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Evaluation of European electric vehicle support schemes

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Abstract

Electric vehicles can reduce carbon dioxide emissions, increase energy efficiency, and help to reduce the dependency on oil imports. However, today's technical and economic challenges are preventing mass-market adoption. In order to create an early market and support economies of scale in production, some European countries have already established support schemes. This research study aims to provide an overview of the existing support schemes in Europe and to assess them using four criteria: effectiveness, efficiency, practicability, and political acceptance. The study concludes with an impact analysis of today's economic support schemes which considers the total costs of ownership. While one-time support schemes help to reduce the large initial investments for EVs, recurring instruments are often more effective and efficient but also smaller in volume. The comparison of the different regional incentive schemes reveals that EVs today are only economically attractive in Denmark and Norway, but at relatively high prices. Thus, regulators need to increase the volume and efficiency of the support schemes, establish high scoring instruments, and align these on a European scale. In addition, non-monetary support, e.g. free-parking, can help to overcome technical or smaller economic hurdles.

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1 Benefits and challenges of electric vehicles

The electrification of today's vehicle fleet is currently being discussed as a major lever for a more environmentally-friendly form of transport while reducing the dependence on oil at the same time. Emissions, e.g. CO_2, NO_x, or particulate matter, can be avoided locally and reduced overall, mostly due to higher efficiencies in central power generation plants. Additionally, noise exposure along high traffic and city routes can be limited to that resulting from drag or rolling. Together with a stronger build-up of renewable generation capacities, electrified transport may even become emission-free at some point.

Today, however, electric vehicles (EVs) are facing technical as well as economic challenges. On the engineering side, trips longer than 150 km are prohibited by the weight restrictions, while charging takes a long time - up to eight hours at a regular 230 V connection. Economically, electric vehicles require higher initial investments but have lower operating costs than an internal combustion engine (ICE) at today's oil and electricity prices. In addition, lack of experience with battery durability means a significant risk – roughly a third of the car's value – for the owner of the battery.

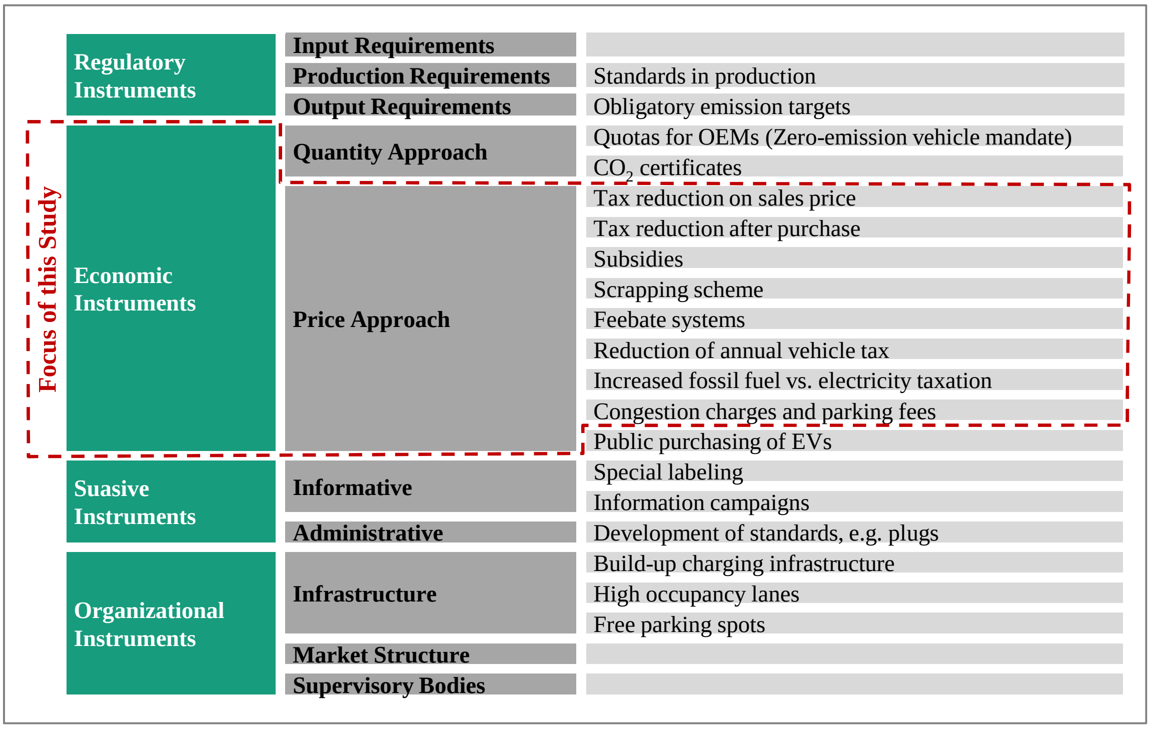
While electric vehicles offer benefits to the public, their restrictions such as the limited range or higher prices have to be accepted by each individual consumer. Therefore, rapid and customer-driven adoption of electric vehicles is rather unlikely. Green customer awareness, or societal perception and image might help but are certainly not enough to offset the technological and economic hurdles of a mass market roll-out. While practical examples of EVs might suffice for some niche customer segments, most other segments will not consider buying an electric car before they have a similar price. Most European countries, therefore, are planning or have already installed support schemes for electric vehicles to reduce the overall costs for the consumer and scale up production. Despite economic support, cities can also use soft factors, e.g. free parking or high occupancy lanes, to pitch the advantages of EVs to car users.

1.1 Support schemes currently in place

In the last few years, most European countries have published politically motivated national development plans for electric vehicles, setting goals for EV driving stock, the expansion of charging infrastructure, or production targets.

Targets for EVs in vehicle stocks differ by year and are either given as a percentage of the market or in absolute figures. Most countries aim for a certain EV market penetration of the vehicle stock by 2020, ranging from roughly 2 % (such as in Germany) up to 10 % (e.g. Ireland or Norway).[1] In order to reach these targets, various support schemes have been established or are under way. This research study analyzed the actual and planned instruments in the largest 16 European economies. The bandwidth of support schemes ranges from free parking in inner-city areas to public purchasing programs. In order to structure the applied support schemes, the classification used by Rentz et al. (2001) for environmental instruments was adapted. This scheme groups instruments into four major categories: regulatory, economic, suasive and organizational instruments (see Figure 1).

Figure 1: Classification of support schemes



1 Country targets in detail are DE 1 million (2020), FR 2 million (2015), IE 10% (2020), NO 10%, ES 1 million incl. hybrids (2014), UK 100k (as soon as possible) and have been taken from Boehm (2009), Bundesregierung (2009), Department for Transport (2008), Doggett (2008), Mayor of London (2009), Tippelt (2009).

Regulatory instruments impose restrictions on automotive manufacturers, e.g. certain emission targets for new vehicles. These restrictions focus on the inputs, the outputs or define certain required production processes. *Economic* instruments aim to influence the natural market outcome using quantity or price changes. Quantity-oriented instruments define the traded volumes, either by limiting the total output (maximum quantity approach) or by defining the minimal necessary contribution (minimum quantity approach). For EVs, changes can be made on the emission side, e.g. reducing the number of CO_2 certificates, or on the car level, e.g. requiring certain quotas from the OEMs. Price changes in the form of tax reductions and subsidies focus on reducing overall vehicle costs (tax reduction on sales price, subsidies, scrapping scheme, reduction of annual vehicle tax); others comparatively penalize ICEs (feebate systems, increased fossil fuel taxes, congestion charges/ parking fees). *Suasive* instruments are used to persuade buyers and manufacturers by providing information (special labeling, campaigns), creating a better administrative landscape (standards), or funding research and development programs. Lastly, *organizational* instruments help to reduce hurdles such as developing the necessary infrastructure (build-up of charging infrastructure, high occupancy lanes) or installing supervisory bodies to control market structures. Besides the presented instruments on the part of governments, some initiatives are also launched by the private sector, but are not further investigated in this study.

The instruments themselves target different steps in the value chain. While many instruments tend to focus on the manufacturer or infrastructure side, price incentives target the end customer directly, such as fleet or private car users. To reach a faster, customer-driven EV adoption, governments are currently discussing which form and volume of price instruments should be applied. Each price instrument mentioned, already exists somewhere in one or more of the European countries considered. The existing instruments are now being compared and evaluated regarding their success in speeding up EV market adoption. As depicted in Figure 2, the incentives for EVs differ strongly in Europe, with some countries already applying up to three price instruments with a high overall volume and others with no dedicated EV incentive scheme in place.

Figure 2: Overview of EV price instruments in Europe

	AT	BE	CH	DE	DK	ES	FI	FR	GR	IE	IT	NL	NO	PL	SE	UK
Tax reduction on sales price	✓	o	✓	×	✓	o	×	×	✓	✓	×	✓	✓	×	×	×
Tax reduction after purchase	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Subsidies	×	×	×	×	×	✓	×	✓	×	×	✓	×	×	×	×	✓
Scrapping scheme	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Feebate systems	✓	×	×	×	×	×	×	✓	×	×	×	✓	×	×	×	×
Reduction of annual vehicle tax	✓	o	✓	✓	✓	o	×	×	✓	×	×	✓	✓	×	✓	o
Increased fossil fuel taxes	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Congestion charges and parking fees*)	×	×	×	×	×	×	×	×	×	×	✓	×	✓	×	×	✓

Note: ✓ = existing incentive, o = EV advantage in current system, × = currently no incentive available
(*) Congestion charges/ waived city taxes applied in Milan, Oslo, and London

There seems to be no clear favorite instrument, although almost half the countries use a reduced annual vehicle tax and a reduced sales tax. Legislation can address EVs directly, e.g. excluding them from certain taxes or granting special permissions, or by a more global criterion where EVs can profit indirectly from the system in place. This is especially true for the CO_2-based annual vehicle tax, which most European countries have already adopted, or the different taxation of fuel and electricity.

2 Assessment of today's support schemes

2.1 Criteria for assessment

In order to provide guidance for future legislation, the impact of the presented price instruments on EV market adoption is being evaluated. Effectiveness, efficiency, and practicability were selected as evaluation criteria. These criteria are often used in assessing environmental policies as Enzensberger, Wietschel (2003) have pointed out. Since instruments like increased fossil fuel taxation are also of interest to the public, a fourth criterion was added to the list: political acceptance.

Effectiveness aims to assess whether a policy instrument helps to achieve a certain planned outcome, which is often measured using the number of achieved objectives. In the case of EVs, this is the additional number of vehicles which enter the market due to the considered instrument. Effectiveness does not provide any information about the quality of the instrument, since less ambitious targets can be fulfilled more easily. It measures the number of additional EVs and not the costs of achieving this target. Additionally, effectiveness should be strongly related to a good predictability of the outcome.

The *efficiency* criterion adds a cost perspective to the effectiveness dimension. According to Voß (2000), a policy instrument is more efficient if the same result is achieved at lower cost, meaning that the number of EVs on the street should be reached with minimal costs. In addition, technology choice, transaction costs and windfall gains have a significant effect on efficiency and can be understood as the total macroeconomic costs of applying support schemes. These costs have to be covered by the government, industry, and finally, the customer. Windfall gains originate when technology and support schemes are not appropriately aligned as described in Held (2007). A more dynamic concept requires an efficient instrument to factor in future technology improvements such as in Enzensberger, Wietschel (2003). In addition, Weidner (1996) calls for the alignment with other policy goals in order to minimize counter effects.

Practicability evaluates the regulation and control efforts needed to put a certain instrument in place. A further aspect checks the flexibility to adapt the instrument to a changed environment.

Finally, *political acceptance* is essential for an instrument to be successfully implemented. Even an instrument that scores high on the other criteria might be not accepted politically and therefore fall short of its theoretical potential resulting in increased administration and communication efforts as Weidner (1996) explains.

2.2 Assessment of the selected price instruments

Due to the limited experience with EVs and their support schemes, this study assesses the introduced price instruments based on a literature review of the experiences with hybrid vehicles or similar support schemes for other technologies such as renewable generation technologies. Beforehand, it is important to look at the time scale of when each price instrument is effective, since this might influence customer choice and perception. In general, economic support can be given before, during or after purchase and can be realized as a one-off or as a recurring payment. Tax reductions on the sales price or after purchase, as well as subsidies or scrapping schemes are paid once and are usually based on the initial investment amount. The other price instruments are based on annual taxes or regular fees, which are usually smaller in volume and need to be paid over the useful life.

A comparative assessment is made of the eight price instruments, pointing out individual strengths and weaknesses. A detailed evaluation will be given in the following:

Tax reduction on sales price – When a customer purchases a vehicle, the government has different ways of influencing the decision by adjusting taxes. Most countries charge registration taxes and value added taxes (VAT), which can be easily reduced for certain vehicles. This tax reduction helps to decrease the large difference between the prices for ICEs and those for EVs, and as Edquist, Hommen (2000) show, will be the major driver of EV adoption in the next few years. Direct reductions of the sales price have twice the effect of deferred support schemes such as income tax reimbursements.[2] To some extent, this instrument runs the risk of subsidizing car dealers, as Diamond (2009) describes, although Sallee (2009) finds that the customer receives most of the reduced tax. From a practicability viewpoint, tax reductions are easy to integrate and are well accepted by the public.[3] The findings for tax reductions are mostly based on experiences with hybrid vehicles, which are not as expensive as EVs so that not all the findings may be fully applicable.

Tax reduction after purchase – Similar to the tax reduction on the sales price, governments can offer a reimbursement, usually as part of the annual income tax declaration. However, this instrument has a lower effect than a reduced sales tax as Gallagher, Muehlegger (2008) showed. Additionally, income tax reimbursements are only interesting for some customers and might favor windfall gains. Practicability and acceptance rank lower due to the more complex system for reimbursement.

Subsidies – The consumer receives a certain amount directly instead of reducing taxes or offering reimbursement systems. This subsidy is often coupled with the requirement of buying a specific car and might be staggered

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2 See Gallagher, Muehlegger (2008).

3 Compare de Haan (2008b).

for different vehicle classes. Compared with the sales tax reduction, customers value the separately paid amount of a subsidy higher, as e.g. described in de Haan et al. (2007a). Practicability is highly dependent on the applied system and therefore not assessed in this paper. Acceptability can be evaluated as similar to a sales tax reduction.

Scrapping schemes are comparable to subsidies, except for the additional requirement of scrapping the old and less environmentally-friendly vehicle. Nemry et al. (2009) and Dill (2004) show that a scrapping scheme renews the car fleet but targets different households. Especially the willingness to scrap the old vehicle is not linear with the amount of the subsidy as BenDor, Ford (2006) show. Additionally, some of the replaced cars would have been scrapped anyway which results in a lower efficiency of this instrument as Nemry et al. (2009) concluded. Scrapping schemes are particularly useful when older and less efficient vehicle fleets should be quickly replaced with newer and more efficient ones. However this requires EVs to be available for the mass market, so scrapping schemes are not generally applied for early market adoption.

Feebate systems – In general, a feebate system can be described as an emission-based tax with a reimbursement proportion. Whether charges or reimbursements apply depends on the vehicle's emissions in relation to a defined threshold. High adoption of more environmentally-friendly cars can be shown based on experiences with the implemented feebate systems in Swedish power plants and simulations, e.g. from de Haan et al. (2009) and Nemry et al. (2009). The efficiency of feebate systems, however, depends strongly on their integration into the tax regime. Implementation challenges are discussed by Johnson (2006), who points out that administrative and transaction costs have to be strictly managed. Most feebate systems aim for a zero-sum of charges and reimbursements. In practice, however, this balance is hard to reach in a changing market and might result in costs for the government as described in BenDor, Ford (2006). Feebate systems are accepted instruments, although they are sometimes seen as a small car subsidy.[4]

Reduction of annual vehicle tax – In contrast to the previously discussed instruments, a reduction of the annual vehicle tax has an effect on the operating expenditure and not on the invested sum. Different simulations showed that increased annual vehicle taxes for polluting cars increase the sales of more

[4] See de Haan et al. (2009), Greene et al. (2005), Johnson (2006).

environmentally-friendly vehicles.[5] And de Haan et al. (2007b) showed that waived annual vehicle taxes affected the sale of hybrids in the respective areas. Moreover, annual incentives are considered more efficient since they cannot be easily included in the sales price. Giblin, McNabola (2009) and Ryan et al. (2009) showed that the purchase decision for an efficient vehicle was based on annual payments rather than upfront subsidies or tax cuts. However, since EV investments will be much higher than those in the hybrid vehicle case, further evidence has to be provided for this kind of consumer perception. Greene et al. (2005) note that customers will probably not consider the full period of tax reductions in their decision. In addition, they have to discount future tax reductions in the light of possible changes in the regulatory landscape. Similar to sales tax reductions, annual vehicle tax reductions can be easily integrated in today's systems and are equally accepted.

Increased fossil fuel taxes not only have an effect on driving behavior, they also lead to higher sales of more efficient vehicles and require OEMs to meet these customer demands as described in Mandell (2009). Higher hybrid sales were linked with increasing fuel prices by Benton (2008), Tiggis (2008) and Gallagher, Muehlegger (2008). EVs moreover currently profit from the different taxation of fuel and electricity. This however, could change quickly with higher EV market penetration and missing fuel tax income from the diminishing ICE fleet. Additionally, increased fuel taxes may also impact other industries. As described in Kalinowska et al. (2009), the fuel tax can be easily adapted. Increased fuel taxation is very unpopular as described by de Haan (2008a), and is considered not as acceptable socially due to the comparatively greater effect on households with smaller incomes.

Congestion charges and parking fees – Congestion charges aim to reduce inner-city motorized traffic and require road users to pay a toll when entering a predefined inner-city area. This toll can be reduced or waived for certain, more environmentally-friendly vehicles. Besides the waived toll, these car owners also profit from emptier streets and more parking available in inner-city areas. In addition, parking fees can be waived and special areas can be reserved for EVs. Regarding the instrument's primary target of reducing traffic volumes and travel times, studies in London and Stockholm have proven the congestion charge to be successful.[6] With regard to successfully supporting EVs, there is

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5 See Giblin, McNabola (2009), Hayashi et al. (2001), Ryan et al. (2009).

6 See Marner (2004) and Eliasson (2008).

some indication, e.g. from Transport for London (2009) or Grüneweg (2007), that a waived city tax increases EV adoption, but thwarts the primary target of reduced traffic in the city area. A congestion charge is relatively easy to introduce, has predictable costs and is politically accepted.[7] Waiving congestion charges, however, is only possible for the early stages of market adoption in city areas; with higher penetration, free parking spots and less traffic cannot be kept up. Stockholm has already omitted EV exemption and London has reduced the free parking offered.[8]

2.3 Assessment results

The previous discussion has been ranked on a qualitative scale ranging from '++ very good' to '-- non-existent', and 'n/a' if a statement could not be made. A summary of all instruments and their ranking can be found in Figure 3.

Figure 3: Assessment of support schemes

	Effectiveness	Efficiency	Practicability	Political Acceptance	
Tax reduction on sales price	+/-	+/-	++	+	One-time
Tax reduction after purchase	-	-	+	+/-	
Subsidies	+/-	+	n/a	+	
Scrapping scheme	+/-	-	n/a	+	
Feebate systems	+	+/-	-	+	Recurring
Reduction of annual vehicle tax	+	+	+	+	
Increased fossil fuel taxes	+	+	+	--	
Congestion charges and parking fees	+/-	n/a	-	+/-	

Legend: ++ = very good, + = good, +/- = equal, - = poor, -- = non-existent, n/a = not applicable

There is no clear winner when looking at the assessment summary although the recurring instruments score better overall. Although consumers appreciate

7 See Eliasson (2008), Eliasson (2009), Marner (2004).

8 See City of London (2008), Swedish Transport Agency (2009).

prompt and upfront support as shown by Gallagher, Muehlegger (2008), recurring instruments – reduction of the annual vehicle tax as well as increased fossil fuel taxes in particular – outperform on the criteria of effectiveness, and efficiency. Admittedly, both recurring taxation instruments are rather small at present compared with the overall vehicle costs, and can only form part of the solution. In addition, higher taxes on fossil fuels are politically not very well accepted and therefore hard to implement.[9] The effects of a congestion charge or other local support schemes for EVs cannot be evaluated easily since these are highly dependent on the local context and on consumer usage patterns, but they might be especially interesting in urban conglomeration areas as indicated by the pilot schemes in London and Stockholm[10]. In the case of one-time instruments, tax reductions and subsidies are more attractive if received at the time of purchase rather than deferring payments to a later period. In any case, tax reductions need to be clearly offered to car buyers, otherwise they are likely to be priced in by the car dealers.

Customers may favor one-time instruments not only for hybrid vehicles, since they help to reduce the high investments for an EV. Reducing the large upfront payments helps to align the cash flow for an EV, with high investments and lower operating costs, to that of today's ICE. This effect has not been covered in the literature so far, since hybrid vehicles, to which most articles refer, do not have as large a difference in cost distribution. The qualitative comparison was necessary due to the limited experience with EV-specific support schemes. Looking into the future with the first EVs entering the market, a comparative survey focusing on EV support schemes should detail the summary presented above.

3 Comparison of the support scheme volumes across Europe

3.1 Assumptions, taxes and support schemes in place

In order to compare the various support schemes, different vehicles were defined with their technical specification (engine power, battery capacity, fuel

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9 See also de Haan (2008a).

10 Compare Beser et al. (2006), Eliasson (2008), Grüneweg (2007), Transport for London (2009).

and power usage, as well as CO_2 emissions) as well as their investment and operating costs without taxation or fees and are shown in Table 1.

Table 1: Technical and economic data for the reference vehicles[11]

		Mid-size (Golf class)			**Small/city vehicle**	
		ICE	**PHEV**	**EV**	**ICE**	**EV**
Technical data						
Power ICE	[kW]	77	40		45	
Power EV	[kW]		60	66		30
Battery capacity	[kWh]		14	40		14
CO_2 emissions	[gCO_2/km]	137	55		104	
Fuel consumption	[l/100km]	5.80			4.40	
Electricity consumption	[kWh/km]		0.16			0.12
Charge efficiency	[%]	84%				
Electric driving share	[%]		60%	100%		100%
Annual mileage	[km/a]	12,000			10,000	
Vehicle/ battery lifetime	[a]	12				
Investments						
Chassis	[€]	13,870			6,935	
Combustion engine	[€]	1,933	1,004		1,130	
Electric motor	[€]		1,541	1,677		864
Hybrid power train	[€]		1,258			
Battery, specific costs	[€/kWh]		502	502		502
Battery, total	[€]		7,029	20,084		7,029
Fuel tank	[€]	105	105		105	
Starter and generator	[€]	251			251	
Infrastructure	[€]		669	669		669
Operating expenditure						
Fuel costs	[€/l]	0.53				
	[€/a]	365.40	146.16		231.00	
Electricity costs	[€/kWh]	0.12				
	[€/a]		164.57	274.29		171.43
O&M costs	[€/km]	0.028	0.021	0.018	0.028	0.018
	[€/a]	336.00	255.65	216.00	280.00	180.00
Total costs						
Interest rate	[%]	3%				
Investments	[€]	16,159	16,159	36,300	8,421	15,497
Operating expenditure	[€]	6,982	5,638	4,880	5,086	3,498
Total costs	[€]	23,141	16,159	41,181	13,507	18,996

11 These data are taken from various sources such as Biere et al. (2009), Concawe et al. (2008), Daimler (2009), Duvall (2004), Kley, Wietschel (2010), Wietschel et al. (2010).

All the existing taxes and fees, as well as the existing support schemes for EVs were added to the net total costs. Besides the price incentives of section 3, VAT was included as were taxes on fuel and electricity. The congestion charge was only considered for city vehicles and limited to 100 days in order to account for the strong local dependence. A summary of the taxes and incentives in place can be found in Table 2, based on total costs and discounted with 3 %.

Table 2: Taxes and incentives in the considered European countries in total costs[12]

TCO in [€]			AT	BE	CH	DE	DK	ES	FL	FR	GR	IE	IT	NL	NO	PL	SE	UK
VAT	Mid-size	ICE	3,232	3,393	1,228	3,070	4,040	2,585	3,555	3,167	3,070	3,393	3,232	3,070	4,040	3,555	4,040	2,828
		PHEV	5,101	5,356	1,938	4,846	6,377	4,081	5,611	4,999	4,846	5,356	5,101	4,846	6,377	5,611	6,377	4,464
		EV	7,260	7,623	2,759	6,897	9,075	5,808	7,986	7,115	6,897	7,623	7,260	6,897	0	7,986	9,075	6,353
	City	ICE	1,684	1,768	640	1,600	2,105	1,347	1,853	1,650	1,600	1,768	1,684	1,600	2,105	1,853	2,105	1,474
		EV	3,099	3,254	1,178	2,945	3,874	2,480	3,409	3,038	2,945	3,254	3,099	2,945	0	3,409	3,874	2,712
Registration tax incl, waivers	Mid-size	ICE	970	123	646	0	27,199	768	4,268	277	2,308	3,128	324	4,073	8,761	611	0	0
		PHEV	265	62	1,020	0	23,220	0	3,796	138	0	1,821	181	701	1,522	965	0	0
		EV	0	62	0	0	0	0	5,403	138	0	0	278	0	0	0	0	0
	City	ICE	253	62	337	0	7,257	0	1,808	185	1,202	1,426	181	1,019	2,395	318	0	0
		EV	0	62	0	0	0	0	2,307	46	0	0	181	0	0	0	0	0
Subsidies	Mid-size	ICE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		PHEV	0	-4,540	0	0	0	-2,000	0	0	0	0	0	0	0	0	0	-3,850
		EV	0	-8,890	0	0	0	-6,000	0	0	0	0	-3,500	0	0	0	0	-3,850
	City	ICE	-253	-1,263	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		EV	0	-5,626	0	0	0	-6,000	0	0	0	0	-3,500	0	0	0	0	-2,200
Feebate	Mid-size	ICE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		PHEV	0	0	0	0	0	0	0	-5,000	0	0	0	0	0	0	0	0
		EV	0	0	0	0	0	0	0	-5,000	0	0	0	0	0	0	0	0
	City	ICE	0	0	0	0	0	0	0	-700	0	0	0	0	0	0	0	0
		EV	0	0	0	0	0	0	0	-3,707	0	0	0	0	0	0	0	0
Annual vehicle tax incl, waivers	Mid-size	ICE	3,482	1,640	1,900	577	2,032	637	1,493	0	1,115	1,553	1,977	5,773	3,384	0	901	1,258
		PHEV	1,708	0	338	159	695	55	3,764	0	0	1,035	1,284	0	0	0	190	0
		EV	0	0	0	242	0	55	3,756	0	0	1,035	1,695	0	0	0	190	0
	City	ICE	1,380	1,255	1,571	199	695	219	1,206	0	1,115	1,035	1,156	637	3,384	0	414	229
		EV	0	0	0	151	0	0	2,271	0	0	1,035	770	0	0	0	190	0

12 Among others, the following sources were used: ACEA (2009), Autorità per l'Energia Elettrica e il Gas (2009), Bundesfinanzministerium (2009), Bundesfinanzministerium (2010), Die Bundesbehörde der Schweizerischen Eidgenossenschaften (2007), EDF (2009), HM Revenue & Customs (2009), HM Revenue & Customs (2010), IBERDROLA (2010), Lovdata (2009), NAF (2010), Parkkinen (2008), Postbus51 (2009), Revenue Irish Tax & Customs (2009), Transport for London (2010), wko.at (2009).

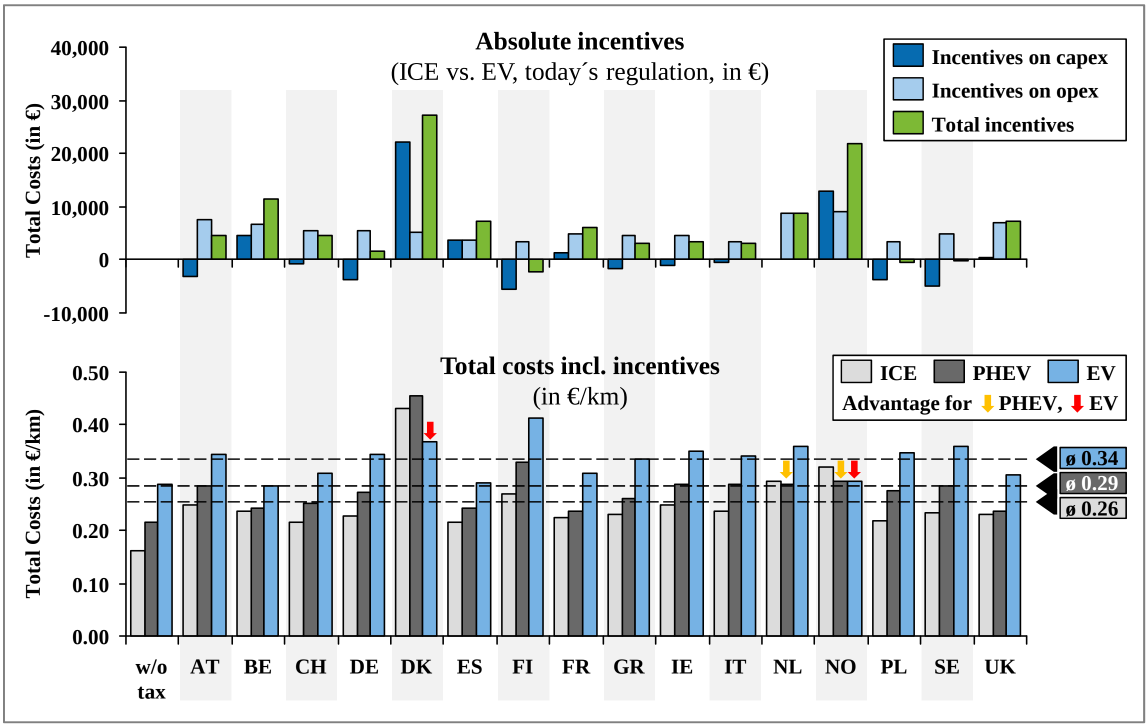
TCO in [€]			AT	BE	CH	DE	DK	ES	FL	FR	GR	IE	IT	NL	NO	PL	SE	UK
Fuel tax	Mid-size	ICE	5,030	5,911	3,971	6,087	5,783	3,764	6,548	5,742	3,687	4,529	5,400	6,380	6,608	4,104	5,601	5,893
		PHEV	2,012	2,364	1,588	2,435	2,313	1,506	2,619	2,297	1,475	1,812	2,160	2,552	2,643	1,642	2,240	2,357
		EV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	City	ICE	3,180	3,737	2,511	3,848	3,656	2,380	4,139	3,630	2,331	2,863	3,414	4,033	4,177	2,595	3,541	3,725
		EV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electricity tax	Mid-size	ICE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		PHEV	573	564	169	644	1,659	346	577	518	147	344	1,319	2,114	622	444	878	82
		EV	956	941	282	1,074	2,764	576	961	863	246	573	2,198	3,524	1,037	739	1,464	137
	City	ICE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		EV	597	588	176	671	1,728	360	601	539	154	358	1,374	2,203	648	462	915	85
Congestion charge	Mid-size	ICE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		PHEV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		EV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	City	ICE	0	0	0	0	0	0	0	0	0	0	0	0	2,426	0	0	9,151
		EV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3.2 Findings

In a first step, the total costs with and without taxes were calculated for the different reference cars. In net terms, mid-sized EVs currently cost an extra 18,000 euros. Even with technology improvements, this requires a significant volume of support over the next years. The difference in ICE and EV taxation are the absolute, discounted amount of incentives granted by the government to EV owners either based on the taxation scheme in place or special subsidies. A negative value can be interpreted as a higher absolute taxation of EVs, a positive as a support for EV purchase, offsetting partly or completely the additional net costs for an EV. Figure 4 shows the results for a mid-sized car equivalent to a VW Golf, , whereas the results for a city vehicle can be found in Figure 5.

For the *mid-sized vehicle*, the comparison of the absolute incentives reveals two interesting findings: Firstly, incentives on the capital expenditure (capex) are negative in 9 of 16 cases, which is mainly due to unchanged VAT taxation on the higher investments for EVs; secondly, the countries can be grouped into three categories with respect to the total incentives: the leaders (with amounts ranging from 10,000 to 28,000 euros: Denmark, Norway, Belgium), the followers (with amounts from 4,000 to 9,000 euros: Netherlands, Spain, UK, France, Switzerland, Austria), and the laggards (with amounts +/- 3,000 euros: Ireland, Greece, Italy, Germany, Sweden, Poland, and Finland).

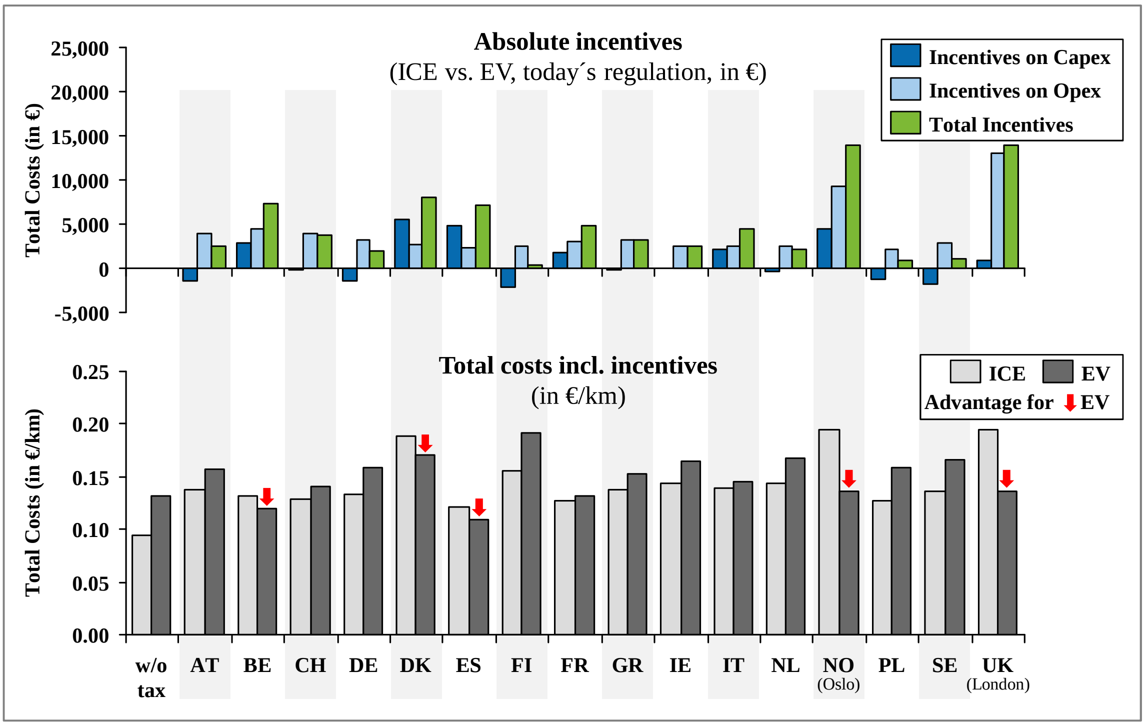
Figure 4: Total cost comparison of support schemes (reference vehicle: Golf)



Looking at the total costs including incentives, as depicted in the lower part of Figure 4, EVs are currently only cheaper in Denmark and Norway, even though Denmark still has the second most expensive EV in Europe. This result is mainly due to the relative national advantage of super-high ICE taxation in Denmark. PHEVs have a marginal advantage over ICEs in the Netherlands and Norway.

For *city vehicles*, absolute support is smaller and can be divided into three equal groups: leaders (with amounts ranging from 7,000 to 14,000 euros: the UK, Norway, Denmark, Belgium, and Spain), followers (with amounts from 3,000 to 5,000 euros: France, Italy, Switzerland, Greece, Austria, Ireland, and the Netherlands), and laggards (with amounts up to 2,000 euros: Germany, Sweden, Poland, and Finland). The groups are different to those for the mid-size vehicle and Belgium, Spain, and the UK now also feature among the strong supporters of electric vehicles. The congestion charge in London has a significant impact on the total costs if the vehicle is used in this area.

Figure 5: Total cost comparison of support schemes (city vehicle)



3.3 Sensitivities

The presented results depend on the assumptions detailed in paragraph 4.1. Main sensitivities are driven by five parameters: battery costs, vehicle and battery lifetime, fuel prices, annual mileage and interest rates. While capital expenditure is only affected by different battery costs, operating expenditure changes with all other parameters. Fuel prices and lifetime expectations can even change after purchase and resulting in higher total costs than calculated with. These changes can also be driven by regulation: As mentioned above, fuel and electricity are subject to different taxation schemes which can be changed in order to align the taxation of different energy sources, and thus have a huge impact on the operating expenditure for ICEs vs. EVs.

Today's support schemes differ not only in their total volume, but also in how they are applied. Thus, changes in some of the parameters such as interest rate or mileage can have a heavier or lighter impact on the total costs. The total incentive volume of countries which focus on one-time and upfront support is not as affected by changes in the interest rate or annual mileage as that of countries which focus on recurring tax incentives. In the light of volatilities on the commodity markets and constantly changing taxation schemes, upfront incentives are valued more from a customer point of view. In addition to financial support, governments could think about reducing this uncertainty by providing a steady investment environment, e.g. in which some parameters are fixed at the time of the investment.

On the other hand, incentive schemes need to be able to adapt to the technical development as already described for the dynamic efficiency criterion in order to avoid over-incentivized technologies. Therefore, tax reductions and subsidies granted at the time of purchase in order to reduce differences in the investments for ICE and EV need to be closely monitored and potentially adapted. This is especially true for changes in battery costs.

4 Conclusion

The additional costs for an EV are currently being targeted by European policy makers with a multitude of different incentives. This study provides an overview of the policy instruments in place, assesses these using four criteria, and concludes with a total cost assessment. One-time support schemes are often more practical and more appreciated by the customer if paid at the time of the initial investment. Recurring instruments like an annual tax reduction score higher with respect to effectiveness and efficiency, but are often smaller in total volume. The comparison of all the incentives in place reveals that EVs are economically unattractive in every European country except Denmark and Norway, which apply relatively high taxes to standard ICEs. For fast EV market penetration, regulators throughout Europe need to up the volumes of support schemes, establish high scoring instruments, and align these on a European scale. Potentially, some of the current tax incentives could even be switched to electric vehicles.

The main object of the research was to shed light on economic support schemes, so that soft factors were not examined in further detail. However, these might be interesting, especially when used to complement economic support. Further research should be undertaken in this field, for instance examining information policies for faster market penetration. The effects of efficiency or energy consumption standards on the purchasing decision also merit further research as these are especially important for EVs because consumers are not used to energy consumption figures measured in kWh.

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