13

POLICY INCENTIVES FOR MARKET INTRODUCTION OF ELECTRIC VEHICLES

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INTRODUCTION

This chapter outlines and analyses the policy options available to stimulate consumers into buying plug-in electric vehicles (PEV or EV), i.e., mainly battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV). As seen in previous chapters, PEVs offer the opportunity to mitigate some of the sustainability issues of today's transportation system: propulsion energy supply, energy efficiency, environmental concerns such as emissions of regulated pollutants and greenhouse gases and noise (see Chapters 5 and 6). Thus, if the possible rebound effect[1] due to lower driving costs is curbed, there are societal gains of shifting towards electric mobility. PEVs still face a number of market disadvantages compared to the incumbent technology: there are knowledge gaps for the consumers, PEVs provide a slightly different service (e.g., range limitations) and they are still more expensive (see Chapters 11, 12 and 14 for further discussions on performance dimensions, consumer attitudes and alternative business models).

The standard economic solution to address these issues would be to tax the externality, i.e., the undesired side effect of the activity. An example in this case

1 The rebound effect is a term that captures that with increased efficiency the cost of e.g., driving are decreased and thus may lead to increased driving and thus not all the assumed energy saving is realized.

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would be an economy or sector wide carbon tax. While fuel or carbon taxes are cost effective and address both the efficiency of the vehicles as well as distance travelled, they are generally not sufficient to spur the development and market introduction of less mature technologies, at least if the tax increase is to remain politically feasible. Extra policies might be needed to decrease uncertainty, increase learning by using and to be able to tap into economies of scale. Through incentives, part of the risk of a new technology is moved from the individual consumers to the governmental level.

In this chapter we investigate incentives that are directed toward the consumers of PEVs, focusing primarily on private cars and not commercial vehicles such as trucks (Chapter 14). Other options, such as changes in regulations that might simplify the introduction of PEVs, support for R&D (Chapter 15) and other supply side activities are not included. Each section represents perspectives related to: geography, the impact for the consumer and on vehicle sales, the timing on the adoption curve, and the related costs of the incentives.

NATIONAL STRATEGIES AND COUNTRY WIDE INCENTIVES

There is a range of incentives that target different cost components of the PEV. Addressing *purchase price* there are e.g., point of sale rebates (Sweden), income tax credits (USA), registration tax exemptions (Norway and Denmark). Exemptions from the annual circulation tax in Germany targets *annual costs*; while free parking and charging (Norwegian cities) reduce *other costs related to usage*.

Incentives can also be non-monetary but still have a large effect on sales since they might reduce risks such as extended battery guarantees for hybrids in California or provide other benefits such as reducing commute times by giving access to High Occupancy lanes (California) and bus lanes (Oslo).

Looking at the European countries you can find varying strategies on how to promote sales of electric vehicles. The different strategies might depend on issues such as budget constraints (become increasingly important), national car production (was a driver for high incentives in Norway and France), overall climate change related goals and strategies. We chose here to present a few examples that are representative of the different types of efforts.

Denmark has the highest registration tax for new vehicles in Europe (105 % on the price of the vehicle up to 9 500 EUR, thereafter 180 %).[2] PEVs are exempt from the registration tax and the green ownership fee[3] (*grønejerafgift* – max 1 200 EUR), making Denmark one of the countries with the highest incentive levels in Europe. This incentive should balance the much higher purchasing cost of PEVs and make them price competitive with conventional vehicles. This is part of Denmark's strategy to achieve its target of 200 000 EVs on the road for 2020. So far however sales have been moderate and are still below 0.5 % of new sold cars.

The strategy in *Germany* has been to fund R&D and local and regional initiatives rather than give incentives to individual consumers. Now however, as part of the

2 Registreringsafgift for nye køretøjer - satser (accessed 2013)

3 A fee paid every 6 months based on the fuel consumption of the vehicle.

National E-mobility Strategy from 2012 to 2020, with the goal to put one million electric vehicles on German roads, the individual customer can get an exemption from the yearly car tax, which is based on the weight of the vehicle. For a car weighing 1 500 kg the tax equals 45 EUR.[4] The national strategy also includes support to development of vehicle production and infrastructure.

The strategy for promoting EVs in *Norway* has been to facilitate the purchase and usage of PEVs. In this strategy the construction of charging stations has been included, as of September 2012 there were 3 500 of them. The majority of the charging stations are in the capital Oslo, but chargers have been installed even in the most Northern provinces.[5]

Norway has a target of 200 000 electric vehicles on the road in 2020. By the end of 2012, 8 600 electric vehicles had been sold, making it the country in Europe with the largest fleet of PEVs, out of which about 3000 were sold from January to September 2012. The large fleet of PEVs is highly related to the high amount of incentives in place. PEVs are not subjected to registration tax. The tax is based on three characteristics of the vehicle: weight, engine power and CO_2 emissions. E.g., a car weighing 1 300 kg, with a 100 kW engine and 140 gCO_2/km would have a tax of 13 100 EUR.[6] The annual registration fee is also lower. This amounts to 330 EUR for vehicles below 7500 kg.[7] There is no VAT compared to 25 % of the retail price of conventional vehicles. They are exempted from road tolls such as those to enter Oslo. In a number of cities parking in public parking spaces is free and they have access to bus lanes. They also receive free admission on national road ferries, but the driver still has to pay. The mileage allowance is higher and the taxable benefit of company cars is reduced by 50 %. Besides the level of incentives, the time and learning aspect may also be of relevance. Norway has been promoting EVs for at least ten years. Thus, compared to other countries, there may be larger experience amongst all actors.

Sweden has chosen not to be explicit on choice of vehicle technology. The goal of the Government is to have a vehicle stock that is “independent” of fossil fuels by 2030. An official inquiry is currently being made on the meaning of “independent”. To promote vehicles with low CO_2 emissions a consumer incentive *supermiljöbilspremien* (super green vehicle rebate) was presented in September 2011. It reduces the purchase price of environmentally enhanced cars (with tailpipe emissions of maximum 50 gCO_2/km, i.e. only electric vehicles for now) with 4 500 EUR for private owners and 35 percent of the premium cost of such a car for companies (such as car pools). A prolongation of the validity of the present reduction by 40 % of the fringe tax value (max 1 800 EUR) for leased company cars is discussed.

In the *UK,* purchasers of PEVs with CO_2 emissions below 75 g/km receive a premium of 5 800 EUR (maximum) or 25 % of the value of the vehicle.[8] Electric

4 Kfz-Steuer Elektrofahrzeuge (accessed 2013)
5 Grønn Bil (accessed 2013)
6 Kalkulator: import av kjøretøy (accessed 2013)
7 Årsavgiften 2013 (accessed 2013)
8 Must meet a series of eligibility criteria (for example, min. range 70 miles for electric vehicles, 10 miles electric range for plug-in hybrid vehicles). See Plug-in car grant (2010)

vehicles are exempt from the annual circulation tax. This tax is based on CO_2 emissions and all vehicles with emissions below 100 g/km are exempt from it. Electric cars are exempt from company car tax for a period of five years from the date of their first registration. Electric vans are exempt from the "van benefit charge" for a period of five years.

REGIONAL AND LOCAL INCENTIVES

There are examples of *regional cooperation* regarding EVs in the US e.g., in North Carolina the cities of Raleigh, Durham, Cary, and Chapel-Hill are collaborating on a number of EV related initiatives. An example in Europe is the Green Highway connecting Sundsvall-Östersund-Trondheim through a system of linked charging stations to enable longer trips. Many of these charging stations are free. Fast charging stations are also part of the concept.[9] The impact of these regional incentives is hard to evaluate at this early stage.

A number of *cities* are competing around the world to become EV capitals. There are Investments in infrastructure for charging and various consortiums are established. Few cities have given upfront monetary incentives even if examples exist such as Shanghai and Amsterdam. The most common way for a city to support PEVs is through free public charging and parking (e.g., Oslo and other Norwegian cities). Generally, if the city has other policies in place to manage other transportation issues such as congestion charging, these can be used to create special cases for PEVs. A typical example of this is the congestion charging in London. Shanghai caps the amount of vehicles registered per year by auctioning out a limited amount of license plates (prices have reached over 7 000 EUR at times), however EVs can get these for free. Another option is to give access to special roads and lanes such as bus lanes. This can be a major driver as in Oslo where surveys show it has been an important factor in the decision to purchase an EV.

Paris and neighboring municipalities have created a joint EV car sharing scheme, Autolib, providing the possibility for short-term rental of EVs. As of mid-2012, about 1900 EVs are rolling under the scheme, making up 32 % of the EVs sold in France.[10] While this is a service that people actually have to pay for, it promotes EVs by allowing more people to test EV driving without having to invest and take the risk of purchasing their own vehicle. Stockholm city in collaboration with one of the major Swedish utilities have in place a EV procurement project that has gathered 296 organizations and companies from all of Sweden that have signed up for the purchase of totally 1250 EVs during four years.[11]

Evaluating the effect of city level incentives at this stage is hampered by lack of reliable data with the exemption of Norway. Around 52 % of the PEVs in Norway are sold in the Oslo metropolitan area, while only 28% of the population live there, implying that local incentives such as access to bus lanes have spurred sales.[12]

9 Green Highway – En fossilbränslefri transportkorridor (accessed 2013)
10 Présentation d'Autolib' (accessed 2013)
11 Elbilsupphandling.se (accessed 2013)
12 Income might also have contributed to the higher sales numbers.

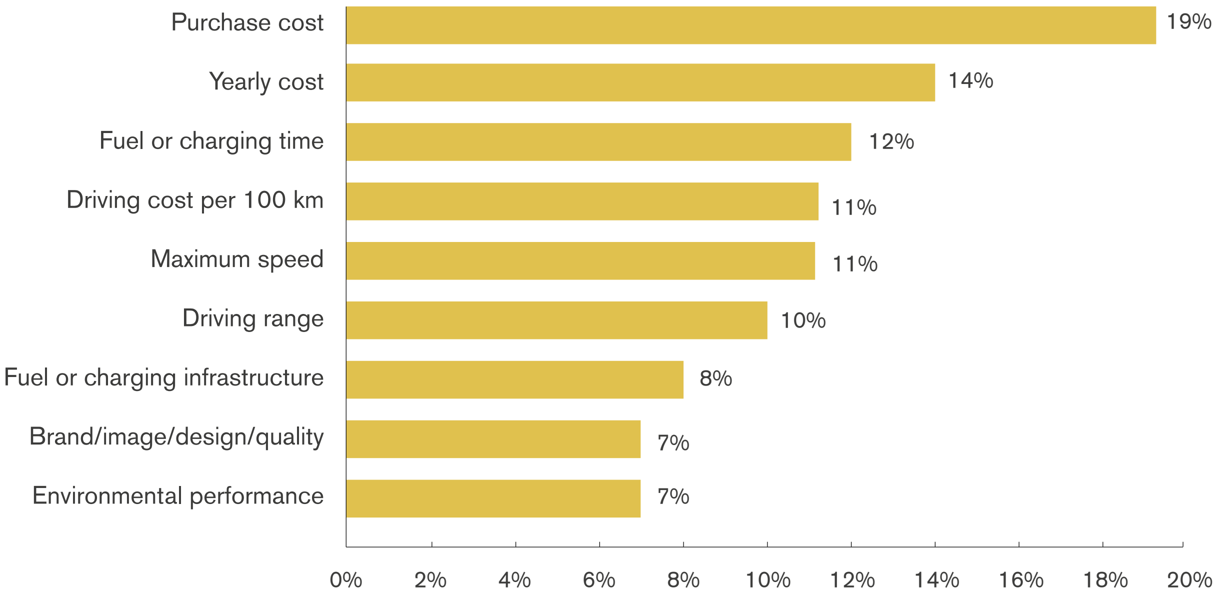

Figure 13.1 Importance of attributes in decision making process of a new car. Source: Lebeau et al., 2012.

THE RELATIONSHIP BETWEEN COSTS, INCENTIVES AND SALES

When purchasing a new vehicle, different parameters are taken into account. A survey with 1196 respondents in Belgium showed that costs are perceived as the most important parameter in the decision making process (see Figure 13.1).[13] For electric vehicles, this is not ideal, as these vehicles are sold at a high initial purchase cost. However, driving an EV is cheaper compared to driving conventional petrol or diesel cars, as the cost of electricity is relatively low. Therefore, a total cost of ownership (TCO) analysis is necessary to understand the cost structure of both electric and conventional vehicles (see also Chapter 10-12).

The costs associated with a vehicle occur at different moments in time. Therefore, in order to calculate a correct TCO, it is necessary to calculate the present value of all costs. The present value methodology makes use of a discount rate,[14] in this case the real discount rate, which does not take into account the inflation. To calculate the present value (*PV*) of future one-time costs, we use the following formula:

$$PV = A_t \times \frac{1}{(1+I)^t}$$

where A_t is the one-time cost at a time t, I is the real discount rate, and t is the time expressed as number of years. To calculate the present value of future recurring costs, we use:

$$PV = A_0 \times \frac{(1+I)^t - 1}{I \times (1+I)^t}$$

where A_0 is the recurring cost.

13 Lebeau, K., Van Mierlo, J., Lebeau, P., Mairesse, O. and C. Macharis (2012). The market potential for plug-in hybrid and battery electric vehicles in Flanders: a choice-based conjoint analysis. Transportation Research Part D 17, 592-597.
14 A discount rate is the interest rate that is used to calculate the present value of future investments or costs.

We use a vehicle lifetime of seven years and a yearly mileage of 15 000 km/year as a starting point.[15] The real discount rate used is 2.5%. The three investigated cars are located in the same segment (medium size) and their initial sales prices are 20 000 EUR (petrol), 22 000 EUR (diesel) and 35 000 EUR (EV). The incentives included in this TCO calculation are an exemption of the registration tax and a direct subsidy of 9 190 EUR (which was applicable in Belgium until December 2012).

Figure 13.2 illustrates the cost components of a petrol and a diesel car compared to an EV. The different cost components are: depreciation, registration tax, yearly driving tax, insurance, maintenance (including tires), fuel/electricity cost and battery costs. Below the x-axis, the direct subsidy is shown. We used different depreciation values for the different vehicle technologies. The yearly value lost per vehicle technology is: 15.5% for a petrol vehicle, 17.3% for a diesel vehicle and 28.0% for an electric vehicle.[16] These figures should not be taken as universal facts. There are many factors that influence the depreciation, and hence the residual value of cars, such as vehicle technology, brand and the condition of the car. In the TCO calculation, we replace the battery for the EVs when the amount of years passed exceeds the warranty period. This is a worst-case scenario, but since replacing the battery is expensive, consumers have to take into account that this cost may occur.

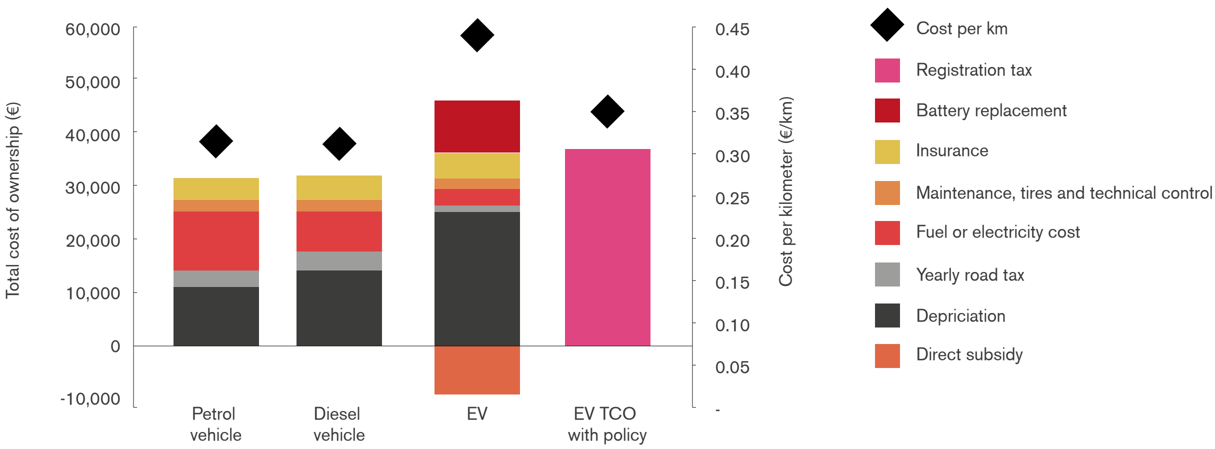

Figure 13.2 Total cost of ownership and cost per km of petrol, diesel and electric car (EV), with and without policy.

For the electric vehicle, two vertical bars are shown: one with the cost structure (left) and one with the final TCO taking the subsidy and tax exemption into account (in red, right). We can conclude that without financial incentives, the EV is not competitive with the conventional vehicles from a financial point of view. Its cost per kilometer is 46% higher than the petrol and diesel counterpart (see Table 12.3 for an alternative view). However, when we take into account the incentives, the difference is lowered to 15%. This is largely due to the governmental direct subsidy. In this model, the exemption of the registration tax has almost no effect on the TCO of the electric vehicles.

15 In Belgium, the average lifetime of a vehicle is 13.7 years. However, the average Belgian consumer only owns the vehicle for 7 years before selling it.
16 Lebeau, K., Lebeau, P., Van Mierlo, J. and C. Macharis, 2013. How expensive are electric vehicles? Working paper.

As seen in Figure 13.2 incentives can lower the TCO and make the PEVs more competitive. The effect of these incentives on sales of PEV however depends on how sensitive the consumer is to prices and costs. Sensitivity to prices are, in economics, normally calculated through so called elasticities, i.e., a measure of how many more vehicles are sold by decreasing the price or increasing the incentive in this case. To calculate the effect of monetary incentives on market shares of PEVs an econometric analysis including income, gasoline, diesel and electricity prices, and monetary incentives was applied to 13 European countries. [17] We collected data for 2010, 2011 and January to September 2012. The effect of incentives was significant and positive but the effect on actual number of cars sold was low. An increase of 1000 EUR in incentives would result in an increase of 12% in the market share, given that all other variables remained constant. Considering that the market share numbers are low this implies a very limit number of vehicles (approximately 70 – 300 PEVs depending on the market share). Previously, similar calculations have been made including sales until June 2011. The results give elasticities of the same magnitude. This means that the effect of the incentives has not changed markedly between 2011 and 2012.

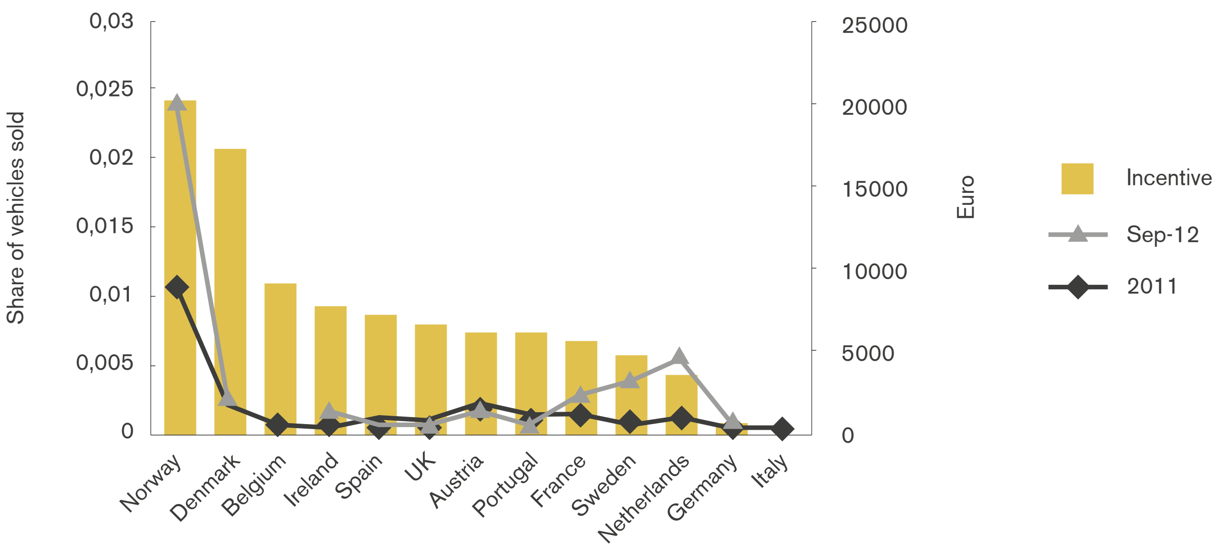

Figure 13.3: Lines and left axis show EVs share of new cars sold in 2011 and 2012 (for Belgium and Italy only 2011). Right axis and bars show incentive levels for each country.

To capture the effect of non-monetary incentives a dummy variable for Norway was introduced,[18] since these types of incentives are most prevalent here. The coefficient for the dummy is positive and significant, implying that the favorable conditions for PEVs in Norway have boosted sales. The coefficient for the monetary incentive remains significant, illustrating that the estimated effect in the previous calculations is not only driven by sales in Norway. The value of the coefficient however is slightly lower meaning that the effect of incentives might be smaller than previously presented.[19]

17 In the econometric model used the share of EVs sold was logged, while the incentive was kept linear to achieve the most reasonable fit. For a full description of the model see: Sprei, F. and D. Bauner (2011). Incentives impact on EV markets - Report to the Electromobility project. Gothenburg, Viktoria Institute.

18 A dummy variable is a variable that is one for Norway in this case and zero for all others. It is introduced to capture the effect of the non-monetary incentives, including infrastructure, available in Norway.

19 Sprei, F. and D. Bauner (2011). Incentives impact on EV markets - Report to the Electromobility project. Gothenburg, Viktoria Institute.

It is also possible that the increase in sales between years may be due to other dynamics of the market, such as increased number of models available and more knowledge about PEVs among consumers. In the model this was tested by introducing a variable for time. The coefficient for this variable was positive and statistically significant, showing that that these other developments have had an impact on sales. However, it does not alter the effect of the incentive. Between 2011 and 2012, Sweden, Norway, France and the Netherlands were the countries with the largest increase in EV shares of new cars sold. The consumer rebate in Sweden was introduced in 2012, partly explaining the increase in sales. In France the higher sales can partially be attributed to the introduction of the Autolib car sharing system.

There are a number of limitations of this analysis: data reliability is an issue; the model does not take into account that the limited supply of electric vehicles on many markets and the limited availability of electric vehicles in different market segments; constraints related to infrastructure are not included; and there might be basic differences in what cars people prefer buying in the various countries that affect the sales of PEVs as well. Thus the results should be interpreted in the light of these limitations and the reader should be aware that the analysis aims at assessing this early market environment and should not be generalised to other market conditions. So far, BEVs and PHEVs available on the market have quite similar characteristics and prices thus aggregating them to one group thus not undermine the results from the analysis.

POLICY TIMING AND TECHNOLOGICAL MATURITY

The adoption of a new technology is traditionally depicted as an S-curve, starting slowly with the innovators adopting the technology and moving on to early adopters. These are followed by the early majority.[20] PEVs today are at the early adopter stage. Early adopters are often characterized by being wealthier and more technology savvy compared to the average consumer and it has been shown that purchase price and TCO are less salient for these purchasers. For early adopters of the Toyota Prius hybrid vehicle the symbolic value of the vehicle was just as important.[21] It is thus plausible to assume that the amount of free-riders, i.e., people that would purchase the vehicle even without incentives would be quite high. This could mean that the role of the incentive as a driver for sales is even lower than what the elasticities show. However, early incentives might have other benefits. For example, it could be a signal to consumers and producers, that this is a good technology, supported by society, and thereby push car manufacturers to put new vehicles on the market. In the US, the Chevy Volt and Nissan Leaf were first launched in states with extra incentives or regulations. Nissan also selected countries in Europe for the market introduction of the Nissan Leaf based on the existence of incentives.

The S-curve has been complemented with concepts such as ‘valley of death’, ‘crossing the chasm’ and ‘the hype cycle’, i.e., the challenge of moving from the early adopters to the more pragmatic early majority and moving beyond initial

20 Rogers, E. M. (2003). Diffusion of Innovations. New York, Free Press.

21 Heffner, R. R., K. S. Kurani, et al. (2007). “Symbolism in California’s early market for hybrid electric vehicles.” Transportation Research Part D: Transport and Environment 12(6): 396-413.

funding to revenue generation.[22] Maybe incentives at this stage are more effective than earlier for the long term adoption of the technology. In Japan, while hybrids had crossed the line from the early adopters to the early majority, incentives were still in place until September 2012.[23] Pertinent questions related to this are: what incentives are most appropriate at what stage? Does the early majority need other incentives than the early adopters?

Another important question about timing is when to discontinue the incentives. At the moment in Europe budget constraints are posing a threat to many incentives. In Belgium the financial rebate for vehicles emitting less than 105 gCO_2/km was dropped in 2012. The number of vehicles sold in this category decreased with two-thirds during the first nine months of 2012 compared to the same period in 2011. This could be an example of how an incentive removed prematurely (?) can make the market collapse.

GOVERNMENT SPENDING ON INCENTIVES

There can be a concern that subsidising PEVs may be expensive for the state, especially in times of economic crises. In such debates it may be useful to be aware of how much money is actually spent on incentivising PEVs. In this section we calculate the total costs (including loss of revenue) for the government when it comes to financial incentives for PEVs as well as the cost of each additional PEV added on the market.

The annual spending (in 2011 and 2012) for the incentive ranges between 1 and 10 million EUR for the different countries, with the exception of Norway that is discussed in detail below. How large the spending is will of course depend on the number of EVs sold and the size of the incentive. Generous incentives to PEVs could easily reach large sums if the market takes off, however most governments have capped the incentives either by designating a specific pot of money for the subsidies or limiting the total number of vehicles that may receive it. There are as well revenue losses from decreasing sales from fuel taxes. We estimate the net revenue loss from decreased fuel sales from the PEVs sold during one year, based on average fuel consumption of new vehicles, average vehicle kilometres travelled per vehicle and the increased income from electricity taxes. Fuel taxes are fairly similar between countries and thus the differences mainly arise from the number of PEVs sold.

Norway is the country with the highest incentives and the highest penetration rate of PEVs in Europe and thus warrants a closer look at the costs. The calculation of the costs is not straightforward since incentives are based on exemptions from having to pay taxes or fees. Some of these depend on the characteristics of the vehicle and thus the question is what car, if any, the PEV is replacing. The loss of income due to the registration tax during one year may vary between 10.5 million and 20 million EUR (based on sales of 1500 vehicles). Fuel tax losses are in the magnitude of 1 million EUR. The loss of revenue from public parking for one year

22 Moore, G. A. (1991). Crossing the Chasm: Marketing and Selling Disruptive Products to Mainstream Customers. New York, HarperCollins Publisher.

23 Closing the Acceptance of Applications for the Subsidy for Privately-owned Environment-friendly Vehicles (“Eco-cars”) (accessed 2013)

is around 7 million EUR. These give a total of 18 - 28 million EUR.[24] Econ Pöyry calculate the total cost in relation to the CO_2 emissions avoided and find a cost of 3300-4000 EUR / ton CO_2 reduced.[25]

To calculate the cost of adding an extra PEV to the road we use the results from the econometric model. Presume that the incentive would increase with 1000 EUR, how many more PEVs would be sold? Our results give a range between 70 to 300 vehicles depending on the country. The total cost of adding those vehicles to the fleet would be 1000 EUR times the total number of PEVs sold. This total cost is then divided with the number of the number of additional vehicles (70-300), since we presume that the other vehicles sold would be sold at the old level of incentives. Our calculation gives us a price of 9 300 EUR per additional PEV. 9 300 EUR is quite a high subsidy; still it might be warranted at an introductory phase of a new technology. It is also cheaper than the government directly buying the vehicles for demonstration fleets, which may be an alternative.

CONCLUSIONS

Taking a total cost of ownership (TCO) perspective is important for PEVs since their initial cost is higher but the cost of driving the vehicle is lower, due to the price of electricity and the higher efficiency of the vehicle (Chapter 5). New business models that take this perspective into account may increase the competitiveness of PEVs (Chapter 12), but financial policy incentives might also be needed to lower the gap between the TCO of PEVs and conventional cars.

Current incentives have a positive but limited effect on PEV sales. Hence, in order for the market to really take off, more efforts are needed. Denmark, for example, has a strong economic incentive that in principle should make PEVs economically competitive with conventional vehicles. Nevertheless, sales have been moderate. Norway, on the other hand, has made use of a wider variety of policy instruments to stimulate sales and usage of PEVs and has today the largest fleet of PEVs in Europe.

The Norwegian example shows that sales of EVs can be successfully stimulated. However, the total costs for these incentives are high, especially if one only considers short term CO_2 emission reductions. There are, however, long term effects that are harder to quantify today (see discussions in Chapters 5, 6, 8 and 9). Incentives at city level are a strong complement to national policies considering that PEVs will be more popular in urban centres. Some of these, such as access to special lanes can be implemented with lower financial costs.[26]

Incentives for PEVs are not only important from a consumer's point of view, car manufacturers may also react to the national incentives within countries. Car manufacturers have selected the countries with the most PEV friendly institutional setup for the introduction of their first electric cars. Also the stability of the incentive structure system matters. Sudden changes in policy impacts the way car manufacturers estimate the market potential for PEVs within a country.

24 Sprei, F. and D. Bauner (2011). Incentives impact on EV markets - Report to the Electromobility project. Gothenburg, Viktoria Institute.
25 Econ Pöyry (2009). Virkemidler for introduksjon av el- oghybridbiler. Oslo, Econ Pöyry.
26 There might be other drawbacks such as increased congestion.

It should be noted that, despite strong stimuli for a new vehicle technology the market may collapse if there is a shift of public opinion due to e.g., negative news coverage and major improvements of the environmental performance of conventional vehicles. The market for flex-fuel vehicles in Sweden is an example of this. After a promising start with sales reaching almost 25% of new cars sold, the market share relapsed back to 5% in 2011, in despite of the fact that policies to promote flex-fuel vehicles and alternative fuels were still in place.[27]

27 Sprei, F. (2013). Boom and bust of flex-fuel vehicles in Sweden. Proceeding of the eceee 2013 Summer Study on energy efficiency, Toulon/Hyères, France.