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JOINT TRANSPORT RESEARCH CENTRE

Discussion Paper No. 2008-13
May 2008

Transport Outlook 2008

Focusing on CO_2 Emissions from Road Vehicles

ORGANISATION
FOR ECONOMIC
CO-OPERATION AND
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International
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Forum

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FOCUSSING ON CO_2 EMISSIONS FROM ROAD VEHICLES

Joint Transport Research Centre
of the OECD and the International Transport Forum

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Transport Outlook

Transport Outlook 2008 - Focussing on CO_2 Emissions from Road Vehicles

1. INTRODUCTION

Modeling the developments of transport activity and potential trends in CO_2 emissions provides invaluable information for policy making. It can provide a quantitive illustration of the way alternative policy measures influence emissions over time and indicate the maximum limits to the mitigation potential of particular interventions. Just as importantly it can illustrate the degree to which uncertainties in key assumptions on the economic behaviour of the sector affect emissions trends and the effectiveness of interventions. This is critical if policies are to be designed to address the risks of over- and underestimating their effectiveness in mitigating emissions.

This short outlook is designed to test the potential for key policy instruments for mitigating emissions from road transport, and particularly from light duty vehicles, the largest source of CO_2 emissions from transport (see Figure 1 and Table 1). It also examines uncertainties in the baseline scenario for the development of CO_2 emissions from the sector. In contrast to the OECD's Economic Outlook and the IEA's World Energy Outlook, the Transport Outlook is produced making use of external modeling tools. The work uses the most transparent and robust model developed to date for the sector, the MoMo model[i] constructed and maintained by the International Energy Agency and initially developed for the World Business Council for Sustainable Development. We are grateful to the MoMo-team for their willingness to share this product.

The present document is only a first step towards the development of a full-fledged Transport Outlook. It is limited in scope, with its focus on road transport and on emissions of CO_2. Despite the limitations, this mini-Outlook provides elements of a useful framework for discussions on the policy challenges presented by the risk of costly consequences from anthropogenic emissions of greenhouse gases. As will become clear, permanent reductions of CO_2-emissions from transport are difficult to achieve because of strong underlying global growth in transport demand. At the same time, our scenarios suggest that emissions could be stabilized even with strong growth of demand, given *immediate and continued* efforts to reduce the sector's carbon intensity. If stabilization is the goal, then finding cost-effective ways of achieving it becomes the critical issue.

Section 2 discusses the Business as Usual (BAU) scenario. The BAU is the 2008 reference scenario as constructed by the IEA team that developed the MoMo model. Adopting this scenario facilitates comparison of our scenarios to those developed at the IEA and used widely (e.g. by the IPCC and the WBCSD), and this generates a useful complementarity between IEA and ITF scenarios. We discuss the main features of the BAU in Section 2.1. The BAU projects trends through 2050. It is self-evident that such an exercise is fraught with uncertainty and error. This is not a problem in itself, as the BAU provides a reasonable benchmark for learning about alternative scenarios, not an attempt to provide the best possible prediction. It is however important to understand the "stance" of the BAU, and this is examined by using alternative sources of data or alternative methods to project transport demand. For this, the ITF has developed alternative baseline scenarios for light-duty vehicles. As can be seen from Section 2.2, these alternative baselines result in stronger growth in CO_2-emissions.

Section 3 discusses scenarios that deviate from the BAU and alternative baseline benchmarks. The focus is on the effects of improving fuel economy for road transport. We evaluate the impacts of fast implementation of improvements that are considered cost-effective by some over the short term, and we ask which improvements are necessary to stabilize emissions from light-duty vehicles around present levels in the longer run. The bottom line from these exercises is that the challenge is huge, but that stabilization is not an impossibility.

Section 4 summarizes and concludes.

2. BUSINESS AS USUAL

Section 2.1 lays out the main features of the BAU. Section 2.2 shows how the BAU changes under alternative assumptions on the evolution of the stock of light-duty vehicles and on how much these vehicles are driven.

2.1 The ITF BAU – the ETP 2008 Reference Scenario

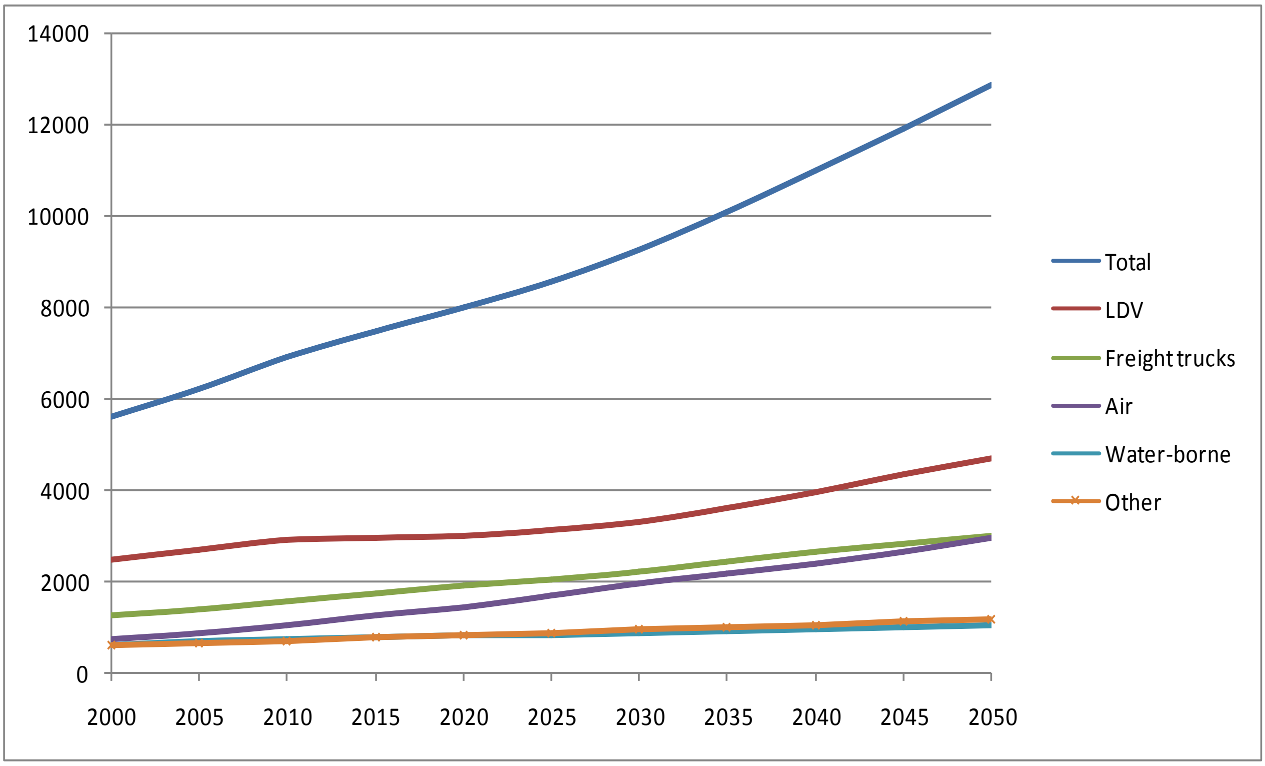
The BAU scenario used here is the same as the IEA Energy Technology Policy Division's 2008 Reference Scenario. Figure 1 displays the model output of key interest: tank-to-wheel CO_2-emissions from vehicles, in Million tons of CO_2-equivalent, from 2000 through 2050. The emission paths for the transport modes contained in the MoMo-model are shown. Our analysis emphasizes emissions from light-duty vehicle (LDV) emissions. This is justified given the large share of these emission in the total, but it is clear that emissions from air transport are expected to grow more rapidly than those from light-duty vehicles, and that emissions from other modes are expected to grow as well. Table 1 provides detail on the model composition of global vehicle emissions.

Emissions from light-duty vehicles grow strongly over the model horizon: emissions in 2050 are nearly 91% higher than in 2000. Growth is moderate between 2010 and 2030 but accelerates after 2030. The drivers of light-duty vehicle emissions are the following: the size of the car stock, the intensity with which vehicles are used, and the carbon-intensity of the energy sources used. The growth of the total stock is the key driver of increased emission levels, with global ownership levels rising threefold from 669.3 million vehicles in 2000 to 2029.9 million vehicles in 2050. This expansion in turn is the consequence of increased ownership rates that occur mainly in emerging economies. The technological composition of the stock changes, as the share of conventional gasoline vehicles declines from 87% to 68% while that of diesel vehicles increases from 12% to 26% and that of hybrid gasoline vehicles rises from 0.1% to 4%.

Hence, there is a shift to less carbon-intensive technologies, but not a major switch to true low carbon technologies.

With respect to the intensity of vehicle use, the BAU assumes a decline in developed economies. The average light-duty vehicle is driven about 18,000 km per year in OECD North America in 2000, declining to about 16,000 km per year in 2050. In OECD Europe, average use declines from 13,000 km to 11,000 km per year over the same period. The underlying assumption is that an expansion of the stock in these economies reduces usage of each individual vehicle. In non-OECD economies, the average distance driven remains more or less constant throughout the period.

Figure 1. World Tank to Wheel CO_2 Emissions, BAU, 2000 – 2050, Mt of CO_2-equivalent



Source: ITF calculations using the IEA MoMo Model Version 2008

1. The emission profile in Figure 1 directly depends on assumptions concerning the size of the vehicle stock, vehicle use, and vehicle technology. In order to evaluate this dependence, the next section shows alternative profiles for light-duty vehicle emissions, resulting from alternative assumptions on the evolution of the stock and on vehicle use. Before doing so, it is useful to note that the baseline scenarios presented in Section 1 are an outline of "where demand would like to go". By this we mean that the supply of energy is assumed to be fairly elastic, so that strong growth in demand does not lead to strong increases in the price of transport energy. This is not a straightforward assumption, given for example the growing concern about supply side constraints and consequent high prices in current oil markets, which are beginning to affect demand[ii].

Table 1. Modal shares in World Vehicle CO_2-emission, BAU, 2000 – 2050, %

BAU	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Freight + Passenger rai	2.1	2.2	2.3	2.5	2.7	2.8	2.9	2.9	2.9	2.9	3.0
Buses	6.8	6.3	5.7	5.4	5.2	4.9	4.6	4.3	4.1	3.8	3.6
Air	12.9	13.5	14.8	16.8	18.1	19.5	21.1	21.5	21.8	22.3	23.0
Freight trucks	22.4	22.2	22.8	23.4	23.9	24.0	23.7	24.1	24.1	23.8	23.4
LDVs	43.8	43.3	41.9	39.5	37.6	36.4	35.6	35.6	35.9	36.4	36.5
2-3 wheelers	1.6	1.8	2.0	2.2	2.5	2.6	2.6	2.6	2.6	2.5	2.4
Water-borne	10.4	10.8	10.3	10.2	10.0	9.8	9.5	9.0	8.6	8.3	8.0
Total	100	100	100	100	100	100	100	100	100	100	100

Source: ITF calculations using the IEA MoMo Model Version 2008

2.2 The Reference Scenario under alternative assumptions on the evolution of demand

The standard BAU assumptions on the evolution of the vehicle stock are closely in line with those underlying the IEA's World Energy Model. But future levels of ownership and use are highly uncertain, in particular in regions where large changes compared to current levels are expected. This section presents a scenario that modifies Momo's benchmark for ownership levels in Brasil, Russia, India, and China, by choosing new vehicle sales so that ownership rates close to Goldman Sachs's projections are obtained.[iii] The scenario is labeled BAU – alternative 1. The Goldman Sachs projections find higher ownership rates for India, Russia, and Brazil, and lower rates for China. The methodology underlying the ownership projections for both scenarios is similar, but we have no particular information that indicates whether one scenario is more likely than another. Hence, to the extent this exercise is seen as a quantification of uncertainty, it reflects a premise that both scenarios are equally probable.

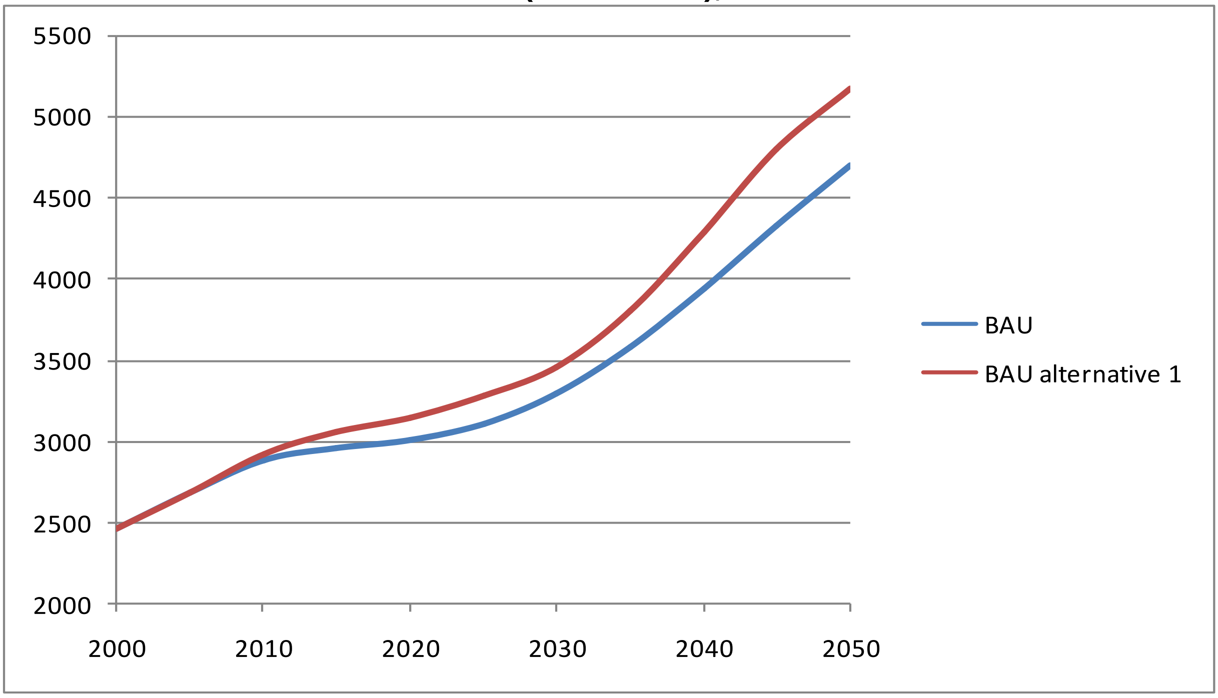
As can be seen from Figure 2, projected CO_2-emissions in BAU – alternative 1 are substantially higher than in BAU, underlining the importance of vehicle ownership rates in emerging economies in determining the level of transport sector CO_2-emissions world-wide. More specifically, in 2050 CO_2-emissions are some 10% higher under BAU – alternative 1. This difference has no strong impact on the evaluation of the performance of better fuel economy, as presented in Section 3. But the scenario does illustrate that the future level of transport sector emissions and its share in total emissions is subject to considerable uncertainty. The next scenario makes this point even more strongly.

The standard BAU assumptions on vehicle use are that use per vehicle in highly developed economies will decline as the stock expands further, and that use in emerging economies will remain more or less constant. These assumptions are reasonable but their impact is worth considering. While aggregate statistics suggest that average vehicle use does not change too much over time in developed economies[iv], econometric analysis shows that when other factors (such as urbanisation, prices, etc.) are controlled for, vehicle use does increase with income given the level of the vehicle stock. The impact of allowing for such a positive response to income growth was assessed as follows:

- In the standard version of the MoMo model, scenarios for vehicle ownership and vehicle use are externally defined. The model was extended to allow specifying elastic responses of vehicle use to the fuel cost of driving and to income. The elasticities are allowed to vary with income and with the fuel cost of driving. The first step was to reproduce the BAU scenario with this extended version of the model. Figure 3 compares CO_2-emissions from BAU and the present scenario, showing that results are strongly similar. In 2000, the elasticity of demand with respect to the fuel cost of driving is around -0.24 in economies with higher GDPs and around -0.30 at lower GDPs. In 2050, they decline to around -0.22 and -0.28. Overall, this reflects a limited decline of (absolute values of) elasticities as incomes rise. Similar orders of magnitude and similar patterns have been observed in the literature (e.g. Small and Van Dender, 2007[v]), and stand to reason in the sense that demand becomes less responsive to price as consumers become richer. While the pattern is reasonable, there is hardly any empirical basis for judging its size. The income elasticties that reproduce the BAU are essentially zero.

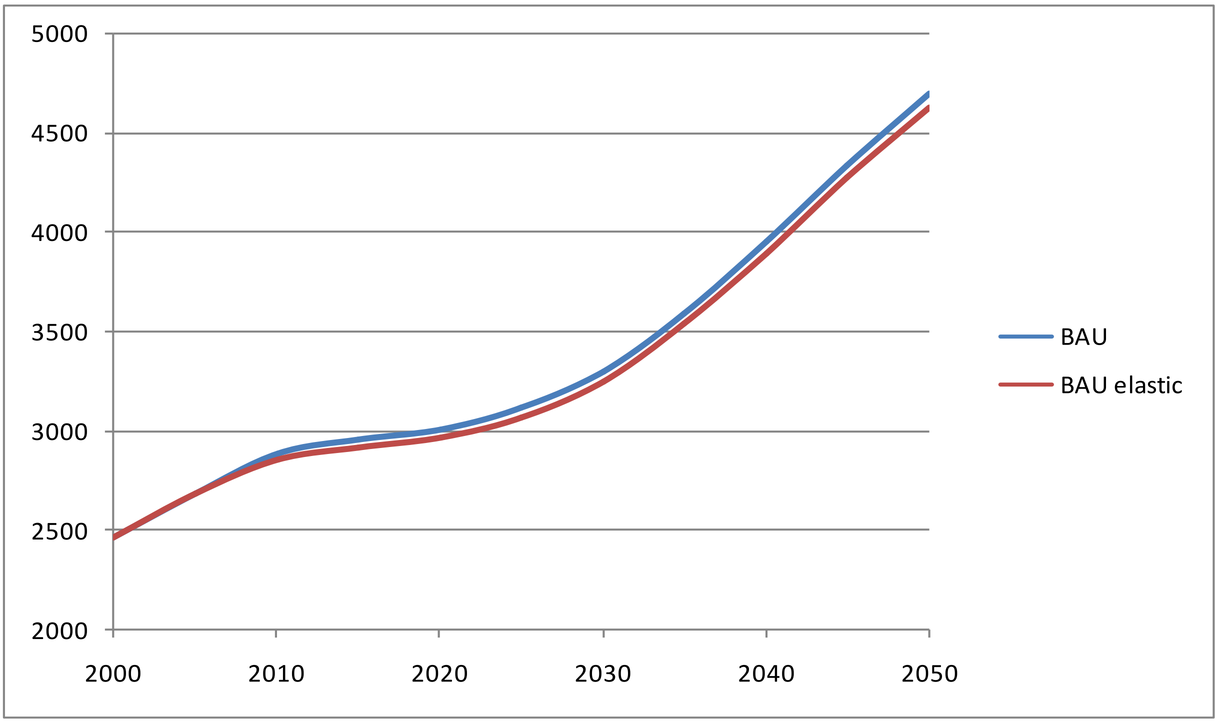
- While a small or zero response of the demand for driving with respect to income may be reasonable for high income economies, it is a much more tenuous assumption for developing economies. Making demand more responsive to income will generate faster growth of demand and of emissions, as is illustrated in Figure 4. The emissions under "BAU – alternative 2" are 45% higher in 2050 compared to the standard BAU. To generate this emission path, income elasticities in non-OECD countries have been increased to values found in econometric work for the USA, by Small and Van Dender, 2007. These authors find a short run elasticity of 0.1 and long run elasticity of 0.5 for the US from 1966 through 2004. It is not entirely obvious how this translates into a 5 year elasticity, but 0.35 is a reasonable guess. With these elasticities, the emission path clearly is much higher. Note that income elasticities inside the OECD are still zero, just as in the standard BAU.
- Since there is little empirical information for projecting elasticities, in particular outside the OECD, this exercise should be seen as illustrations of uncertainty. In addition, the exercise contains no feedback mechanism from faster growth of demand to energy prices. It is likely that accelerated increase of demand pushes prices up, but probably not by enough to "check" growth. It hence seems reasonable to conclude that the BAU with zero income elasticities seems to be a lower bound of a reasonable interval.

Figure 2. World LDV Tank-to-wheel CO_2 Emissions (Mt of CO_2 equivalent): BAU, Alternative ownership assumptions for Brazil, Russia, India, and China (alternative 1), 2000 - 2050



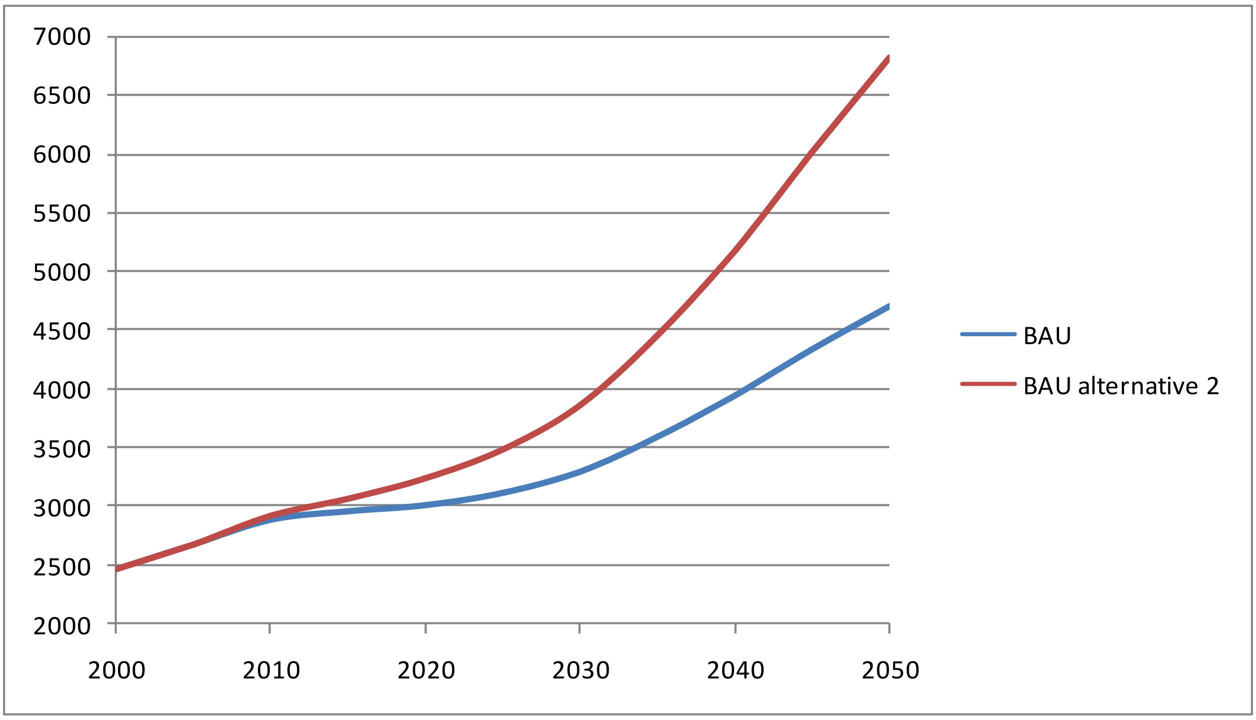
Source: ITF calculations using the IEA MoMo Model Version 2008

Figure 3. World LDV Tank-to-wheel CO_2 Emissions (Mt of CO_2 equivalent): BAU, and BAU replicated with elastic demand version of the model, 2000-2050



Source: ITF calculations using the IEA MoMo Model Version 2008

Figure 4. World LDV Tank-to-wheel CO_2 Emissions (Mt of CO_2 equivalent): BAU, and positive income elasticity of demand for driving in non-OECD (alternative 2), 2000 - 2050



Source: ITF calculations using the IEA MoMo Model Version 2008

We conclude from these exercises with alternative assumptions on the development of the vehicle stock and on the intensity of vehicle use, that the standard BAU implies a view of relatively modest development of demand, in the sense that alternative assumptions imply stronger growth of demand and of emissions. However, we have not assessed the potential impact of growing demand on energy prices.

3. THE EFFECT ON CO_2 EMISSIONS OF IMPROVING FUEL ECONOMY

3.1 Fast improvement of the efficiency of conventional technology

Some experts argue that considerable improvements of the fuel economy of conventional powertrains are possible and even cost-effective, citing "barriers to implementation" such as information problems, consumer myopia, sunk costs, and regulatory uncertainty as reasons for lack of take-up (e.g. the King Review, 2007; JTRC, 2008[vi]). For example, Part I of the King Review[vii] states that the take-up of such "near to market" technologies can improve fuel economy of new cars by about 30% in the UK within a decade. Further improvements, up to

50% by 2050, are feasible but require through technological improvements that include battery and hybrid elements. For the USA, Cheah et al. (2007)[viii] find similar orders of magnitude for improved fuel economy (keeping vehicle quality constant).

The goal of the two scenarios presented in this section is to Illustrate how rapid realization of improvements of around 30% in the near future reduces emissions compared to the business as usual scenario. The idea is to capture an order of magnitude of the potential of more efficient conventional technology, not a precise investigation of how this improvement is attained. We also illustrate the difference between take-up in the OECD (the King review is primarily concerned with the UK, but loosely argues similar improvements are feasible in "the developed world"; Cheah et al. support this view for the USA) and global take-up. As before, the BAU scenario is the ETP 2008 Reference Scenario. Compared to the BAU, the alternatives mainly differ by the speed at which improvements in fuel economy are realized, not so much by the fuel economy level for new cars attained in 2050.

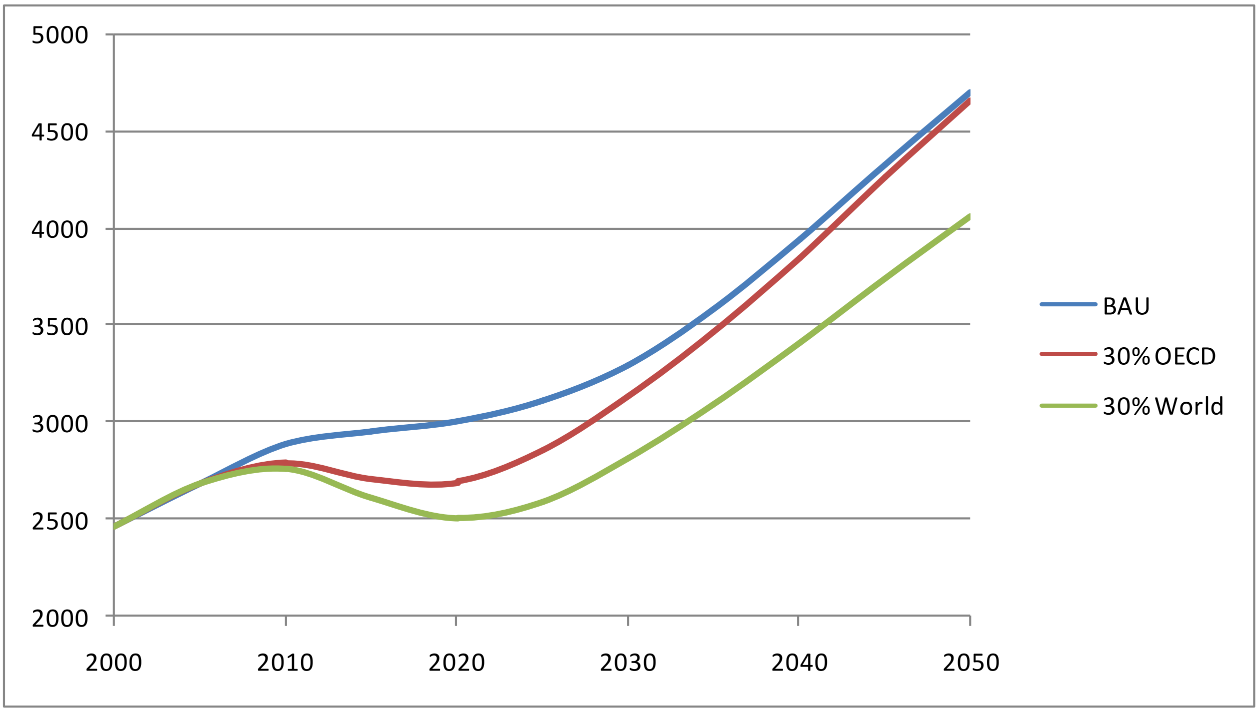
The scenarios are labeled "30% OECD" and "30% World". Compared to BAU, the scenarios involve changing (1) the potential for fuel economy improvement by 2050 (increased to 30% for all fuel types, whereas BAU levels range from 40-50%), (2) drastically changing the share of the potential actually used for fuel economy improvements (increased to 100% as of 2015), (3) drastically increasing the rapidity of the exploitation of the potential (starts at 0.1 in BAU and ends at 0.9, while it equals 1.0 all along in the alternative scenarios), (4) changing regional differences in intensity (BAU and "30% World" are similar, with just slightly higher factors in the latter; for OECD, BAU and "30% OECD" are similar, but the factors are lower in "30% OECD" for non-OECD countries, only converging to higher levels from 2035 onwards). The effect of changing these four parameters is that new car and ultimately fleet fuel economy paths are modified. The resulting fuel economy levels are summarized in Table 2. Note that the fuel economy improvements don't affect the demand for driving (no rebound effect). Including the rebound effect would reduce the CO_2-mitigation potential of the fuel-economy improvements, unless these improvements there are compensating increases in the financial cost of driving.

Tables 2 through 4 show fuel economy for light duty vehicles under BAU, "30% OECD" and "30% World". Changes occur as of 2015. In , "30% OECD", fuel economy for the OECD improves by about 30% in 2015 compared to 2000; outside of the OECD, fuel economies are similar to BAU (but not identical). In "30% World", OECD fuel economies are the same as in "30% OECD", but non-OECD fuel economies improve in 2010 by about the same factor. Note that fuel economies in the three scenarios are similar as of 2045. Note also that the changes in 2015 are drastic: all potential is used as quickly as possible to improve fuel economy – in this sense the scenarios sketch the upper bound of the potential of this approach.

Figure 5 shows time paths for CO_2-emissions under BAU, "30% OECD" and "30% World". Both alternative scenarios reduce emissions compared to BAU. However, In 2050 emissions in "30% OECD" are practically the same as in BAU, whereas in "30% World" they are around 13% lower than in BAU. This difference illustrates the importance of acting in non-OECD economies as well as in the OECD. Neither alternative scenario reverses the long run upward trend of CO_2-emissions. This simply says that fuel economy improvements of the magnitude and duration presented here are insufficient to curb emissions.

It is noteworthy that in "30% OECD", emissions are roughly constant between 2010 and 2025. In "30% World", emissions are below 2010 levels until 2030, while after 2030 emission paths converge to growth rates similar to those of BAU. In sum, the results suggest that immediate and strong fuel economy improvements for conventional technology have a noticeable effect on emissions in the next two decades. But after that, the growth in demand outstrips the effect of better fuel economy, and the growth rate of emissions returns to BAU levels. More fuel-efficient conventional technology hence contributes to lower emissions over the next two decades, but in the longer run alternative solutions are required. Unless one believes growth of demand can strongly be changed, such solutions likely are in the realm of alternative technologies, such as all-electric vehicles.

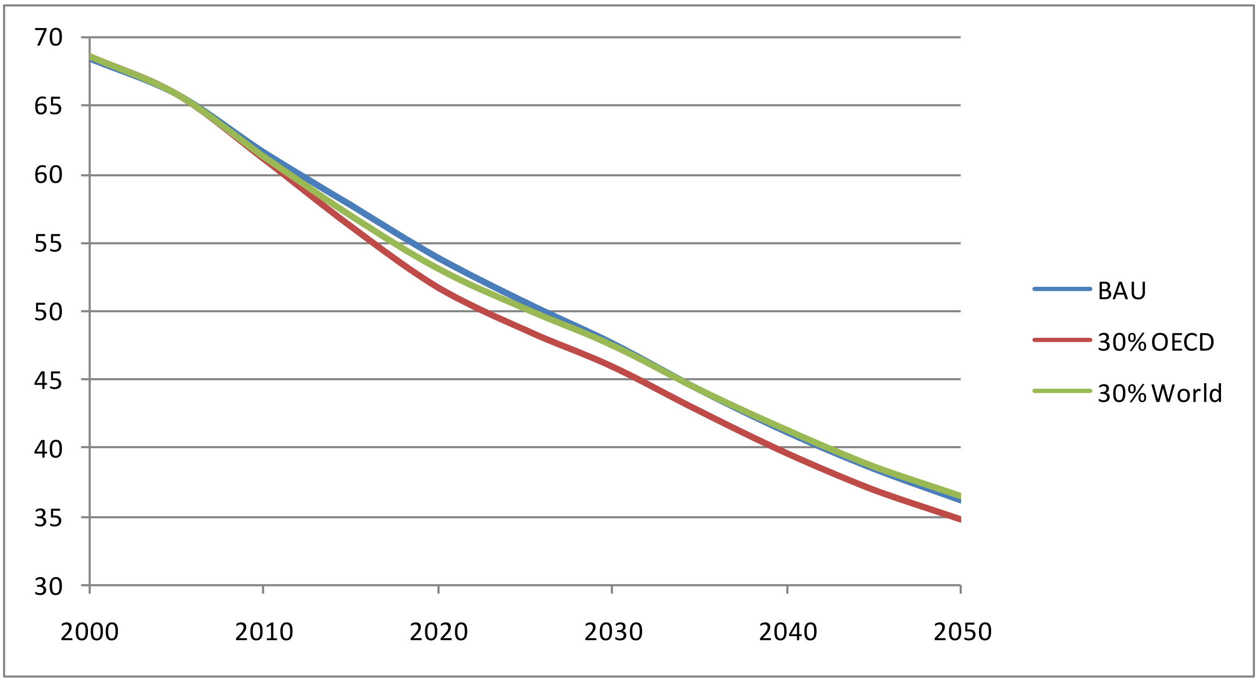
Figure 5. World LDV Tank-to-wheel CO_2 Emissions (Mt of CO_2 equivalent): BAU, and "30% OECD" and "30% World", 2000 - 2050



Source: ITF calculations using the IEA MoMo Model Version 2008

Figure 6 shows the share of CO_2-emissions by LDV generated in OECD countries. The key insight is that it declines rapidly, pretty much irrespective of the particular fuel economy scenario. This decline of course is driven by quick growth of demand outside the OECD, which is also the reason why the fuel economy scenarios don't manage to reduce CO_2 emissions from LDVs in the long run.

Figure 6. OECD percentage share in World Transport Sector CO_2 Emissions: BAU, 30% OECD, 30% World, 2000 - 2050



Source: ITF calculations using the IEA MoMo Model Version 2008

Table 2. Fleet average fuel economy under BAU and alternative scenarios, litre/100km, 2000 - 2050

BAU

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
OECD North America	9.2	9.1	8.9	8.0	7.5	7.3	7.3	7.4	7.4	7.4	7.4
OECD Europe	7.0	6.5	6.2	6.0	5.9	5.9	6.0	5.9	5.9	5.9	5.9
OECD Pacific	7.8	7.1	7.0	6.4	6.1	6.1	6.1	6.1	6.2	6.2	6.3
FSU	7.9	7.6	7.7	7.3	7.2	7.2	7.3	7.3	7.3	7.2	7.2
Eastern Europe	7.8	7.6	7.4	7.0	6.9	6.9	7.0	7.0	7.1	7.1	7.1
China	8.7	7.7	7.4	6.8	6.6	6.5	6.5	6.5	6.4	6.4	6.4
Other Asia	8.8	8.5	8.3	7.9	7.6	7.6	7.6	7.5	7.5	7.5	7.5
India	6.7	6.2	6.1	5.8	5.6	5.6	5.5	5.5	5.5	5.5	5.4
Middle East	9.3	9.1	8.9	8.5	8.4	8.3	8.3	8.3	8.3	8.3	8.3
Latin America	7.4	7.2	7.0	6.6	6.5	6.4	6.5	6.5	6.5	6.5	6.5
Africa	8.9	8.6	8.6	8.1	7.8	7.7	7.6	7.6	7.6	7.5	7.5

30% OECD

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
OECD North America	9.2	9.1	6.5	6.4	6.4	6.4	6.4	6.5	6.5	6.5	6.5
OECD Europe	7.0	6.5	5.1	5.2	5.3	5.3	5.3	5.3	5.3	5.3	5.3
OECD Pacific	7.8	7.1	5.3	5.3	5.4	5.4	5.4	5.4	5.5	5.5	5.5
FSU	7.9	7.6	7.6	7.5	7.3	7.5	7.4	7.4	7.4	7.4	7.4
Eastern Europe	7.8	7.6	7.5	7.2	7.0	7.2	7.2	7.3	7.5	7.5	7.5
China	8.7	7.7	7.3	7.1	6.9	6.8	6.8	6.8	6.8	6.8	6.8
Other Asia	8.8	8.5	8.4	8.1	7.9	7.8	7.9	7.8	7.8	7.8	7.8
India	6.7	6.2	6.1	5.9	5.8	5.8	5.7	5.7	5.7	5.7	5.7
Middle East	9.3	9.1	8.9	8.7	8.5	8.7	8.5	8.5	8.5	8.5	8.5
Latin America	7.4	7.2	7.0	6.8	6.7	6.7	6.7	6.7	6.8	6.8	6.8
Africa	8.9	8.6	8.6	8.2	8.1	8.0	7.8	7.8	7.8	7.8	7.8

30% World

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
OECD North America	9.2	9.1	6.5	6.4	6.4	6.4	6.4	6.5	6.5	6.5	6.5
OECD Europe	7.0	6.5	5.1	5.2	5.3	5.3	5.3	5.3	5.3	5.3	5.3
OECD Pacific	7.8	7.1	5.3	5.3	5.4	5.4	5.4	5.4	5.5	5.5	5.5
FSU	7.9	7.6	5.5	5.6	5.6	5.7	5.7	5.7	5.7	5.7	5.7
Eastern Europe	7.8	7.6	5.7	5.7	5.8	5.9	6.0	6.1	6.3	6.3	6.3
China	8.7	7.7	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Other Asia	8.8	8.5	6.2	6.2	6.2	6.1	6.1	6.1	6.1	6.1	6.1
India	6.7	6.2	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Middle East	9.3	9.1	6.4	6.4	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Latin America	7.4	7.2	5.1	5.1	5.1	5.2	5.2	5.3	5.3	5.3	5.3
Africa	8.9	8.6	6.2	6.2	6.2	6.1	6.2	6.2	6.1	6.1	6.1

30% World and continued

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
OECD North America	9.2	9.1	6.5	6.4	5.9	5.9	5.5	5.6	5.6	5.6	5.6
OECD Europe	7.0	6.5	5.1	5.2	5.3	5.3	5.3	5.3	5.3	5.1	5.1
OECD Pacific	7.8	7.1	5.3	5.3	5.4	5.4	5.4	5.4	5.5	5.3	5.3
FSU	7.9	7.6	5.5	5.6	5.6	5.7	5.7	5.7	5.7	5.5	5.5
Eastern Europe	7.8	7.6	5.7	5.7	5.8	5.9	6.0	6.1	6.3	6.0	6.0
China	8.7	7.7	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.2	5.2
Other Asia	8.8	8.5	6.2	6.2	6.2	6.1	6.1	6.1	6.1	5.9	5.9
India	6.7	6.2	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.6	4.6
Middle East	9.3	9.1	6.4	6.4	6.5	6.5	6.5	6.5	6.5	6.2	6.2
Latin America	7.4	7.2	5.1	5.1	5.1	5.2	5.2	5.3	5.3	5.1	5.1
Africa	8.9	8.6	6.2	6.2	6.2	6.1	6.2	6.2	6.1	5.9	5.8

Stabilising emissions

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
OECD North America	9.2	9.1	8.1	8.0	7.3	6.6	4.1	4.4	4.3	3.4	2.9
OECD Europe	7.0	6.5	5.8	5.9	5.7	5.5	4.9	5.0	4.9	4.2	4.0
OECD Pacific	7.8	7.1	6.4	6.5	6.2	5.8	4.7	4.8	4.8	4.0	3.8
FSU	7.9	7.6	6.9	6.9	6.6	6.2	4.8	4.9	4.8	3.9	3.5
Eastern Europe	7.8	7.6	6.8	6.7	6.5	6.2	5.5	5.7	5.9	5.1	4.8
China	8.7	7.7	6.7	6.7	6.3	5.9	4.7	4.8	4.7	3.8	3.5
Other Asia	8.8	8.5	7.6	7.6	7.2	6.6	5.3	5.4	5.3	4.3	4.0
India	6.7	6.2	5.6	5.6	5.4	5.1	4.3	4.4	4.3	3.6	3.4
Middle East	9.3	9.1	8.0	8.0	7.6	7.1	5.5	5.6	5.5	4.4	4.0
Latin America	7.4	7.2	6.3	6.3	6.0	5.6	4.4	4.6	4.5	3.6	3.3
Africa	8.9	8.6	7.7	7.7	7.3	6.7	5.2	5.3	5.2	4.2	3.8

Source: ITF calculations using the IEA MoMo Model Version 2008

3.2. Fast and continued improvement of the efficiency of conventional technology

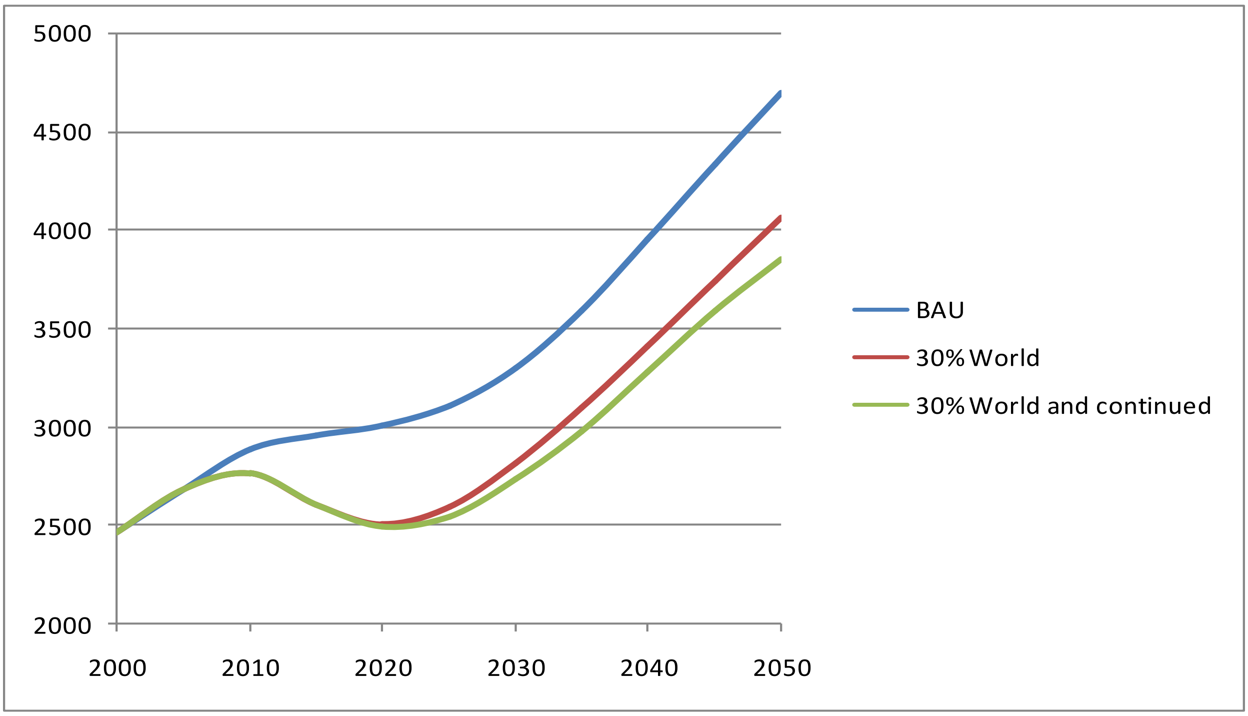
The scenarios of section 3.1 show the effects of immediate improvements in fuel economy, combined with roughly stable levels as of 2030. The present scenario shows the impact of fast improvement combined with continued improvement in the longer run. The further improvements are particularly strong in OECD North America, where they actually are stronger in the near future compared to the previous scenarios, more in line with Cheah et al.'s "factor of two". The results are best compared to that of the "30% World" scenario.

Whereas some would argue that the previous scenarios are "no regret" in the sense of being cost effective, the current scenario likely entails economic costs. In addition, the assumed levels of improvement likely involve use of innovative technology, not just marginal improvements of conventional technology (unless substantial downsizing is assumed).

Table 2 shows the fuel economy levels assumed for this scenario. Fuel economy converges to about 5l/100km around the world.

Figure 7 shows that continued improvement puts global emissions from LDV on a slightly lower growth path, but is not sufficient to curb the effect of strong growth of demand.

Figure 7. World LDV Tank-to-wheel CO_2 Emissions (Mt of CO_2 equivalent): BAU, 30% World, and 30% World Continued, 2000 - 2050

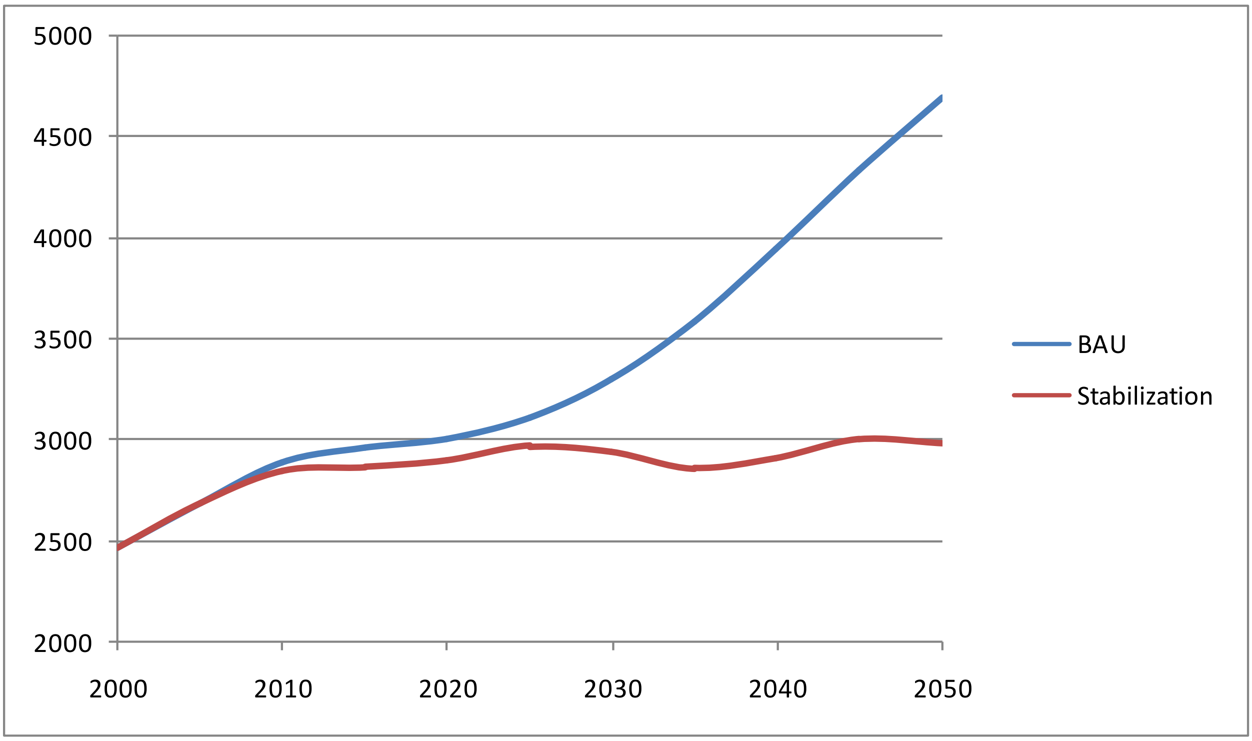


Source: ITF calculations using the IEA MoMo Model Version 2008

3.3 What fuel economy to stabilize light-duty vehicle emissions?

Here we present one possible path for fuel economy levels that more or less stabilize emissions at 2010 levels through 2050. This obviously is just one of many possible paths. A characteristic of the current scenario is that it uses the regional distribution of use of fuel economy potential used in the "30% world and continued" scenario. As can be seen from Table 2, the fuel economy levels required to stabilize emissions through 2050 are between 3-4 l/100km around the world.

Figure 8. World LDV Tank-to-wheel CO_2 Emissions (Mt of CO_2 equivalent): BAU, Stabilization, 2000 - 2050



Source: ITF calculations using the IEA MoMo Model Version 2008

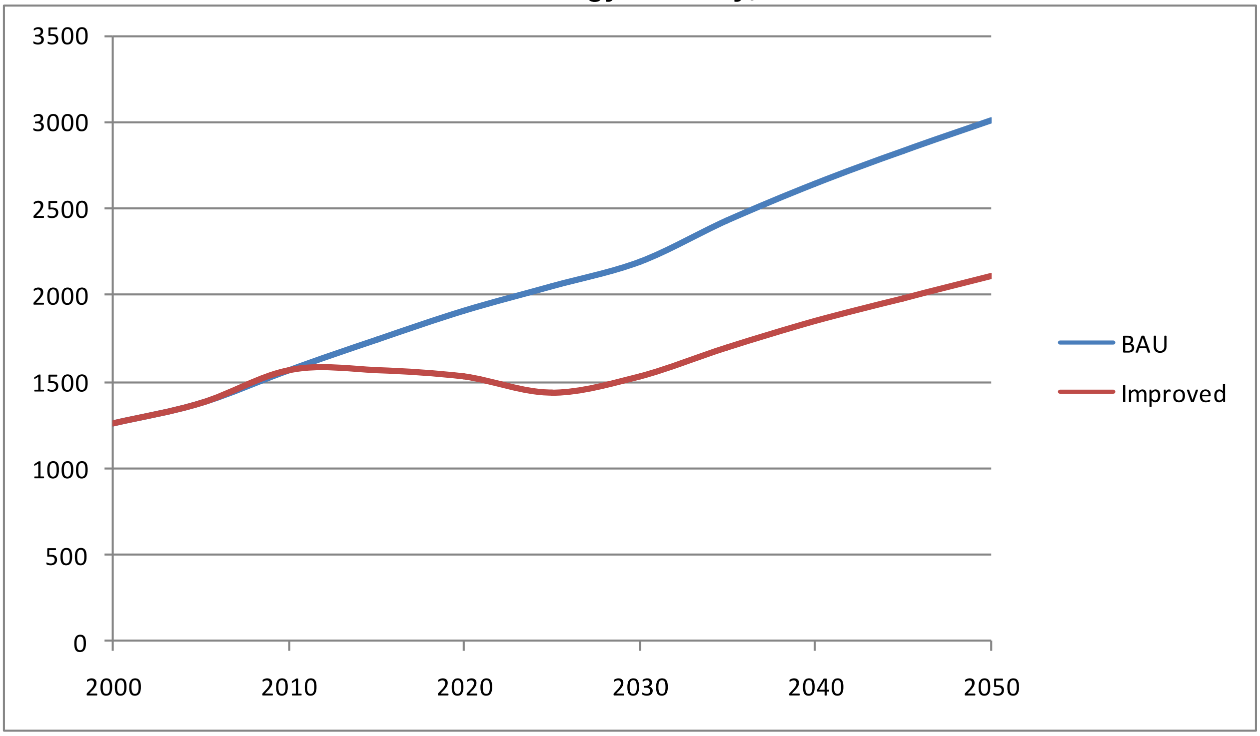
3.4 Reducing the energy intensity of road freight traffic

It is argued that the fuel economy of road freight can be improved through better choice of fuel economy, because current choices are subject to shortcomings similar to those observed for light-duty vehicle choice[ix] and through better logistics (which has the potential to reduce energy intensity per tonkilometre, through various channels). The scenario illustrates the contribution of such improvements to overall reduction of CO_2-emissions, under the assumption that fuel economy is improved by the same order of magnitude (around 30%) as for light-duty vehicles discussed in Section 3.1. The goal is to illustrate the relative importance of road freight, not to provide a detailed analysis of the sector itself.

The alternative scenario ("reduced energy intensity") assumes reductions of the energy intensity of freight, expressed in Mj/tkm by 10% in 2010, 20% in 2015, and 30% as of 2020, compared to the MoMo reference scenario. It is far from clear exactly how large the fuel economy improvement potential is in the road freight sector. We assume improvements of the same order of magnitude as assumed in the LDV scenarios. Note that the reference scenario itself assumes an improvement of nearly 20% between 2015 and 2050; the "improved" scenario adds to these improvements.

As is clear from Figure 9, the resulting CO_2-emissions display a path roughly similar to the one found for LDVs: the improvements initially are stabilized but growth picks up as of 2025 at a slightly lower rate as in BAU.

Figure 9. World Vehicle CO_2-Emissions from road freight [Mt], BAU and reduced energy intensity, 2000 - 2050:



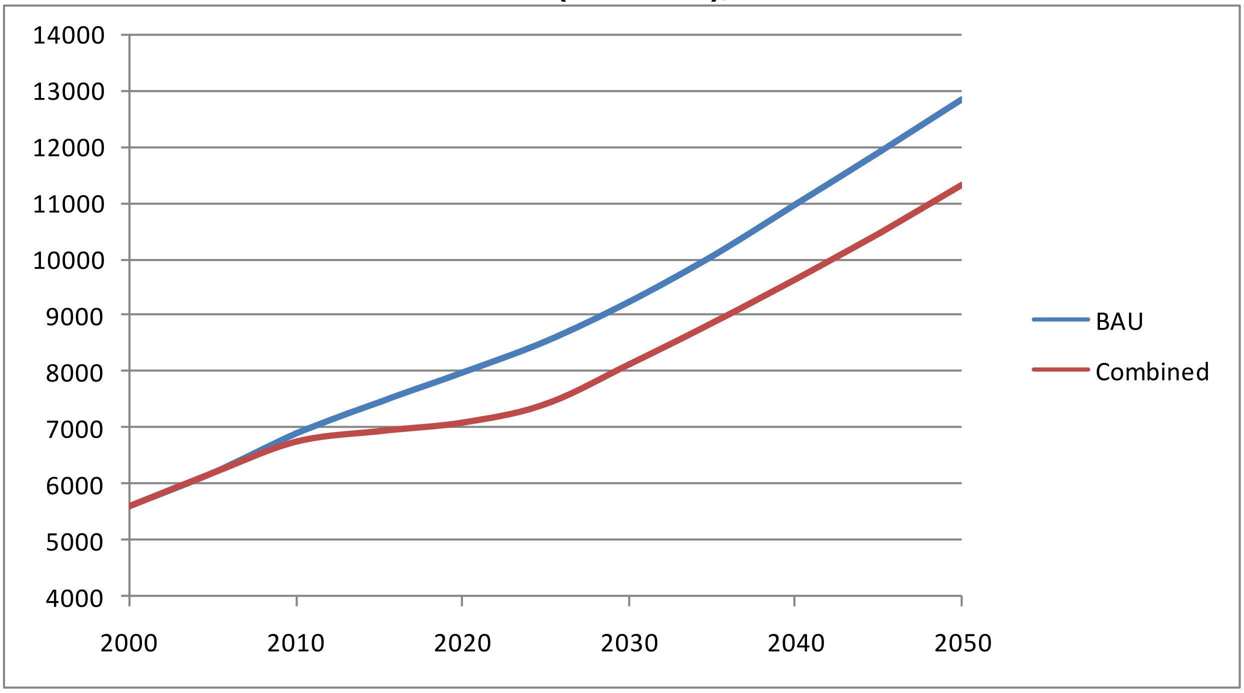
Source: ITF calculations using the IEA MoMo Model Version 2008

3.5 A composite scenario: improved conventional technology in road freight and road passenger transport

This scenario combines "30% World" and "reduced energy intensity for freight". Figure 10 shows that improving the efficiency of conventional technology in road freight and passenger transport is insufficient to halt the trend of rising CO_2-emissions from the transport sector as a whole.

The CO_2-reductions look smaller in a relative sense than in the earlier figures and tables. Also, the potential for stabilization until 2025 is less pronounced. This is, of course, partly the consequence of aggregation over modes. But, as can be seen from Table 1, there is the additional issue that the road transport scenarios do nothing to curb the growing share of air transport emissions in the total. This is of some interest, as in BAU the air transport share growns from 13% in 2000 to 23% in 2050, and it suggests that efforts in air transport are required if the trend is to be reversed. Needless to say that final judgment ideally depends on relative abatement costs across modes and sectors.

Figure 10. World Vehicle CO_2-Emissions from transport [Mt], BAU and combined efficiency improvements in road freight and passenger transport (30% world), 2000 – 2050



Source: ITF calculations using the IEA MoMo Model Version 2008

4. CONCLUDING REMARKS

- In the Business as Usual Scenario, CO_2-emissions from the transport sector are expected to grow by 120% by 2050 compared to 2000 levels. Emissions from light-duty vehicles grow more slowly, but will still be 90% higher in 2050 than in 2000.

- Sensitivity analysis on the light-duty vehicle module of the Business as Usual baseline suggests that emissions may grow faster than in the standard BAU. The main reason is the growth of traffic in emerging economies. Using income elasticities for vehicle use similar to those observed in the USA over the past 40 years implies faster growth than assumed in the Business as Usual Scenario.

- The projections illustrate "where demand would like to go", in the sense that it is assumed that sufficient energy supplies are available to meet demand without sharply rising prices. It is not straightforward that this indeed will be the case.

- Rapid improvements of the fuel economy of light-duty vehicles and freight trucks by about 30% would reduce emissions and may even stabilize them for these modes over the next two decades. This approach is particularly powerful when implemented on a global scale, not just in the OECD.

- In the longer run the expected growth in vehicle fleets and useage outstrips these fuel economy improvements, leading to rapid growth of emissions. Stabilizing emissions from light-duty vehicles over this horizon would require fuel economy levels of around 3.5l/100km (roughly 67 mpg or 80 gCO_2/km) by 2050, around the world.

- It is sometimes argued that improving fuel economy by about 30% would be cost-effective, though it does require government intervention to shape consumer choice and manage risk for industry investment decisions. The projections suggest that ambitious targets, like stabilizing emissions from cars through 2050, require further technological change that could entail significant economic cost. The task for research is to direct policies to promoting the most cost-effective ways of reaching ambitious targets, .

- Fast improvements of fuel economy may stabilize emissions over the next two decades. Such results may induce complacency, which the long run analysis shows would be misplaced if a goal of stabilizing vehicle emissions were to be adopted. For this, long run emissions standards would need to be established soon, in order to facilitate the more costly switch to low-carbon technologies and provide the certainty required for industry to make the necessary investments.

NOTES AND REFERENCES

1. IEA, 2008, *Energy Technology Perspectives 2008 – Scenarios and strategies to 2050*, International Energy Agency, Paris.

2. *Financial Times*, 20 May 2008, Running on empty? Fears over oil supply move into the mainstream.

3. Wilson D., R. Purushothaman and D. Fiotakis, 2004, The BRICs and global markets: crude, cars and capital, Goldman Sachs – Global Economics Paper 188.

4. For example, Table 4.1 of the 2007 Transportation Energy Data Book implies that in the USA the average distance driven per car was more or less constant between 1970 and 1990 (with a limited decline around the oil shocks), followed by a slow increase through 2005 (Davis S.C. and S.W. Diegel, 2007, *Transportation Energy Data Book*, Edition 26, Oak Ridge National Laboratory, US Department of Energy).

5. Small, Kenneth A. and Kurt Van Dender, 2007a, Fuel efficiency and motor vehicle travel: the declining rebound effect, *The Energy Journal*, 28, 1, 25-51

6. JTRC, 2008, The cost and effectiveness of policies to reduce vehicle emissions, JTRC Discussion Paper 2008/9, Paris.
http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP200809.pdf

7. ---, 2007, *The King Review of Low Carbon Cars* – Part I: the potential for CO2 reduction, Crown, UK.

8. Cheah, Lynette, Christopher Evans, Anup Bandivadekar, and John Heywood, 2007, Factor of two: halving the fuel consumption of new U.S. automobiles by 2035, Laboratory for Energy and the Environment, Massachusetts Institute of Technology, Cambridge, Mass.

9. JTRC, 2008, The cost and effectiveness of policies to reduce vehicle emissions, JTRC Discussion Paper 2008/9, Paris
http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP200809.pdf