported.

- With respect to charging infrastructure and creating market pull, improvements in both areas were realised, as demonstrated by the *Workplace Charging Challenge*, which more than 50 U.S. employers joined and pledged to provide charging access at more than 150 sites.
- In terms of consumer acceptance, the report indicated that the large growth in PEV sales could largely be attributed to a growing variety of EV and PHEVs to select from, as well as positive feedback regarding their performance and value.

Norway

In terms of EVs as a % of total new vehicle sales, with over 5% in 2013, and a staggering 20% for March of 2014, Norway is relevant to review in order to determine what is driving these sales (Clean Technica, 2014) (Gronne bil, 2014).

With respect to economic drivers, EVs in Norway are not subject to registration taxes or VAT (ICEs are taxed heavily), and are subject to lower annual fees as well. In addition, EVs are not subject to road tolls, have access to free parking in municipal parking lots, and can also charge free in some locations (cars21.com, 2013). Coupled with the much lower fuel prices (electricity vs. gasoline or diesel), the total cost of ownership (TCO) in Norway for the majority of car segments is lower for EVs than its diesel or gasoline counterparts. Norway has a target of having 50,000 EVs on the road by 2018, and the above incentives will be in effect until 2018, or until the 50,000 EV target is achieved (AVERE, 2012).

In addition to economic incentives, EVs are also permitted to drive in lanes otherwise designated for busses, which given the congestion in large cities, has been deemed to be an effective incentive.

A 2013 paper that summarised a study aimed at explaining the rapid EV development concluded that (Hannisdahl, Malvik, & Wensaas, 2013):

> *" If EVs are competitive in terms of usability and TCO, today's EV technology is good enough for users to be quite happy with their cars, and recommend them to their neighbours…any government wishing to speed up EV introduction will have to provide incentives that are strong enough*

to give EVs a competitive edge…in general tax reductions and usage incentives seem to be better measures than direct subsidies."

In reviewing what has worked for Norway, it is important to note that other than allowing EVs to drive in bus lanes, all the above named measures result in forgone revenues and/or additional costs to the Norwegian state. Given the country's substantial oil and gas revenues, Norway is perhaps in a rather unique situation in that it can afford to absorb these additional costs, even as EV penetration levels increase. Therefore it is perhaps unrealistic to assume that financial incentives of this magnitude can be implemented on a broad EU scale.

Germany

As the 4th largest global vehicle producer, and the leading manufacturer within the EU, Germany is likely to have a significant role in EV development within the EU. In 2009, the German Federal government published the National Electromobility Development Plan (NEDP), with its stated goal of: "speeding up research and development in battery electric vehicles and their market preparation and introduction in Germany" (Federal Ministry of Economic Affairs and Energy, 2009). As part of this plan the German Government has set a goal of having one million electric cars on German roads by 2020.[17]

In order to achieve this goal, the German government has pledged more than 1 billion euro in incentives for development of vehicles, energy storage devices, and infrastructure. The two stated key areas for research support are the (i) battery, and (ii) smart energy efficiency, safety and reliability systems for EVs. (Germany Trade & Invest, 2013).

Key elements that have resulted from the NEDP include (Germany Trade and Invest, 2014):

- Electric Mobility in Pilot Regions – This program has allocated €130 million in total to eight pilot electric mobility projects.
- Joint Agency for Electric Mobility (GGEMO) – The purpose of this agency is to coordinate all of Germany's electromobility activities.
- National Electric Mobility Platform (NPE) – This entity brings actors from politics, science and industry together to set out the road map for achieving the objectives of the NEDP.

[17] As of spring 2014 the total amount of EVs on German roads was estimated at roughly 17,000. (German government, 2014) As such, achieving this target by 2020 will require a significant increase in EV sales.

- Government Program Electromobility – This program will flag and showcase ministry supported projects in order to capture synergies within the smart mobility sector.

The German government is naturally interested in supporting its large automotive industry and positioning it favourably in a future likely to be dominated by electric drives. This is reflected in the strong R&D focus of the NEDP, as well as its focus on collaboration with the automotive industry. These efforts are likely to boost long-term EV penetration and development within the EU, however EU countries without a large automotive industry will be unlikely to have the incentive to implement similar R&D investment programs.

China

Given that China is the largest car manufacturer in the world, it is worthwhile to briefly review its EV related plans. In 2012, the State Council approved the New Energy Automotive Industry Development Plan, which includes targets of 500,000 EVs and PHEVs on the road by the end of 2015, with this figure growing to 5 million by 2020 (Yue, 2013). To date, EV and PHEV sales in China have however been quite sluggish, with total sales in 2013 of less than 18,000 (Economy, 2014). As such, it appears quite unlikely that China will meet is 2015 yearend target. A 2013 paper analysed the policies put forward by the Chinese government and found that (Tao, 2013):

- China decided to rely primarily on its own innovation and indigenous vehicle manufacturers, however the technology gap between China and leading countries needs to be closed faster.
- Chinese automakers still have little incentive to focus on electric vehicles.
- The major barrier for Chinese consumers is not the cost—it is the lack of infrastructure and incentives to use electric vehicles instead of conventional vehicles.

Local Chinese governments have also tried to encourage EV ownership in other ways. For example, in Beijing, where license plates are such in demand that they are allocated via a lottery system, potential EV owners have a much higher chance of receiving a licence plate. Despite this, Chinese consumers have still be reluctant to purchase EVs. This was exemplified by a 2014 licence plate lottery round where 1,428 EV owners applied for the 1,666 new energy vehicle licence plates, while the ratio for conventional vehicles was 90 applicants per available licence plate (Bloomberg, 2014).

Experience with public procurement in China and France

In both China and France public procurement has been an important tool to increase the deployment of electric vehicles.

China

In July 2014, the Chinese National Government Offices Administration (NGOA) announced a plan to encourage government agencies to purchase more new energy vehicles. This plan specifies that in 2014, 15% of all new vehicles bought by public institutions and government bodies in the Beijing-Tianjin-Hebei region, the Yangtze River Delta, and the Pearl River Delta should be electric, hybrid or plug-ins. The goal is that the share of clean energy cars owned by the state should gradually increase, and reach 30% by 2016 (China.org.cn, 2014).

To comply with this goal, the central government has issued subsidies for new energy vehicles and ordered local governments to construct more facilities, such as charging interfaces for the new energy vehicles.

France

In February of 2013, the French government announced that they intend to buy more than 17,000 electric vehicles from Renault for themselves and other public authorities. In addition to an order of 15,000 Kangoo Z.E. EVs, the Union des Groupements d'Achats Publics (UGAP) ordered 2,000 Renault ZOE EVs and 100 Renault Fluence Z.E. EVs to be delivered over the next 3 years (Renault, 2013).

Moreover, twenty large companies, namely ADP, Air France, Areva, Bouygues, EDF, Eiffage, ERDF, Orange France Telecom, GDF Suez, Suez Environment, GRT Gaz , GrDF, La Poste, RATP, SAUR, SNCF, SPIE, UGAP, Veolia and Vinci, have plans to introduce electric vehicles in France by creating a joint public call of 100,000 vehicles by 2015 (Clean Vehicle Europe, 2014).

In addition, many cities have introduced electric vehicle sharing systems, such as “Autolib” in Paris, “l’Auto bleue” in Nice, “Sunmoove” in Lyon and “Bluecub” in Bordeaux (France Diplomatie, 2014).

4.3 Experiences with non-EV related EU polices

EU member state obligations

EU energy and environmental policies have historically consisted of a combination of EU wide measures and obligations on member states. The “Cars regulation” and the EU Emissions Trading Scheme (ETS) are examples of EU wide measures, targeting car manufacturers and the large emitters of greenhouse gases, whereas for example the renewable energy directive (see text box below), sets mandatory targets on the member states.

Complying with national targets for CO_2, renewable energy and energy efficiency

In January 2008, the European Commission proposed binding legislation to implement the 20-20-20 targets. The member states are committed to a GHG target for emissions not covered by the EU ETS, to increases the share of renewable energy, and to improve energy efficiency. According to the EEA report 'Trends and projections' (EEA, 2013), overall, the EU is making relatively good progress towards its climate and energy targets set for 2020, but at the same time, no EU Member State is on track towards meeting targets across all policy domains. See table below.

Countries	EEA assessment of progress		
	National GHG targets under the ESD	National targets on RES share in gross final energy consumption	Improving energy efficiency
Austria	↘	→	→
Belgium	↘	↘	→
Bulgaria	→	↗	↗
Croatia	↗	n.a.	n.a.
Cyprus	↗	→	↘
Czech Republic	↗	→	→
Denmark	↗	→	↗
Estonia (a)	↘	↗	↘
Finland	↘	↗	→
France	↗	↘	↗
Germany	→	↗	↗
Greece	↗	↗	→
Hungary	↗	↗	→
Ireland	↘	→	→
Italy	→	↗	↘
Latvia	→	↘	→
Lithuania	→	↗	→
Luxembourg	↘	↗	↘
Malta	↗	↘	↘
Netherlands	→	↘	→
Poland	↗	→	→
Portugal	↗	→	→
Romania	↗	↗	↘
Slovakia	↗	↗	↘
Slovenia	→	↗	→
Spain	↘	↗	↘
Sweden	↗	↗	→
United Kingdom	↗	↘	→
EU	↗	↗	→

Note: 'National GHG targets under the ESD' (second column):
↗ 2012 non-ETS emissions were below the 2013 ESD targets and 2020 non-ETS emissions are projected to be lower than the 2020 ESD target with existing measures;
→ 2012 non-ETS emissions were below their 2013 ESD targets and 2020 non-ETS emissions are projected to be lower than the 2020 ESD target only if planned additional measures are implemented;
↘ 2012 non-ETS emissions were above the 2013 ESD targets or 2020 non-ETS emissions are projected to be higher than the 2020 ESD target even if the planned additional measures are implemented.

'National targets on RES share in gross final energy consumption' (third column):
↗ the 2011 RES share was above the RED and NREAP 2011–2012 trajectories;
→ the 2011 RES share was above the RED 2011–2012 trajectory, but below the NREAP 2011–2012 trajectory;
↘ the 2011 RES share was still below the RED and NREAP 2011–2012 trajectory values.

'Improving energy efficiency' (fourth column):
↗ a well-balanced policy package exists across relevant sectors and good progress is made in reducing energy consumption and primary energy intensity;
→ some progress is made in reducing energy consumption but further improvements are necessary to further develop policies or to better implement the existing ones;
↘ limited progress is made so far in improving energy efficiency and further efforts are needed to develop polices across the relevant sectors and to implement them.

(a) Estonia updated its energy statistics in September 2013. As this information was not received by the EEA in time for the publishing deadline of the report *Approximated EU GHG inventory: proxy GHG estimates for 2012* (EEA, 2013a), 2012 emissions in non-ETS sectors appear to have been overestimated. The EEA has therefore not been able to take these new data into account for the assessments in the present report.

In the latter case, member states must prepare actions plans and demonstrate every second year to the Commission how far they have progressed. EU Member States agreed on a burden sharing methodology laying out the RE targets for each member state. The allocation of differentiated national targets is based on a flat rate approach (the same additional share for each country) adjusted to the member state's GDP, which does not necessarily correlate with the member states' renewable energy source potentials.

The renewable energy directive does not prescribe which kind of measures the individual member states should apply to reach the target, this is up the member states to decide. Therefore, a range of different policy measure are currently applied including feed-in schemes, tax rebates, and renewable energy certificate schemes. If a country does not comply with its target the Commission is likely to start infringements proceedings. An infringement procedure will normally result in a fine to be paid. (RE-Shaping, 2010).

National support allows member states to address national (or regional specificities), but as pointed out by the European Commission "at the same time can hinder market integration and reduce cost-efficiency". In the future, the Commission seeks to exploit renewables in a way which is to the greatest extent possible market driven. Therefore, according to the Commission, the directive on renewable energy sources has to be substantially revised for the period after 2020 to give the EU the means to comply with its 2030 EU level targets (European Commission, 2014b).

Central to the policy approach is the principle of subsidiarity, which aims at determining the level of intervention that is most relevant in the areas of competences shared between the EU and the Member States (cf. Article 5 of the Treaty on European Union). The idea is that the EU may only intervene if it is able to act more effectively than Member States.

The Protocol on the application of the principles of subsidiarity and proportionality has established three criteria aimed at establishing the appropriateness of intervention at the European level (EU, 2010):

- Does the action have transnational aspects that cannot be resolved by Member States?
- Would national action or an absence of action be contrary to the requirements of the Treaty?
- Does action at the European level have clear advantages?

With respect to EV deployment, it would be possible to implement an EU legislation similar to that of the renewable energy directive - or an addendum to the existing 10% renewable energy target in the transport - where the EU sets mandatory minimum EV targets for EU countries, and allows them to meet these targets as they see fit. Member states would have a high degree of influence on policies measures, but on the other hand, decisions would need to be made on burden sharing between member states, which may be difficult, and the national approach may not necessarily result in the most cost-efficient measures being implemented.

5 Selection of measures for further analysis

In dialogue with the Danish Energy Agency, an initial screening of potential measures for further analysis was undertaken. This chapter will outline the criteria for the screening of the measures, and an application of this screening.

5.1 Selection of screening criteria

The purpose of this report is to identify measures that will be effective in promoting EV utilisation and market penetration. As such it is important to ask why current EV growth is not on pace to reach some of the previously announced targets? If this question can be sufficiently answered, then selecting criteria that address these specific issues will be prioritised.

Lack of EV growth

Numerous studies have been undertaken to investigate the barriers towards a wide adaption of electric vehicles in the mass market. The section below reviews a few of them to illustrate the conclusion that more or less all studies reach the same results: The overall barriers, both to citizens and to companies and public institutions, are the price of the EV, concerns about the range of the EV and general insecurity towards the stability of the technology.

Denmark: The Etrans study

The Etrans study is an EU funded project carried out by 'Designskolen i Kolding' in 2010-2011. Through surveys and by gathering experiences from pilot tests, the project investigated the barriers for Danish private car users and companies/institutions for purchasing electric vehicles.

The study identified two main barriers for companies and public institutions to buy EVs (Jensen, 2011):

- The price of the EV
  - EVs are still much more expensive to buy than conventional vehicles, and for a company to buy a fleet of cars this can be a rather large extra investment.
- The fear of investing in an 'immature technology'.
  - There are several competing technologies on the market (EVs, hybrids, hydrogen and conventional energy effective vehicles), and the companies are afraid of investing in the wrong technology (will they stop producing it tomorrow?). Therefore many companies and public institutions wait to see what others do and hope to benefit from their experiences.

For private car users, the study conducted a survey among 1022 Danish citizens in 2010 with the question: ‘What will it take for you to choose an EV the next time you are buying a car?’ A total of 40.7% of the responders answered that the purchasing price of the vehicle is essential for choosing an EV. The barriers for the citizens to towards choosing an electric car were (Jensen, 2011):

- The purchase price of the EV (40.7%)
- Insecurity about range of vehicle (15.2%)
- Availability of charging stations (13.7%)
- Comfort issues (10%)
- Size and space issues (7.2%)
- Environmental considerations (4.5%)
- Speed requirements (1.4%)
- Design (0.4%)
- (‘Don’t know’ 6.9%)

Hence, the conclusion of the private individual survey is that the single most important reason for not choosing an electric vehicle is the purchase price of the car, followed by battery issues such as insecurity about the range of the vehicle and the ability to charge it when needed.

Deloitte European EV survey

In 2011, Deloitte[18] conducted a survey among 4,760 European citizens in 7 countries[19] on the willingness to purchase electric vehicles. In addition to questions about willingness and intent to buy EVs, the survey also included questions related to the respondents’ expectations to price, range and charging time. This survey revealed a gap between the respondents’ willingness to invest in an electric vehicle and the EVs ability to fulfil the respondents’ expectations to the cars.

The survey showed that 16% of the respondents identified themselves as potential ‘first movers’ with a very high probability to buying an EV while 53% answered that they ‘might be willing to consider’ buying an EV. The remaining 31% answered that they are ‘not likely to consider’ buying an EV. (Deloitte, European Electric Vehicle Survey 2011, 2011).

[18] Deloitte Touche Tohmatsu Limited’s (DTTL) Global Manufacturing Industry group
[19] Belgium, France, Germany, Italy, Spain, Turkey and UK.

Among the respondents who say that they ‘may be willing to consider’ buying an EV, 57% expect to pay the same or less for an EV compared to a conventional vehicle.

The leader of the Deloitte department responsible for the survey, Graig Griffi, stated:

> “*While interest in battery electric vehicles is growing, with 69 percent of European respondents having identified themselves as either potential first movers or as might be willing to consider an EV today, current market offerings generally fall far short of consumers’ expectations for driving range, charging time and purchase price. As a result, we estimate only one to two percent of these consumers actually adopting battery electric vehicles by 2020.*” (Deloitte, European Electric Vehicle Survey 2011, 2011)

The Deloitte survey states that factors such as rising fuel prices, advancements in conventional vehicles and the availability of government incentives significantly influences the adoption of EVs. With regards to fuel prices, the survey shows a tipping point where 63% of the respondents says that they are ‘much more likely’ to buy an EV if the cost of fuel rises to 2€/litre. However, if fuel efficiency reaches more than 3 litres extra per 100 kilometres in conventional cars, the same respondents will be less willing to buy an EV.

Additional results of the survey were:

- More than 80% of the survey respondents stated that convenience to charge, range and the cost of charging was ‘extremely’ or ‘very important considerations when leasing or buying an EV.
- 74% said that before they would consider buying an EV, they would expect it to be able to travel 480 kilometres per charge.
- 62% said that two hours was the longest that they would be willing to wait to fully recharge the EV battery.

(Deloitte, European Electric Vehicle Survey 2011, 2011)

Extremely similar results were reached in a global EV survey among 13,000 citizens in 17 countries, also carried out by Deloitte in 2011. This survey resulted in an even clearer picture of the gap between EV performance today and the respondents’ expectations to range, charging time and purchase price. (Deloitte, Electric Vehicle realities versus consumer expectations, 2011).

IEA's IA-HEV

The IEA's Implementing Agreement for co-operation on Hybrid and Electric Vehicle Technologies and Programmes carries out a number of hybrid and EV related tasks. Task 14 focused on EV development efforts with the main objective being to outline the lessons learned. This was primarily done via 11 workshops that were organised in areas where EV deployment efforts have been undertaken. The information gained here was also supplemented by a literature review and interviews with relevant experts.

A brief summary from a 2012 publication summarised the main findings (IEA, 2012):

- Subsidies were required to promote use of EVs in France.
- It is difficult to transition from demonstration to commercialisation; there is a lack of instruments to foster this stage.
- Low-consumption ICE cars, hybrid vehicles, and battery electric vehicles compete for many of the same customers.
- There is a potential positive influence of new information technologies on the future development of electric vehicles and charging infrastructure.
- It is necessary to reduce the cost of batteries (high production volume needed).
- Infrastructure investment should be carefully focused. Limited, effectively located public charging is needed.
- Accurately predicting EV customer locations is desirable in order to plan public infrastructure.
- Cost-effective charging infrastructure at the dwelling is crucial; there are complications for multiple unit dwellings.
- Charging equipment standardization remains an issue.
- Charging times must be advantageous to electric utilities. Electric vehicles should charge up at off-peak hours, during the night; reinforcing existing daytime peaks or creating new peaks is to be avoided.
- The fuels and technologies used for electricity generation vary widely across nations and by time of day; net full fuel cycle carbon emissions therefore vary. Increasing renewable use can be technically enabled via battery storage, but is economically challenging.
- Many of today's EVs can be fun to drive in the city and perform adequately even on limited-access highways.

Conclusions

The studies listed above show that both Danish, European and Global surveys come to the same conclusions regarding the lack of EV growth: The number one barrier for car users to buy an EV is the purchase price. This is followed by concerns about the range of the vehicle and the availability of charging stations. Questions of comfort, design, space and speed is only to a minor extent essential to the car users' choice of vehicle. In addition, the European and global sturdies also identified a large gap between the respondent's expectations to the price and performance of the EV, and the actual available market offerings today.

Resulting criteria

The previous section identified the following aspects to be the leading reasons why EV sales have been lower than anticipated:

- Cost
- Range
- Consumer knowledge/confidence

In addition to these above criteria, the below were also added:

- EU scalability
- Whether the measure has been utilised before
- Anticipated effect

5.2 Application of screening

Given the above screening criteria, a long-list of potential measures was reviewed. These are displayed in the table below. As a result of the screening, and dialogue with the Danish Energy Agency, the following measures were selected for further analysis.

- Public procurement
- Super credits and/or Mandated minimum EV requirements
- EU member state obligations

	Measure	Aimed at	Scalable to EU level	Existing framework	Addresses vehicle cost	Addresses vehicle range	Consumer confidence	Impact on EV penetration
Economic	Public procurement standards/restrictions	Buyers (market)	++	+++			++	++
	Tax incentives[20]	Buyers (market)	+	++ (in some countries)	+++		+	++
	Subsidies	Buyers	+	+++	+++			+++
	Guidelines for road pricing	Buyers (market)	+++	++ (in some countries)	++			++
	Market for sale of used batteries/EVs	Buyers	+++		+ (resale)		+	+
Infrastructural	Traffic benefits	Buyers (market)	+	++ (in some countries)	(+)		++	++
	Infrastructure initiatives[21]	Charging companies (buyers)	++	++		++	++	++
EU	EU obligation on member states[22]	EU countries	+++	++	+		++	++
Various	CO_2 emission limits	Producers	+++	+++	(++)			++
	Super credits	Producers	+++	+++	++			++
	Minimum EV requirements	Producers	+++	+++	++			+++
	Vehicle labelling[23]	Producers	+++	+++			++	(+)
	Revised testing cycle	Producers	+++	+++			+	+
	Favourable permitting schemes[24]	Buyers	++	+++			+	+
R&D	Funding of R&D	Producers	++	+++	+++ (long term)	+++	++	++ (long term)

Table 10: Screening of long-list of potential EV diffusion measures according to the deemed: EU scalability, whether the measure has been used before, whether it addresses the vehicle cost, range, and/or consumer confidence, and the resulting overall anticipated impact on EV penetration.

[20] Changes to taxation of fuels and vehicles (registration fee, sales tax, and annual circulation taxes)
[21] Number of charging stations, common charging standards etc.
[22] Could be inspired by for example, the Renewable Energy and Energy Efficiency Directives – Could require member states to comply with national EV targets such public purchase requirements, EV share in total sales, charging infrastructure etc.
[23] Could be based on km driven - lifetime cost, first 5 year cost, etc. including taxes, fees, fuel costs, maintenance, resale, etc.
[24] I.e. less expensive access to airports, etc. as has been done in San Diego

6 Findings and Recommendations

6.1 Review of selected policies and measures

In reviewing the selected policies and measures, primary questions posed included:

- What is the potential for the measure to promote EV diffusion in the period up till 2020, and for the period beyond 2020?
- Where does the economic burden of implementing and monitoring the policy lie?
- Is it better suited at an EU or national level?

Obligations on member states

It would be possible to implement EU legislation similar to that of the renewable energy directive (or an addendum to the existing 10% renewable energy target in the transport), where the EU sets mandatory minimum EV targets for EU countries, and allows them to meet these targets as they see fit. This would involve many of the same pros and cons as has been the case with the renewable energy directive.

Assessment

Positives of such an approach include the fact that member states are free to select national policies. On the other hand, national targets may lead to a sub-optimal dispersal of EVs (I.e. EVs may be better suited to some countries rather than others), and thus would also involve serious negotiations on how this effort should be shared among members states. Due to the fact that it may be difficult to enforce, this approach also involves a significant risk that the overall target will not be reached. Moreover, it may be difficult for member states to identify cost-efficient policy measures providing the desirable penetration of EVs in their individual market. Some countries would be able to support EVs through tax reductions on the registration and circulations fees, whereas other countries, which do not impose taxes at large scale, would likely have to provide direct support to EV purchasers.

Public procurement

Positives

One of the positives associated with a public procurement scheme is that it can be designed in such a manner that it specifically targets a desired technology. As such, in the case of EVs, it can ensure that a particular number of EVs are purchased within a targeted time period. Relative to private citizens, governments generally have easier access to, and lower rates of, financing. This is well-suited to EVs which have significant up-front costs relative to ICEs, but considerably lower operations and maintenance costs thereafter. Some public fleets are particularly well-suited to be EVs due to their known driving patterns and needs. A perfect example here could be home care providers, who have a known and limited number of visits each day. Lastly, public procurement of EVs by government agencies or organisations often results in a number of different people gaining access to, and experience with, an EV, thereby allowing for wider consumer awareness regarding the positives of EV utilisation.

Negatives

One of the primary drawbacks related to public procurement is that the economic burden lies with governments. Many governments at federal, state and municipal levels would probably see a public procurement cost as an additional cost, which they would attempt to avoid. As a result, it may be difficult to ensure a uniform implementation of public procurement policy across the EU. This postulation appears to be verified by the initial evaluation report from the EU Commission regarding member states progress on requirements for public procurement.

Assessment

Public procurement legislation that specifically targets electric drive vehicles, and includes minimum technical standards can definitely aid EV diffusion particularly in the short term. Thus far however, implementing EU wide legislation of this nature has proved difficult, and therefore this form of policy is not anticipated to be able to ensure widespread EV diffusion on the EU level. As a result, public procurement is deemed to likely be a more effective national policy tool, rather than a tool to encourage EU wide EV deployment.

Super credits and/or mandated minimum EV requirements

Super credits

Rather than placing the economic burden on governments, another reviewed option involved mandated targets on the automotive industry. As described previously, this form of policy is already in place in the EU via the CO_2 requirements for new passenger vehicles. While this specific policy does allow for EVs to assist in fulfilling the CO_2 target via "supercredits", EV production and sales are by no means a mandatory requirement under the current CO_2 requirements.

Minimum EV requirements

The California ZEV program is also a credit based system where vehicle manufactures must present credits based on the number of total vehicles sold. However, in this case there are minimum requirements for PEVs, as the amount of credits earned per vehicle varies depending on the vehicle technology (EV, PHEV, etc.) and the all-electric range.

Positives

The positives associated with this particular policy tool include:

- The system would not confer a significant economic burden on the EU country governments.
- The system has proven to be effective in promoting EV diffusion and meeting specific targets in other regions in the past.
- If a credit system is established, then this credit becomes a commodity that can be bought and sold, thereby allowing market forces to determine which companies produce EVs.
- The system allows for EVs to be sold in those countries where it is most attractive for the automobile manufacturers to do so.
- Notwithstanding potential resistance from the automobile industry, it would be relatively straight forward to implement on an EU level.

Negatives

Such a system is not without its potential drawbacks and risks though:

- The system requires an estimate from the regulator regarding the anticipated development of the technology. If the specified technology develops slower than anticipated, and/or an alternative technology advances quicker than anticipated, then the implementation of the specified technology will become overly costly.
- Car manufactures have been effective in exploring loopholes in the past
- It must avoid the production of ‘compliance cars’.

Assessment

Seen from the viewpoint of a government, the strength of a California style system is that the economic burden lies with automobile manufacturers. In order for manufactures to achieve the required EV and PHEV sales targets, part of the additional cost of these vehicles is likely to be subsidised by other vehicles, and is therefore spread over a wide consumer base. If a similar system were to be implemented in the EU, it would be prudent to look at some of the lessons learned from the early experiences in California, for example avoiding the production of ‘compliance cars’ (i.e. low quality EVs produced solely to meet EV targets) and ensuring the credit system is established in such a way that it promotes electric drive vehicles with varying all-electric ranges, while at the same time not overcompensating specific manufactures. It should be noted that with respect to the potential for ‘compliance cars’, minimum technical standards, and the much larger EV product range found today, make it less likely that this will be a significant risk going forward.

6.2 Findings and conclusions

Given the long-term EU goals and targets, of the options reviewed above, the most effective is likely to be the adoption of an EU industry mandated EV/PHEV/HEV credit system similar to the system in place in California. This electric drive credit system could run in parallel with the current CO_2 requirement system, which should also continually have its targets strengthened. Having both systems in place would allow the EU to continue to control the level of CO_2 emissions from new vehicles (thus reducing short/medium term CO_2 emissions dominated by ICEs), while at the same time also ensuring that a growing amount of electric drive vehicles are being developed and brought to market. While these two systems would be running in parallel, they would also be linked due to the fact that the electric drive vehicles will also count toward the CO_2 emission requirements.

These targets should be made in conjunction with the overall EU targets, and therefore also take into account the CO_2 savings from other sectors, and other transport sector segments. In this regard, the new requirements should be developed in accordance with overall EU and transport roadmaps. Specific EV roadmaps such as those implemented in the U.S. or Germany could provide inspiration in this regard.

Danish Viewpoint

Seen from a Danish viewpoint, the establishment of EU wide industry mandates for electric drive vehicles would increase the number of EVs on the market, as well as encourage additional R&D in vehicle and battery technology. This will most likely result in lower vehicle costs and increased all-electric driving ranges, thereby addressing the two most important customer concerns regarding EVs.

With Denmark having more aggressive long-term transport related climate targets then the rest of the EU, Denmark would stand to benefit most from lower EV prices.

In order to reach national targets, and thereby ensure that a portion of the EU sale of EVs and PHEVs occur in Denmark, Denmark could promote initiatives such as public procurement, and/or direct cost reduction tools as have been utilised in Norway.

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