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Hydrogen and fuel taxation

by

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Abstract

The competitiveness of hydrogen depends on how it is integrated in the energy tax system in Europe. This paper addresses the competitiveness of hydrogen and fuel cell technology when the taxation of fuels is taken into consideration. The study shows that even if hydrogen is taxed with exactly the same rate as conventional fuels, fuel taxes will amplify the competitiveness of hydrogen and fuel cell technology due to its superior energy efficiency. The higher the fuel taxes the more competitive is hydrogen. Thus, hydrogen and fuel cell technology must be expected to become competitive in Europe before it does so in the USA if the present difference in fuel taxes prevails. The study also examines some more realistic scenarios of fuel taxation at the time when hydrogen is introduced in Europe, all making hydrogen and fuel cells more competitive. Finally, the study points to some difficulties in maintaining the prevailing taxation principles in European fuel taxation when hydrogen is introduced in large scale.

Acknowledgements:

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Academic disciplines involved:

Energy economics, environmental economics, public finance

Keywords:

Taxation principles, hydrogen competitiveness, European energy taxes

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Introduction

This paper addresses the role that taxes and subsidies – or fiscal incentives – have or may have for the implementation the HFC technology in automotive use. It starts by defining the principles of European fuel and vehicle taxation that must be assumed to prevail in the period 2015-2025 when hydrogen as a transport fuel is supposed to be introduced. Then it gives a brief overview of how they are being used in affecting the transition from conventional to alternative fuels. This leads to the question of in which sense government has a case for affecting the implementation of HFC by fiscal incentives. Finally, the practical aspects of taxing hydrogen according to the energy taxation principles applied in Europe is discussed.

The study should be seen as complementary to the other study on the subject carried through as deliverable D7.6 of the Zero Regio project by Chernyavs'ka and Lanfranconi (2006). The reader is referred to this report for details on environmentally adjusted fuel taxation.

The two reports divide the field of study between them in another way than originally intended. The original intention was to divide it along geographical lines (Southern and Northern Europe) which is reflected in the report titles. However, it turned out to be expedient to let one report focus on facts about the present state of hydrogen taxation and detailed calculations of external costs associated with hydrogen and other fuels whereas the present report focuses on the European taxation principles, their implications for hydrogen competitiveness and for taxation of hydrogen in practice.

European fuel taxes

Minimum tax rates

The European energy taxes are set by the member states, but the EU has adopted minimum rates of taxation for the various fuels allocated to various applications. The minimum rates are set per unit in which the fuel is traded and pragmatically based on the existing tax designs of the member states. Therefore, the EU minimum rates also reflect the typical taxation principles of the member states.

This means that the tax rates in the member states are set in, e.g., €/litre or €/ton and this is mirrored in the minimum tax rates of the EU directive. For comparison all the EU minimum tax rates are converted from to €/GJ in the figure below. The rate depends on whether the energy consumption along the entire fuel chain or only the energy consumption in the end-use is used as denominator. Both are shown in the figure below.

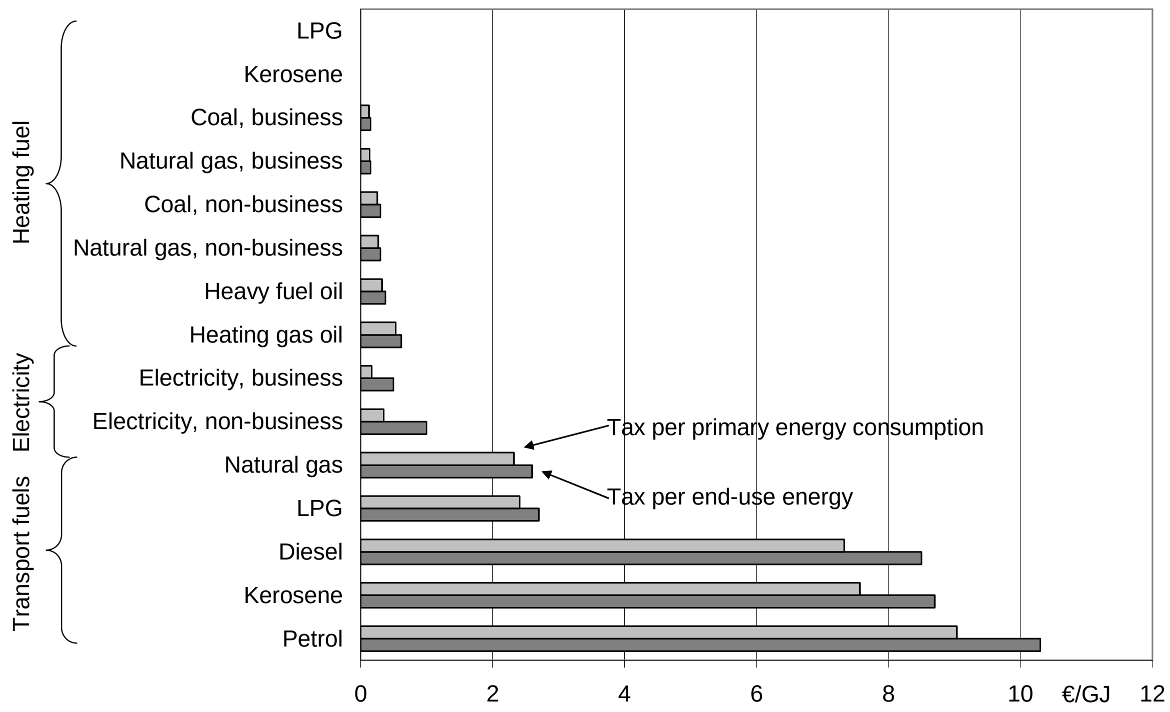

Figure 1. Implicit EU minimum tax rates per end use and primary energy consumption (€/GJ, 2005 prices).

Source: Commission of the European Communities (2007) and adjusted by primary energy/end-use ratios from Edwards, Griesemann et al. (2006) .

The minimum rates displayed in figure 1 reveals a tax differentiation favouring business over non-business use of energy, heating over electricity, electricity over transport, and gaseous over liquid fuels. The latter is due to a temporary preferential treatment of natural gas to promote its introduction on the European fuel market. There are no minimum tax rates for LPG and kerosene for heating use. Again, the EU minimum taxes merely represent a mirror image of the lower tax rates in the member states.

Actual tax rates

The actual tax rates are much higher than the minimum tax rates in many member states. The following figure shows the minimum and the actual tax rates applied by each member state.

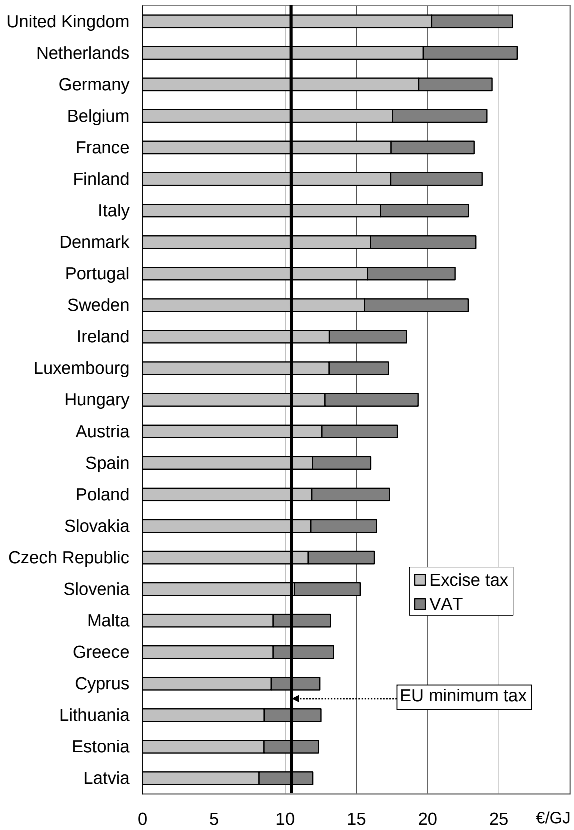

Figure 3. EU minimum tax rate for unleaded petrol (95) and member state excise taxes and value added taxes (VAT). €/GJ, 2005.

Source: EUROSTAT, Commission of the European Communities (2007)[1], and author's calculations.

The figure shows that the minimum tax rate corresponds to €10.3 per GJ. It was set in 2003 and has not been adjusted since then. As a result of this the real value and thus the incentive effect of the tax is eroded by inflation. In 2005 it should have been €10.7 per GJ to maintain its real value. However, many of the "old" member states apply considerably higher excise taxes on petrol whereas many of the new member states just comply with the minimum rate or are in a transition process with the aim of attaining the minimum tax.

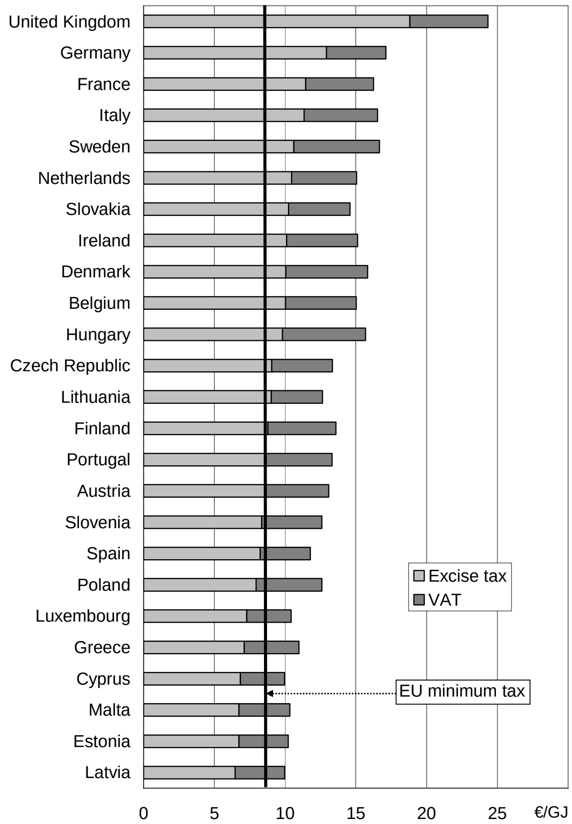

Figure 2. EU minimum tax rate for diesel and member state excise taxes and value added taxes (VAT). €/GJ, 2005.

Source: As figure 2

It should be noted that the fuel tax is far from the full story about the fiscal incentives involved in car transport. Taxes on ownership (registration and circulation taxes) are high, in particular in member states without domestic car industry. Road tolls, Eurovignette, and congestion charges are increasingly used. To avoid adverse impacts of these incentives on the mobility of the labour force some member states offer tax allowances related to commuting either directly or via the employer.

[1] The heating values for petrol, diesel, and natural gas used for these calculations are the lower heating value (LHV or NCV).

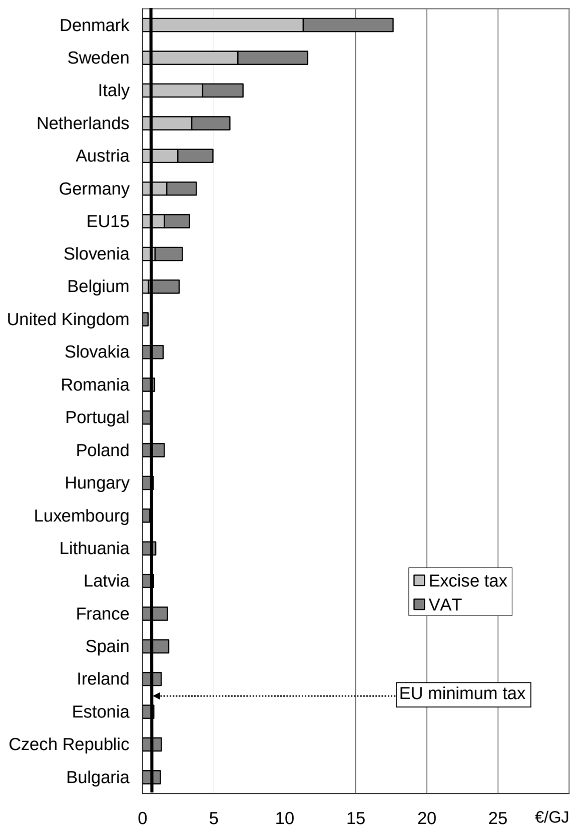

Figure 4. EU minimum tax rate for natural gas for non-business use and member state excise taxes and value added taxes (VAT). €/GJ, 2005.

Source: As figure 2.

Natural gas has – at least until recently - been considered an alternative to oil with better supply security and emission characteristics than oil products. This is reflected in lower taxes and lower EU minimum tax rates.

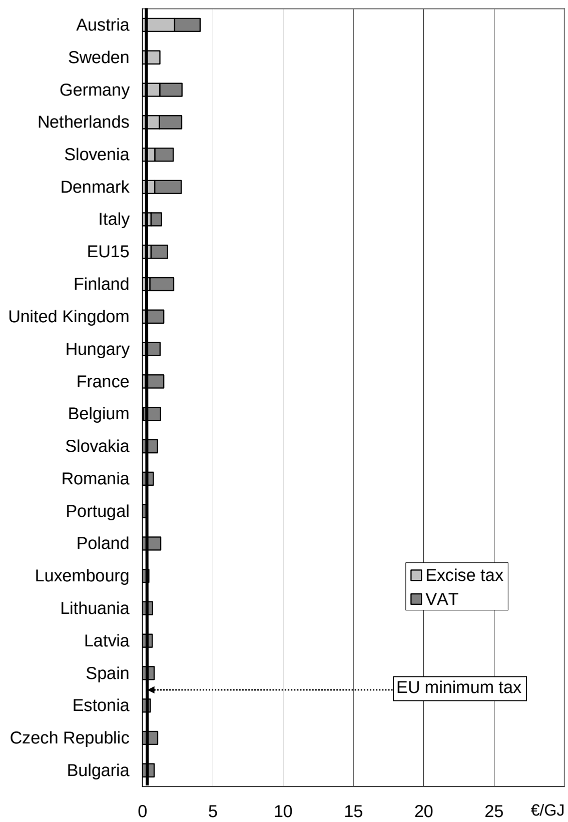

Figure 5. EU minimum tax rate for natural gas for business use and member state excise taxes and value added taxes (VAT). €/GJ, 2005.

Source: As figure 2.

The EU minimum tax rate for industrial use of natural gas is negligible.

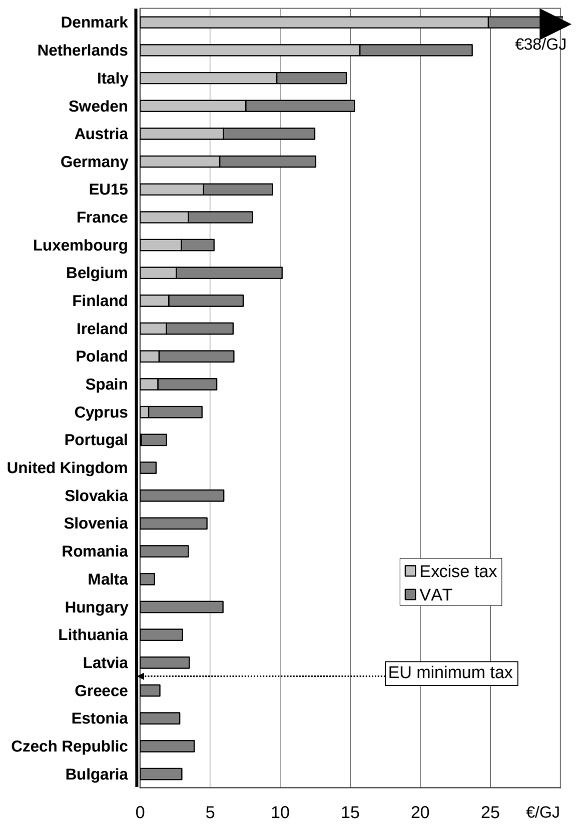

Figure 6. EU minimum tax rate for electricity for non-business use and member state excise taxes and value added taxes (VAT). €/GJ, 2005.

Source: As figure 2.

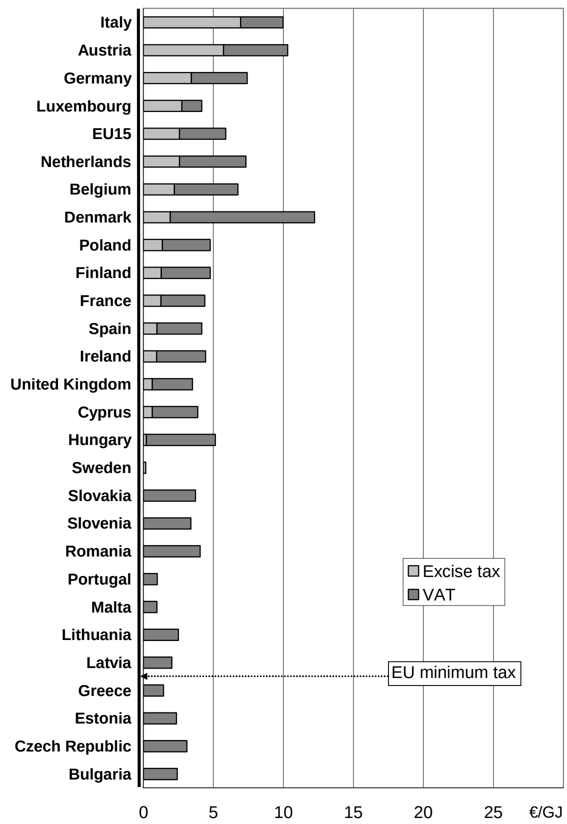

Figure 7. EU minimum tax rate for electricity for business use and member state excise taxes and value added taxes (VAT). €/GJ, 2005.

Source: As figure 2.

Electricity taxes differ more than other energy taxes partly due to the different environmental pressure and supply security associated with power generation in the different member states. In Denmark, e.g., end-use of electricity entails a lot of coal consumption with heavy environmental pressure.

The EU minimum tax rate for electricity for industrial use is negligible.

Taxation Principles and Hydrogen as a Transport Fuel

To compare the consumer costs of fuel it is necessary to assume a range of scenarios about the principles of fuel taxation in Europe in 2015-2025. The radical changes that currently take place in European energy and climate policy makes it probable that the taxation principles applied to this area will be adjusted too.

First, as it appears from the figures above, the *minimum level* for European transport fuel taxes is approximately *€10 per GJ*. Some member states do, however, apply twice as high fuel taxes and they could very well be setting the example for the future fuel taxation in Europe.

Second, the fuel taxation directive explicitly *exempts* energy used in the *transformation sector* from taxation. The Council of the European Union (2003) restricts the scope of the directive to the use of energy products as heating fuels or motor fuels. Other uses include the use as raw materials or where the heat or electricity itself is the main input. These and the so called "dual uses" are exempt and sea and air transport is exempt as well.

The consequence of this is that only end-use of energy is taxed, whereas energy used in the transformation sector and in the most energy intensive economic activities is not taxed.

The principle of taxing end-use of rather than production of fuels is important for avoiding distortions in the international trade in fuels. At the same time it does, however, gives rise to economic inefficiencies because the losses in the transformation sector could be avoided with rather inexpensive efforts whereas the end-use taxation provides incentives to undertake more expensive efforts to save the same amount of energy.

This principle has already been modified to some extent by the European Union Emission Trading Scheme (ETS) that adds a modest quota price to the use of fossil energy for these purposes. This quota price plays in many respects the same role as an energy tax. The intended global extension of this quota market in the international climate policy implies that the quota price will be equal for all countries included in the global cap with climate commitments. They will, however, only include large plants whereas a large part of the hydrogen supply must be expected to come from smaller plants.

The principle of taxing end-use rather than energy leads to an energy flow in which the energy losses during conversion, transmission, and distribution are untaxed and this is obviously inexpedient from an energy efficiency perspective. However, for transport fuels, the losses hardly amount to more than 10% of the primary fuel (i.e., crude oil). In the electricity sector, it is possible to intervene with government regulation requiring cogeneration of heat and power and other measures to minimise the energy losses in the transformation sector.

The future conversion and distribution of hydrogen will, however, involve energy losses maybe in the range of 40-50% and much of it will take place in small units making it difficult to apply regulations of heat recovering and similar measures. In such a situation taxation of the energy used in the transition will be of utmost importance to ensure efficient use of the energy – which is one of the purposes of introducing hydrogen as transport fuel at all.

As mentioned above, the fuel tax directive as well as the taxation practice in most member states taxes fuels used for heating lighter than fuels used for transport. As long as they are different fuels (natural gas and heating oil for heating and petrol and diesel for transport) this represents not a difficulty. However, when the same natural gas can be used by end-users for heating as well as a transport fuel, it will become difficult to maintain this distinction. Raising the tax on fuels for heating to the same level as fuels for transport would involve adverse changes in the distribution of consumption opportunities. However, the higher taxes also means higher revenue that can be "recycled" back in a way that neutralises the adverse distribution effects.

Similarly, higher taxes on fuels that are mainly used for industrial purposes will imply higher costs and thus weaken competitiveness in relation to industries located outside Europe. Such adverse effects can be neutralised by recycling an appropriate part of the revenue back to the industries according to their value added or wage bill.

In the future transformation sector will probably be characterised by more co-generation of not only heat and power, but also hydrogen and liquid fuels. For this reason as well as for increasing energy efficiency in an economically efficient way, there can be good reasons for examining models for replacing the now prevailing principle of taxing end-use rather than transformation use of energy with a principle of a uniform tax rate applied along the entire fuel chain.

A *third* principle in European fuel taxation concerns differentiating according to the *environmental pressure* caused by combusting the fuel. For instance, unleaded petrol is taxed with a smaller rate than leaded and natural gas is in many countries taxed lighter than oil or coal with reference to its lower impact on the environment when combusted.

The trend in European taxation - and in the policies advocated by the EU indeed – is to strengthen this principle, not only in the taxation of fuels but also in the taxation of vehicles. For hydrogen promoted partly as an environmentally friendly fuel it must be expected that this principle will be perceptibly reflected in the tax rate. The environmental pressure caused by hydrogen as a fuel applied with a fuel cell will, however, not be associated with the end-use of the hydrogen, but rather in the production process. Moreover, it is not possible to tell from the nature of the hydrogen from which feedstock it has been produced and thus the environmental pressure associated with it.

This problem could be solved with a system similar to that of producing renewable electricity: Typically, end-use of all electricity is taxed at the same rate, but renewable electricity is favoured with a high feed-in rate to the grid and/or subsidies. Again, a uniform tax rate differentiated only by the societal priorities due to environmental and other properties would make the system more transparent and increase energy as well as economic efficiency.

The environmental differentiation will reflect the external costs inflicted on the rest of society either as the value of environmental damages caused by the use of the fuel or by the avoidance costs of not using the fuel.

To the extent that the purpose of the European fuel taxes is to reduce the environmental impact of fuel combustion, the European governments apply the latter principle. The avoidance costs then equals the saved tax necessary to compensate for not using a marginal unit of the fuel at the desired level of fuel use in the economy as a whole. For an in depth analysis of a primarily damage based approach, please refer to Chernyavs'ka and Lanfranconi (2006).

In the calculations below, it is calculated how the competitiveness of hydrogen versus conventional fuels is affected by the various taxation principles. The scenarios examined include

No fuel taxes

Only tax on conventional fuels (€10/GJ)

End-use taxation of €10/GJ of hydrogen as well as conventional fuels

Taxing conventional fuels and natural gas used as feedstock for hydrogen by €10/GJ

Like 4. but differentiating to a natural gas tax of €8/GJ

Like 5. but with double rates, i.e., conventional €20 and natural gas €16 per GJ.

Competitiveness of Hydrogen as a Transport Fuel

Vehicle cost competitiveness

The manufacture of fuel cell vehicles is expected to reach a level of performance where it is possible to produce them at a cost comparable to the cost of a comparable conventional car at some point of time in the period 2015-2025. Throughout the calculations below it is therefore assumed that the ownership cost of the vehicle per kilometre is identical to the vehicle to which it is competing. Of course, the fuel cell vehicle will reach, first, the cost level of the hybrid electric vehicle, then, the cost of the 2-3 litres advanced diesel, and finally the cost of a conventional petrol car. The advantage of the fuel cell vehicles in terms of fuel efficiency will, however, be smaller compared to the more technologically advanced vehicles than compared to the conventional petrol car.

The governments can change this situation by changing vehicle related taxes and subsidies. In this respect it is particularly interesting that some countries collect high registration and circulation taxes. Many of these countries have already announced that they are adjusting the basis of their vehicle related taxes in the direction suggested by the European Commission - that is, towards the fuel consumption of the vehicles – and, in particular, they plan to exempt fuel cell and/or battery electric vehicles from vehicle related taxes.

In the following table, the registration taxes are converted to annual payments and added to the annual circulation taxes.

Table 1. Annualised vehicle related taxes in Europe 2005. €.

	Petrol (Golf 1.4)	Diesel (Golf 2.0 SDI)
Denmark	2621	2844
Norway	1559	2286
Ireland	1359	2203
Malta	1128	1752
Netherlands	1057	1354
Finland	605	1215
Portugal	577	1155
Slovenia	465	1061
Greece	405	820
Austria	403	640
Hungary	302	512
Cyprus	297	498
Italy	278	357
Belgium	270	357
Switzerland	268	353
United Kingdom	246	292
Spain	213	284
Latvia	184	283
Sweden	144	241
Germany	138	184
France	111	130
Poland	104	114
Luxemburg	67	96
Lithuania	38	47
Estonia	26	26

Slovakia	13	13
Czech Republic	7	7

Source: Based on Kunert and Hartmut Kuhfeld (2006).

The table shows that exemption of fuel cell vehicles from vehicle related taxes represents considerable opportunities in many countries for advancing the point of time where fuel cell vehicles can be sold for a price comparable to that of the competing conventional or advanced petrol or diesel car. In the following calculations, it is assumed that there is no difference between the vehicle costs per kilometre for fuel cell vehicles and the competing vehicles.

The fuel cost competitiveness model

In the following, the impact on hydrogen competitiveness of a tax system following these principles is analysed using the fuel cost per km model described in Hansen (2007b) (Appendix A).

The model is as simple as possible considering that details of market structure in oil, gas, and fuel markets in 2015-2025 are not known and it would be rather speculative to specify such details. The relative cost of hydrogen and conventional fuels per kilometre is derived from simple models of the relation between the oil price and the fuel. For hydrogen this relation involves a nested structure where the hydrogen cost will depend on the natural gas retail price, which again depends on the international natural gas price, which ultimately depends on the international oil price.

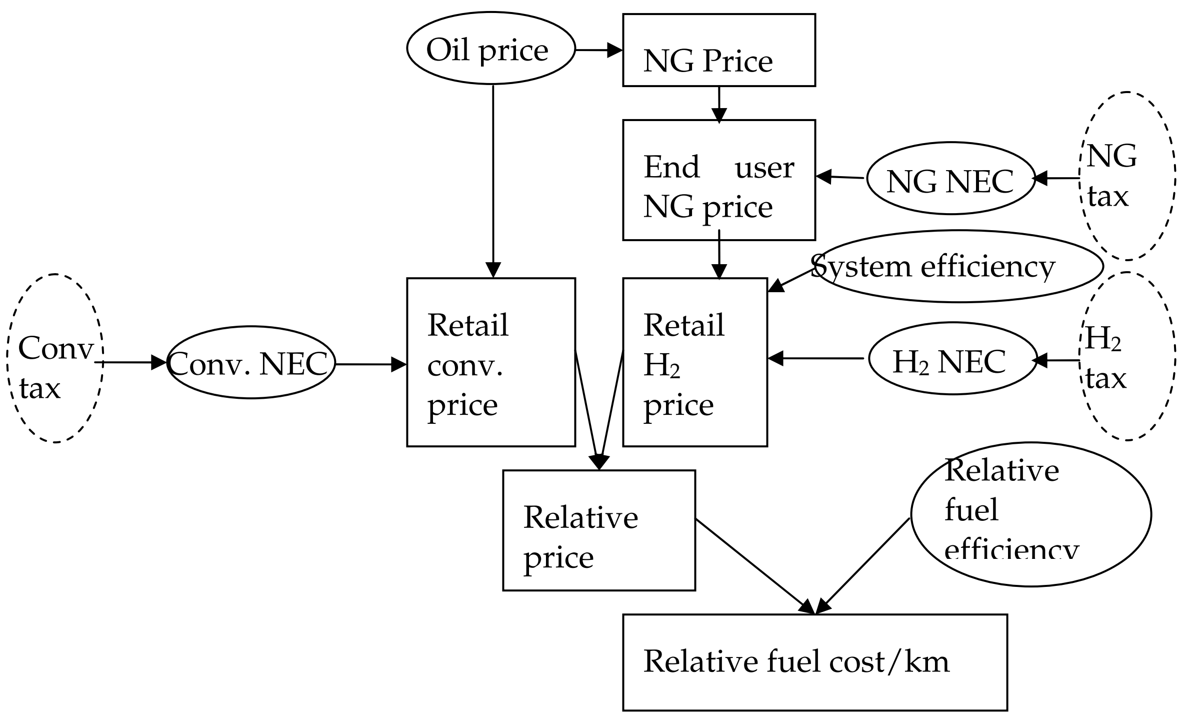

Figure 8. The Fuel Cost per Km Model

The simple structure of the model allows us to study the effect of a limited number of important parameters. They include the non-energy costs of producing and distributing fuels (refinery and infrastructure costs other than energy costs) and the efficiencies by which hydrogen is produced and transformed to work (km) in the vehicle.

The fundamental factor that makes the hydrogen and fuel cell technology competitive is the unique efficiency of the electromotor made possible to use in vehicles comparable in transport performance to vehicles on the market today. The vehicles on the market today as well as by 2020 differ in fuel efficiency. Therefore we consider three classes of vehicles with which the HFC vehicle will have to compete: Conventional vehicles compared to which the HFC vehicle is 100% more fuel efficient. Vehicles compared to which the HFC vehicle is 75% more fuel efficient could be ICE vehicles using more advanced technology. And finally vehicles compared to which HFC vehicles are 50% more fuel efficient. They could be vehicles combining advanced ICE technology with the electro-motor including regeneration of break energy.

The cost of the vehicle itself (purchase, repair, maintenance) is assumed to be identical to the vehicle with competing technology. Of course, we must expect the price of a fuel cell vehicle to decline in accordance with the usual pattern for new types of commodities. The price will first "hit" the price level of the "advanced and hybrid" vehicles above which the fuel cell vehicle has only 50% efficiency advantage. To be more competitive than these vehicles, oil prices would have to be in a totally unrealistic range.

After that the declining costs will pass the price level of the "advanced" internal combustion engine vehicles above which the fuel cell vehicle has 75% efficiency advantage. The oil prices that would make hydrogen a competitive fuel in this competition would have to be well above the price span of $65-85 (2005 price level) per barrel considered most realistic in Hansen (2007b) (Appendix A). That is, unless a technological breakthrough allows for drastically lower non-energy costs.

Eventually the fuel cell vehicles can be produced at a cost comparable to conventional cars and fuel cell cars are 100% more efficient than these.

From a European perspective, there are two reasons for developing these scenarios under additional assumptions. First, energy efficiency – not least in automotive transport – is a societal priority and in Europe it is reflected in the excise duties on fuels. Second, even if natural gas has been promoted in European energy policy it cannot be the long term basis of transport fuels. Europe's energy resources are related to power technologies and bioenergy, not fossil fuels, and sooner or later the challenge will be to transform these resources to transport fuels.

Hydrogen competitiveness without taxes

The results in the case of no energy taxes at all are shown in table 1 below.

Table 2. Hydrogen competitiveness in a no-tax-scenario

Fuel tax	€/GJ	Primary energy basis (feedstock)					
Conventional	0						
H_2	0	Natural gas				Wind power	
NG	0						
H_2 non-energy costs		10	10	13	7	15	10
System efficiency		62%	70%	62%	70%	65%	70%
		$/bbl Brent (2005 price level)					
100%		78	60	107	37	124	75
75%		139	95	185	61	144	88
50%		413	188	542	127	170	105

Source: Hansen (2007b) (Appendix A).

The table shows the oil price at which hydrogen will become competitive. Hydrogen is an energy carrier, an end-use fuel, not a primary energy source. The properties relevant for taxation are the consumption of primary energy and emissions of pollutants related to the end-use of the fuel. Therefore, two technologies of hydrogen are considered: Natural gas based and wind power based hydrogen. They represent what might be call first and second generation hydrogen. In this context "second generation" means hydrogen that is based on primary energy sources characterised by a high degree of security of supply and low emissions of greenhouse gasses.

Under alternative assumptions as to non-energy costs of natural gas based hydrogen (H_2 NEC = 10, 13, or 7 €/GJ), the efficiency by which natural gas is transformed to hydrogen (System eff. = 62% or 70% energy output of energy input), and the efficiency advantage of the fuel cell vehicle above the competing internal combustion engine vehicle (100%, 75%, and 50% efficiency advantage).

The non-energy costs are related to the hydrogen infrastructure, including production and distribution facilities. It is assumed that about 2020 – when this competitiveness becomes relevant – a fully optimised hydrogen system will be able to deliver hydrogen at non-energy costs of €10 per GJ. However, many of the new hydrogen filling stations will supply a limited amount of vehicles with on-site produced hydrogen and they will not be able to take advantage of the scale economies in central production. In particular, it can be difficult to recover waste heat from the process. Thus €13 per GJ is a relevant assumption too. Finally, there can be a technological breakthrough, e.g., in solid hydride technology, which could allow very low non-energy costs such as €7 per GJ. Thus the scenarios studied here are those with non-energy hydrogen costs of €10 +/- 3 per GJ.

The system efficiencies also relate to the expectations of optimised steam reforming of natural gas on-site (62%) and centrally (70%).

When analysing data for conventional ICE technology we have averaged the data for diesel and petrol into an average fuel called "dieseoline" in order to keep the model simple.

In such a "no-tax-scenario" hydrogen will be competitive with conventional fuels at an oil price of $78 per barrel even if hydrogen is produced with natural gas reforming at only 62% system efficiency. For higher efficiency and/or lower non-energy costs hydrogen becomes competitive at even lower oil prices. The high non-energy costs expected to be associated with on-site production at €13 per GJ would however require the oil price to go as high as $107 per barrel to make hydrogen competitive, even with a 100% efficiency advantage of the fuel cell vehicle.

The conclusion is that in the no tax scenario, natural gas based hydrogen is likely to be competitive with petrol or diesel if the fuel cell vehicles are 100% more fuel efficient than the competing vehicles. However, advanced internal combustion engine technology and hybrid solutions will also be competitive at these prices. In the no tax scenario there is no fuel cost argument for preferring the fuel cell vehicle for these other more efficient solutions if the costs of the vehicles themselves are comparable.

The natural gas based hydrogen will be met with competition from other energy sources. The table below shows the result from the European WtW-study of the available technology options and their costs.

Table 3. Expected hydrogen-at-pump costs beyond 2010 assuming $50 per barrel oil (Brent quality).

	NG	Coal	Wood	Nuc	Wind	EU-mix
	€/GJ (2005 price level)					
Electrolysis	44	38	#N/A	47	46	42
Thermal	35	34	21	#N/A	#N/A	#N/A
	€/kg (2005 price level)					
Electrolysis	5.30	4.56	#N/A	5.62	5.54	5.02
Thermal	4.25	4.04	2.47	#N/A	#N/A	#N/A

Source: Edwards, Griesemann et al. (2006) and author's calculations.

The table shows that at an oil price of $50 per barrel hydrogen from reformed natural gas is expected to cost €4.25. This is less expensive than any of the electrolysis alternatives. However, hydrogen based on hydrolysis of cellulosic biomass ("wood") is expected to be much cheaper and the absolute most efficient hydrogen production technology.

The cost figures for electrolysis are aligned with the figures found by Levene, Mann et al. (2005) in a study of electrolysis in industry today. These studies rest, however, on restrictive assumptions that make electrolysis and wind power look more costly than it necessarily is.

Both studies assume a lower efficiency (65%) than expected by the Hydrogen and Fuel-Cell Technology Platform (HFP) (2006) in 2015 (>70% LHV). None of the studies take by-products into account. Even electrolysis dedicated for hydrogen production does, however, produce oxygen and waste heat. With the assumptions used in the WtW study wind power is €cents 7.3 per kWh. This is in the high end of the assumptions applied by the International Energy Agency (IEA) (2006). In its World Energy Outlook 2006, wind power is assumed to cost USc 5.0-7.5 per kWh.

With such improved parameters not only "wood-hydrogen" but also "wind-hydrogen" could become more competitive by already in 2010. Using as realistic but less pessimistic assumptions for non-energy costs of electrolysis (€11.4/GJ), wind power costs (€cents 5.0) and efficiency (70%) for 2015 yields a hydrogen cost at pump of €3.77 per kg H_2.

With these assumptions wind power hydrogen gets as cost competitive as natural gas based hydrogen with high non-energy costs (on-site production).

Hydrogen competitiveness with taxes

The following table shows the oil price at which hydrogen will be competitive if hydrogen is totally exempt from taxation. This actually allowed by the EU energy tax directive as long as the hydrogen is used in experimental and development projects. If this exemption would be made permanent, it would give the following results as to hydrogen competitiveness.

Table 4. Hydrogen competitiveness if only diesoline is taxed.

Fuel tax	€/GJ	Primary energy basis (feedstock)					
Conventional	10						
H_2	0	Natural gas				Wind power	
NG	0						
H_2 non-energy costs		10	10	13	7	15	10
System efficiency		62%	70%	62%	70%	65%	70%
		$/bbl Brent (2005 price level)					
100%		-111	-92	-82	-115	63	14
75%		-133	-99	-86	-133	83	27
50%		-231	-119	-102	-180	110	45

Source: Hansen (2007b) (Appendix A) and author's calculations

The table shows clear that such a tax would make hydrogen very competitive except in the case of very expensive wind power based hydrogen vs. very effective hybrids.

It is probably more likely that hydrogen will be taxed. A more thorough discussion of this is given above. The following table shows the competitiveness of hydrogen when taxed with €10/GJ just as conventional fuels ("diesoline").

Table 5. Hydrogen competitiveness if diesoline and hydrogen are equally taxed.

Fuel tax	€/GJ	Primary energy basis (feedstock)					
Conventional	10						
H_2	10	Natural gas				Wind power	
NG	0						
H_2 non-energy costs		10	10	13	7	15	10
System efficiency		62%	70%	62%	70%	65%	70%
		$/bbl Brent (2005 price level)					
100%		-16	-16	12	-39	93	45
75%		23	12	69	-22	118	62
50%		198	86	327	25	150	85

Source: Hansen (2007b) (Appendix A) and author's calculations.

Even if there is no difference in the taxation of conventional fuels and hydrogen the tax makes hydrogen much more competitive than if none of the fuels were taxed. This is because the fuel efficiency advantage of the HFC vehicle becomes more valuable the more expensive the fuel.

This observation is interesting because it means that hydrogen becomes cost competitive on the European market a long time before it does on the US market. Provided, of course, that US fuel taxes also in the future are negligible whereas European fuel taxes are high and that the same vehicle models are available on both markets.

The equal taxation of energy consumption regardless of fuel shown in table 4 is not really equal when you take the energy consumption throughout the fuel chain from well to tank into account. It is small (around 10%) for conventional fuels, but large for hydrogen (1-system efficiency). This an important point if reducing the oil and gas dependency as much as possible with as small tax rates as possible is a societal priority. In the following table this problem is solved by taxing the primary energy feedstock instead of the produced hydrogen with €10/GJ.

Table 6. Hydrogen competitiveness if diesoline and natural gas are equally taxed.

Fuel tax	€/GJ	Primary energy basis (feedstock)					
Conventional	10						
H_2	0	Natural gas				Wind power	
NG	10						
H_2 non-energy costs		10	10	13	7	15	10
System efficiency		62%	70%	62%	70%	65%	70%
		$/bbl Brent (2005 price level)					
100%		42	16	70	-6	63	14
75%		118	59	164	26	83	27
50%		461	174	590	112	110	45

Source: Hansen (2007b) (Appendix A) and author's calculations.

The result is that the tax per GJ hydrogen exceeds the tax per GJ "dieseoline" and the competitiveness of hydrogen deteriorates accordingly. Note, however, that the competitiveness of hydrogen is still better than in the no-tax scenario.

As noted above, the proposition of shifting the tax base more towards emissions is debated in Europe at the moment. This would imply that fuels with few emissions per GJ would be taxed at a lower rate than fuels with high emissions. If the tax on conventional fuels is €10/GJ then natural gas could be taxed by, e.g., €8/GJ. See Chernyavs'ka and Lanfranconi (2006) for a detailed analysis of applying such principles in European energy tax systems.

Table 7. Hydrogen competitiveness if tax rates are adjusted for emissions.

Fuel tax	€/GJ						
Conventional	10	Primary energy basis (feedstock)					
H_2	0						
NG	8	Natural gas				Wind power	
H_2 non-energy costs		10	10	13	7	15	10
System efficiency		62%	70%	62%	70%	65%	70%
		$/bbl Brent (2005 price level)					
100%		11	-5	40	-28	63	14
75%		68	27	114	-6	83	27
50%		323	115	452	54	110	45

Source: Hansen (2007b) (Appendix A) and author's calculations.

The table shows that such environmental differentiation of tax rates would favour hydrogen.

The assumption of an energy tax of €10/GJ is maybe not realistic considering the targets for increased energy efficiency and reduced CO_2 emission agreed upon recently by the European countries. The realistic future EU-wide tax rate is perhaps more like the high rates in United Kingdom the Netherlands, and Germany. In the following table conventional fuels are taxed by €20/GJ and natural gas adjusted for emissions by €16/GJ.

Table 8. Hydrogen competitiveness if the high tax rates of UK, NL, and D are adopted in EU wide and environmentally adjusted.

Fuel tax	€/GJ	Primary energy basis (feedstock)					
Conventional	20						
H_2	0	Natural gas				Wind power	
NG	16						
H_2 non-energy costs		10	10	13	7	15	10
System efficiency		62%	70%	62%	70%	65%	70%
		$/bbl Brent (2005 price level)					
100%		-56	-71	-28	-93	2	-46
75%		-4	-40	43	-73	22	-33
50%		233	42	362	-19	49	-16

Source: Hansen (2007b) (Appendix A) and author's calculations.

Now hydrogen becomes highly competitive except in the cases with low system efficiency in natural gas based hydrogen production coupled with very fuel efficient hybrid vehicles.

It could be argued that such a high tax rate would be politically impossible in many countries because it would make car driving unaffordable to large low income segments of the population. However, as described above, taxes motivated by their incentive effect rather than their finance effect provide the government with revenue that can be used to neutralise adverse distributional effects. Thus, it is not technically difficult to design an energy tax reform in a politically acceptable way.

In any case, the higher the energy taxes, the more will the efficiency advantage of the fuel cell vehicle mean. Thus, hydrogen and fuel cell vehicles will become competitive to European and Japanese consumers a long time before they do so to North American consumers.

Conclusions

A scenario where hydrogen would be exempt from fuel taxation on a permanent basis is not very likely. Studies in Hansen (2007a) (Appendix B) and Hansen (2007c) show that it is only if it is made on the basis of pollution free primary energy with a high security of supply that it will contribute to reaching the EU goals in these respects. In this sense there is a compelling case for exempting the hydrogen based on such feedstocks, but not all hydrogen from fuel taxation.

There are difficulties in making such a distinction in practice and in the long run could it very well be that the best solution is to replace the principle of end-use rather than transformation taxation with the principle of uniform taxation along the entire fuel chain. In a "hydrogen economy" it can be difficult to maintain a lighter taxation on energy used for heating and energy used for industrial purposes.

However, even if hydrogen is taxed exactly as much as petrol and diesel, the tax system will improve the competitiveness of hydrogen. The higher the uniform tax across fuels is the more competitive hydrogen will be. Fuel taxes amplify the competitiveness of hydrogen due to its energy efficiency. In fact, if the existing high taxes in Europe and negligible taxes in North America prevail then hydrogen will become competitive in Europe a long time before it does in North America. And even more so if the taxation principles are moving more in the direction of energy content and emissions as well as primary energy feedstocks rather than end-use fuels.

But the future energy tax system will hardly be like the present tax system. The recent suggestions for reform points towards a European energy tax system with tax bases reflecting the European objectives such as energy efficiency, supply security and environmental quality. Moreover, to make the energy tax system play a more prominent role in achieving these goals one would expect future tax rates to be higher at least for the member states that currently tax at a low rate.

Adjustment of the fuel tax according to the amount of pollutants emitted by combusting would further strengthen the competitiveness of hydrogen.

The future taxation principles applied in energy taxation and the desirable degree of harmonisation are at present subject to debate among the member states. When this debated is concluded, it will be possible to go into a more detailed analysis of how hydrogen can be implemented in the European energy taxation system.

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