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Least-Cost Policy Strategies For CO_2-Reduction In Passenger Car Transport: Lessons From Europe For Emerging Countries

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ABSTRACT

Emerging countries currently have the highest growth rates in transport energy consumption and straightforward greenhouse gas emissions. In recent years many policy approaches in EU countries have been implemented to cope with problems in transport sector. The core objective of this paper is to derive lessons learned from different EU policies for road passenger transport which can also be implemented in emerging countries. Of high relevance in this context are especially the costs of measures to reduce GHG emissions from road passenger transport and how to derive a corresponding least-cost-portfolio of measures.
The major conclusions and recommendation for emerging countries based on analysis of European policies for road passenger transport are: (i) Improving energy efficiency is a very important measure but implemented alone it does not necessarily lead to an equivalent energy and CO_2 saving effect because rebound effect - people purchase larger cars and drive more; (ii) The major recommendation is that standards have to be accompanied with fuel taxes to reduce km driven as well as with size-dependent registration taxes to limit the size of cars.

Keywords: road transport, emerging countries, policies, Europe, least-cost approach

1. INTRODUCTION

In most countries the transport sector is the major barrier for heading towards sustainable economies. In virtually all OECD and emerging countries greenhouse gas (GHG) emissions from transport have the highest growth rates among all sectors [1]. It is the only sector where world-wide energy consumption has doubled as well as GHG emissions [1]. Due to the IEA the largest share of this growth did take place in the non-OECD regions mainly in the emerging countries. Of specific relevance is this context is road transport which causes more than 90% of transport emissions in all countries.
Aside from GHG emissions other road transport related problems are energy supply security, air pollution, accidents and congestions. Some of these problems are especially expressed in urban areas.

The dynamics of these problems is actually much more pressing in emerging countries with rapidly growing economies, urbanization and corresponding rising need for transport. Currently, the situation with respect to motorization in these countries is quite different in comparison to Europe. With respect to emerging countries it is especially important to consider that a large part of individual transport especially in Asian countries is also provided by two-wheelers, see Fig.1[1].
As Fig.1 depicts countries like Malaysia, Brazil, Mexico and Turkey are "leading" in this category with about 200 cars/capita (total: 300-500 road vehicles/capita) while the largest emerging economies China and India show only 20 cars/capita (total: about 80 - 100 road vehicles/capita). In the light of the looming increases to catch up with the Western "levels" it is extremely important for these countries to avoid the mistakes made in the OECD countries and to learn the lessons from implemented policies.

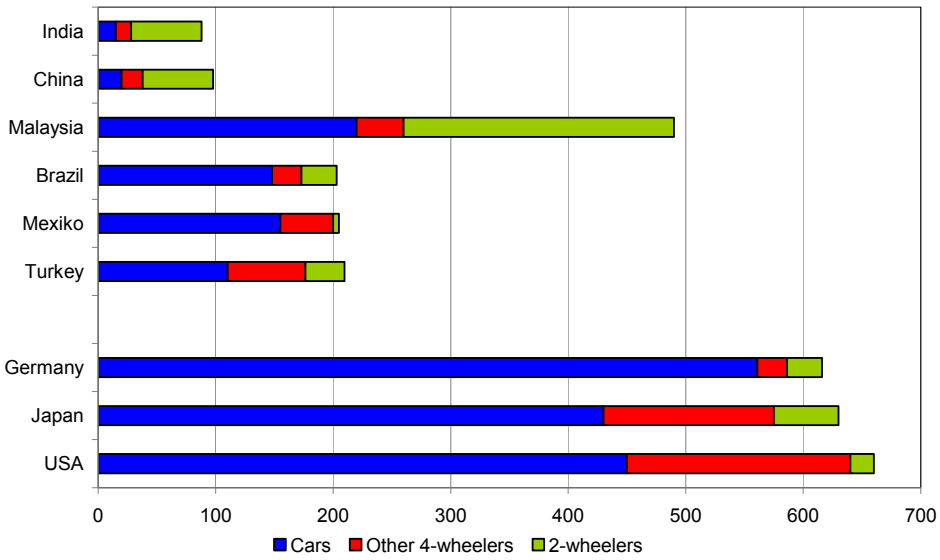

Fig. 1: Motorization in different OECD- and emerging countries (Road vehicles per capita) in 2007 (figures for India and Turkey estimated based on values from 2005) (Sources: [2-4])

To cope with the problems mentioned above in almost all of these countries policy measures are implemented or at least thought about. Yet, so far the most comprehensive portfolios of policies have been implemented in Western European countries and to some extent in the USA and Canada. The most widely known categories of policies are standards (like the CAFE standards in the USA), promotion of biofuels (as in the USA, Brazil and Europe) and electric and fuel cell vehicles (as currently discussed in the USA, Europe and many other countries), fuel taxes (which were implemented already in the 1970s in Western Europe and by mid of the 1980s in Canada) and registration taxes (mainly in Denmark).
The core objective of this paper is to derive lessons learned from different EU policies for road passenger transport which can also be implemented in emerging countries. Of high relevance in this context are especially the costs of measures to reduce GHG emissions from road passenger transport and how to derive a corresponding least-cost-portfolio of measures[2]. In this context it is also very important to consider the conceivable backlashes of policies e.g. the rebound-effect due to more efficient cars and resulting lower service prices.

[1] Two-wheelers have been discussed by Ajanovic/Dahl/Schipper [5], IEA [6] and Schipper et al. [7] and they are not focus of this paper. However, policies also have to take into account this aspect.
[2] This work is based on the outcomes of the EU-funded project ALTER-MOTIVE, see Ajanovic et al. [8], and www.alter-motive.org.

2 METHOD OF APPROACH TO REDUCE CO_2 EMISSIONS

To get a reliable appraisal of the effect of different policy measures on the CO_2 reduction it is very important to recognise what are the major factors that influence CO_2 emissions. Fig. 2 shows how CO_2 emissions in passenger car transport come about and how they can be reduced.

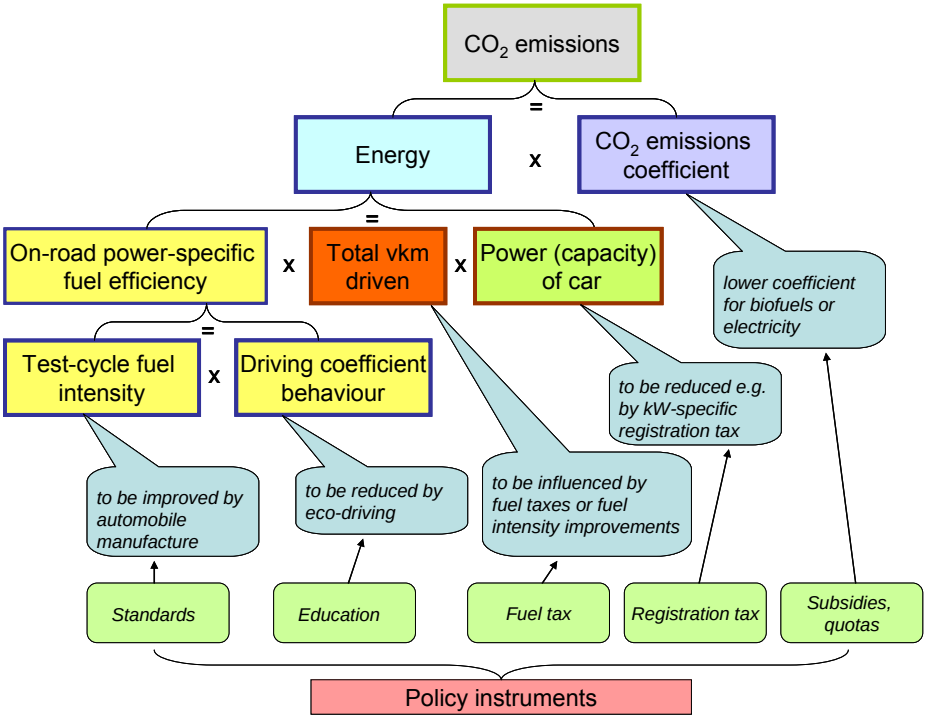

Figure 2. Impact factors on CO_2 emissions in the car passenger transport sector (Source: [8])

As discussed in Ajanovic et al. [8], CO_2 emissions from passenger car transport depend in principle on energy used for transport and the average specific CO_2 emissions coefficient of different fuels used. The coefficient f_{CO2} can be improved, e.g. better quality of fossil fuels, better ecological performance of biofuels, more electricity from renewable energy sources.

CO_2 emissions EM_{CO2} come about as follows:

$$EM_{CO_2} = vkm \cdot FI \cdot f_{CO_2} \tag{1}$$

With vkm is vehicle km driven, F is fuel intensity in litre per 100 km and f_{CO2} are specific CO_2 emissions per litre fuel.

$$vkm = f(P_S, Y) \tag{2}$$

With P_S is service price and Y is income.

$$P_S = P_F FI \tag{3}$$

With P_F is fuel price.

Total energy consumption can be reduced by increasing on-road fuel efficiency (lower energy consumption per km driven and per kW), lower travel activity (less vkm driven) and smaller cars (less kW).
On-road power specific fuel efficiency is influenced by (theoretical) test-cycle fuel efficiency and the individual driving behaviour.

Note that different policies can have multiple and even contradicting impacts. Total vkm driven can be reduced by fuel taxes or increased by fuel intensity improvements due to the rebound as shown in Chapter 5.

Finally, the method of approach is based on calculation of total costs for society and resulting CO_2 reductions:

- For taxes these costs are the welfare losses for society;
- For the technologies we consider the additional investment costs of the technology and the energy cost reduction respectively the increased producer surplus if the technology is produced in the region[3];
- For alternative fuels we have to consider the additional production costs minus the increased producer surplus if the technology is produced in the region.

For the last two categories it is also important to consider technological learning effects.

3 A SURVEY ON POLICY MEASURES

Policy measures implemented in transport sector could be put in three main categories:

- **Switch** from fossil fuels to alternative fuels, in the first line to biofuels;
- **Improve** efficiency of cars including switch to alternative and more efficient powertrains;
- **Reduce** energy consumption with taxes and standards.

Switch

Currently most important alternative fuels are 1st generation biodiesel (BD-1) and bioethanol (BE-1). Although low, share of biofuels in total transport fuels demand is increasing all over the world mostly due to biofuels targets and different government incentive programs. Reason for this policy is the fact that biofuels have potential to contribute to replacing fossil fuels and reduce CO_2 emissions in transport sector. However, over the past decade, biofuels have been more expensive than fossil fuels and reduction of CO_2 emissions was moderate. Since the preferred feedstocks for current biofuels are corn, wheat, sugarcane, rapeseed, soybean and sunflowers, the very important issue is relation between biofuels production and increasing food prices see also [9].

Improve

To reduce energy consumption and at the same time CO_2 emissions, it is important to improve efficiency of conventional diesel and gasoline vehicles as well as to increase the number of alternative and more efficient powertrain systems (such as battery electric vehicles (BEV) and fuel cell vehicles (FCV)) in the total vehicle stock.

Hybrid internal combustion engine vehicles are an alternative with slightly higher costs but clearly better environmental performances than conventional vehicles. BEV and FCV have much better CO_2 balances than conventional cars if electricity and hydrogen are produced from renewable energy sources. However, these technologies are very expensive and not competitive on the market.

Reduce

Fiscal policies currently applied for conventional vehicles need to be distinguished between one time measures such as vehicle purchase tax (also called registration tax) and annually

[3] It is assumed that 75% of the value chain of new technologies is produced within the EU countries and hence these additional costs are converted into producer surplus.

levied road taxes. Vehicle purchase taxes have proven to be influential on the magnitude of car sales and the consumer's choice for a certain model. Annual taxation schemes based on vehicle's CO_2 emissions (and the car footprint, not weight) are seen as a more direct way of influencing consumer decisions. In this case, the limit needs to be defined for maximum allowed emissions level together with penalties that are imposed if the limit is exceeded. Favourable company car depreciation schemes do currently weaken the impact of purchase taxation schemes, therefore more personalized schemes targeting the behaviour of the individual motorist (e.g. incentivising reduction of kilometres driven per car through fuel taxation) are seen as the next step.

4 EU POLICIES

In this chapter we give a short introduction why it is relevant to learn from EU-countries. In recent years in EU ambitious policies have been implemented in transport sector with the goal to move toward more sustainable transport system. Most important policies are:

- Taxes related to fuels and vehicles
- Standards
- Subsidies and other support policies for alternative fuels and alternative automotive technologies.

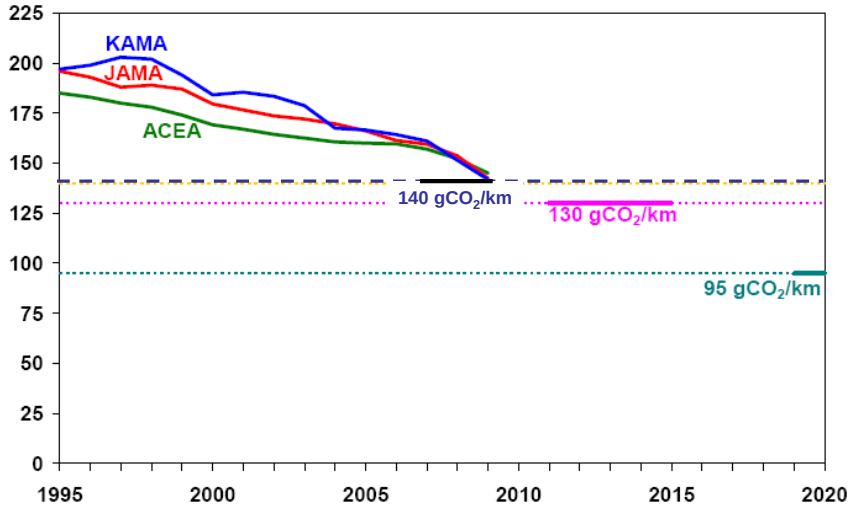

Figure 3. Evolution of CO_2 emissions from new passenger cars by association (adjusted for changes in the test cycle procedure) [11]

Tax

Fuel taxes in EU are the highest in the world. They are slightly different across EU countries. Tax on gasoline in EU countries is ranging from about 42% to 63% of the total gasoline price. The share of tax on diesel is ranging from 36% to 58% [10].

In most of EU countries a registration tax for vehicles is applied as well. This tax is paid once, by each vehicle owner, for each vehicle purchased and entered into service. The most of criterions for this tax are based on fuel consumption, on cylinder capacity, CO_2 emissions and price [10]. This tax is currently by far highest in Denmark.

Additionally there are also taxes on ownership. These taxes are paid annually, regardless of how often the vehicle is used. They are usually based on power (kW), cylinder capacity, CO_2 emissions, fuel consumption and weight.

Standards

The European Commission has designed a comprehensive strategy for reduction of average

CO_2 emissions from new cars. The reduction of CO_2 emissions from new passenger cars is based on the voluntary commitments with the European, Japanese and Korean car manufacturer associations. The target for average CO_2 emissions from new car is 130 gCO_2 per km in period 2012-2015. Target for 2020 is 95 gCO_2 per km, see Fig. 3. The reduction of average CO_2 emissions from new cars can be achieved by means of improvements in vehicle motor technology (e.g. air-conditioning systems, pressure monitoring systems, etc.) as well as with the increased use of biofuels or electric vehicles powered by renewables.

Support policies for alternative fuels

For the currently in Europe not competitive biofuels tax exemptions are implemented and there is a binding target for Member States to achieve a 10% share of renewable energy in the transport sector by 2020 [12].

5 THE PROBLEMS OF STANDARDS

In spite of different implemented measures for the reduction of energy consumption in passenger car transport, energy consumption has been increasing, especially between 1990 and 2000. Fig. 4 depicts the development of vehicle km driven (10^9 vkm), energy consumption (PJ) and the fuel intensity (litre/100 km)[4] of the stock of vehicles in EU-15 from 1990 to 2010. It can clearly be seen that fuel intensity has decreased continuously. However, this effect did not lead to significant energy conservation. Due to the fact that service demand, vkm, has increased almost continuously the over-all energy consumption just stagnated in last years.

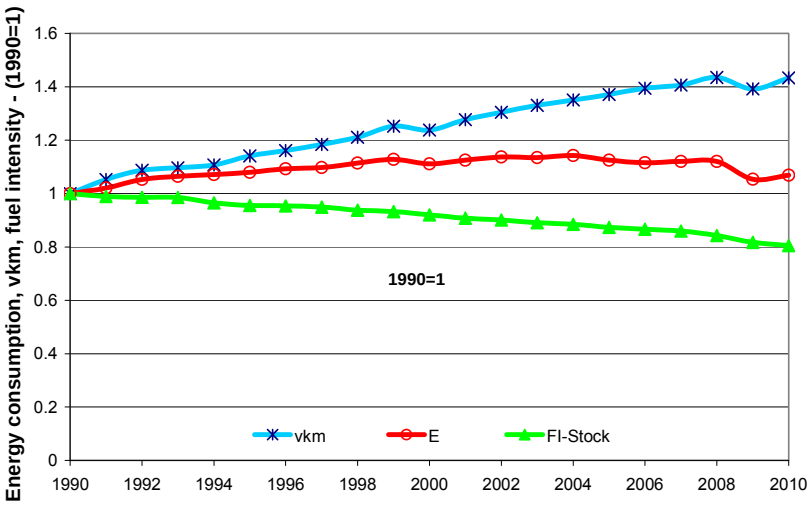

Figure 4. Normalised development (1990=1) of vehicle km driven (vkm), energy consumption (E) and fuel intensity (FI) of stock of vehicles in EU-15 from 1990 to 2010 [13]

However, in Fig. 4 fuel intensity (FI) does not reflect the real efficiency improvement because it is distorted by the switch to larger cars. To correct this we define a power-specific fuel intensity (FIP), see also [13-14]:

$$FIP = \frac{FI}{kW} \qquad \text{(l/(km kW))} \qquad (1)$$

kW….vehicle power.

[4] Note, that litre refers to litre gasoline equivalent throughout the reminder of the paper.

It can clearly be seen from Fig. 5 that the decrease in FIP from 1990 to 2010 was virtually twice as high as the decrease of FI.

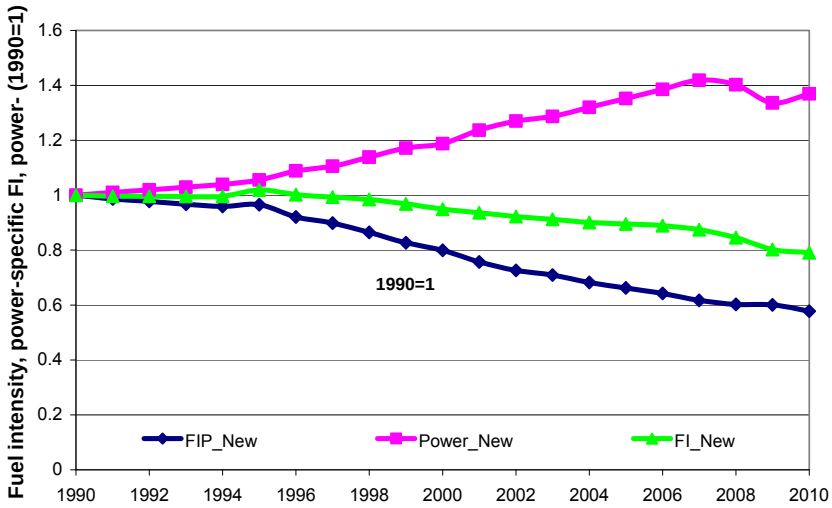

Figure 5. Normalised development (1990=1) of fuel intensity (FI), power-specific fuel intensity (FIP) and power of new vehicles in EU-15 from 1990 to 2010 [13]

A major problem recognised in EU countries is that despite better fuel efficiency energy consumption, as well as CO_2 emissions, are in the best case stabilised. The fact is that better energy efficiency leads to higher service demand (e.g. more vkm, larger vehicles) whereby achieved energy savings due to better fuel efficiency are lower than theoretically it can be expected.

6 THE EFFECTS OF TAXES

There is often the argument that car drivers are not sensitive to fuel prices and hence taxes do not have an impact on fuel consumption and do not lead to fuel savings. There are at least two arguments against this statement:

- Fuel demand in Europe is significantly lower than in the USA (where fuels are virtually not taxed);
- Analyses by several authors in the literature show that price elasticity is in a range of -0.3 to -0.6 leads to energy savings of 30% to 60% due to the introduction of a tax.

We think that these two arguments are sufficient to justify the introduction of a higher tax. Yet, to provide sound evidence for the impact of price, income and fuel intensities (as a proxy for efficiency) in Europe we conducted econometric time series analyses, see [15].
We extracted a long-term price elasticity of about -0.42 for the service vehicle km driven. This result has the following implications:
If we improve the fuel intensity e.g. due to technical standards, the result is that the service price for vkm driven decreases and driving gets cheaper. Straightforward the price elasticity of -0.42 implies a so-called rebound effect of 42%. That is to say, if efficiency is improved by 1% the number of km driven is enhanced by 0.42% and the remaining energy conservation effect is only 0.58% (see ΔE_η in Fig. 6)[5].

[5] Example: Assume FI of old car was 60 kWh/100 km. If it is improved by 10 % and we have initially 10000 km driven we calculate theoretical savings of 60/100 * 0.1 * 10000 = 600 kWh. Yet, due to the rebound – now we drive 420 km (=10000 * 0.42 * 0.1) more, this is 10420 km – we now save only 348 kWh (=58% of 600 kWh).

This effect can be compensated more or less, by the simultaneous introduction of a fuel tax, as shown in Fig. 6. In this case the additional tax – increasing the price P_{s1} to P_{s2} for the service km driven – would fully compensate the rebound and for the owner of a new car the service price would remain the same ($P_{s2} = P_{s0}$).

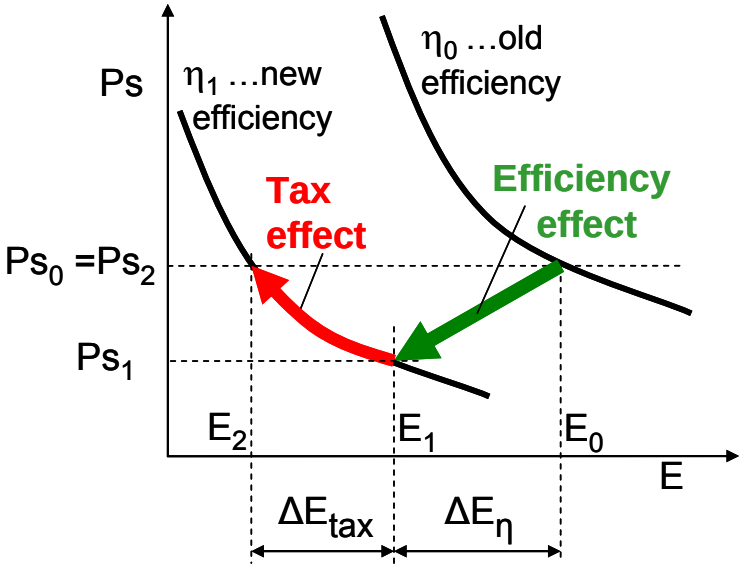

Figure 6. How taxes and standards interact and how they can be implemented in a combined optimal way for society

7 WHICH MEASURES CONTRIBUTES TO CO_2 REDUCTION AND TO WHICH COSTS?

The portfolio of policy measures which can be implemented to reduce CO_2 emissions is very wide. However, the cost of implemented measures could be very different. For all countries but especially for emerging countries, it is important to identify least-cost policies.

The most important policy measures for the reduction of CO_2 emissions in passenger road transport are fuel taxes, standards, biofuels, registration tax and E-mobility. For the example of EU-15 with an appropriate mix of these measures in an ambitious policy scenario we can reduce CO_2 emissions in 2020 by about 100 million tons CO_{2eq}/year comparing to business as usual scenario, see also [16].
However, the crucial question is which price citizens have to pay for achieving these goals. In the following we give a survey on the costs of various measures to head towards the least-cost approach. Fig. 7 shows the basic principle of the least-cost approach. The different measures are put in the least-cost order for achieving finally 100 million tons CO_2 reduction up to 2020 (about 20% compared to 2008).
The major result of this analysis is that the costs of taxes up to 36 million tons CO_2 reduction at a price of about 40 EUR/ton CO_2 are cheapest for society. Therefore reducing the vkm driven and valuing the corresponding welfare loss has the first priority. Next cheapest option is switch to biofuels first generation – biodiesel, bioethanol and biogas (BM). This implies that by 2020 biofuels save at least 70% CO_2 compared to fossil fuels. Based on this pre-condition the biofuels in our scenario save 28 million tons CO_2 at costs between 180 and 350 EUR/ton CO_2. Measures of technical efficiency improvements – starting with start/stop automatics, over electric power assistants (mild hybrids) to power splits (full hybrids) and efficiency improvements of the classical gasoline and diesel engine – are ranging from about

1000 to 1500 EUR/ton CO_2. The most expensive measures are to promote fuel cell cars and battery electric vehicles with saving costs above 2000 EUR/ton CO_2. This is the reason why neither BEV nor FCV show up in this figure for least-cost reduction of 100 million tons CO_2. Also BF 2nd generation are not among the least-cost solutions up to 2020 and do, hence, not show up in Fig. 7[6].

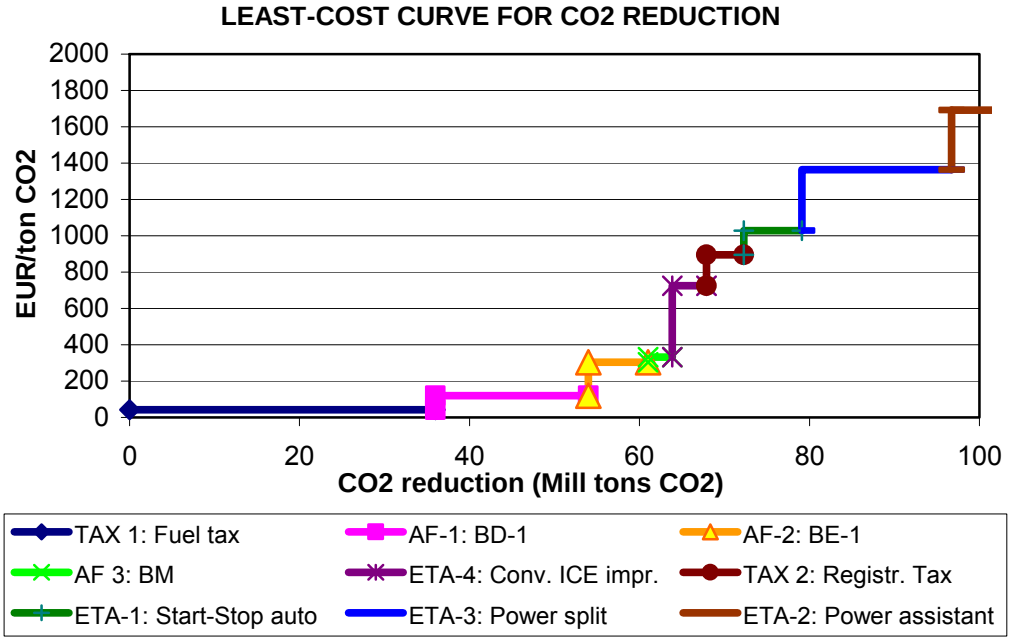

Figure 7. Least-cost curve for CO_2 reduction in passenger car transport in the EU-15 in 2010

8 CONCLUSIONS

The major conclusions from this analysis and the major recommendations for emerging countries regarding passenger car transport policies are:

- Regarding electric vehicles and fuel cell cars in the next decade no CO_2 savings at reasonable costs for society will be achieved. If these vehicles might reach in a very optimistic scenario 1% market share by 2020 they will straightforward only contribute at the maximum in the same range to CO_2 reduction. This aspect applies in principle to all countries world-wide. Some reasonable niches where these new technologies can be applied are e.g. taxis in large cities;
- The use of biofuels is strongly depending on the country-specific circumstances and potentials and no general conclusions can be drawn. However, it is very important that biofuels production process is very effective and sustainable as well as that competition with food production is avoided;
- Improving energy efficiency is a very important measure but implemented alone does not necessarily lead to an equivalent energy and CO_2 saving effect. We have seen this problem in recent years in passenger car transport from two major features: (i) Europeans purchased larger cars which reduced savings that were expected due to efficiency improvements by about half; (ii) Car owners increased vehicle km driven – to some extent due to lower service prices due to lower fuel intensity (as well as increase in income);

[6] For a more detailed description of our calculations see [16]

- Therefore it is very important that standards are accompanied by taxes. It should be an additional focus on energy conservation by introducing fuel taxes to reduce km driven and by introducing size-dependent registration taxes to limit the size of cars;
- There are also other important measures which were not part of this investigation such as changes in the modal split, switch to public and non-motorized transport and implement proper measures of spatial and urban planning.

Currently, standards and taxes are relatively cheap and in short-term effective measures for the reduction of CO_2 emissions. A simple but very important message is that if targets are set they have to be pursued very strictly and that continuous pressure is put on the involved stakeholders: international and national policy makers, car manufacturers and also the citizens regarding their driving and car purchase behaviour.

Of course, in the long-term in every country only a very broad portfolio of policy instruments (taxes, standards, quotas, emissions free-zones…), new technologies (electric and fuel cell vehicles…) and alternative fuels (biofuels, hydrogen…) can reduce energy consumption and straightforward specific CO_2 emissions per km driven significantly.

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