Scenarios, policies and impacts for the linked transport and energy systems – results of the European TRIAS project

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Abstract

High oil prices and the growing awareness that this will not be a temporary but a permanent situation fosters the search for alternative fuels and new technologies to propel the transport system, which, so far, in Europe depends to more than 96% on fossil fuels. Two of these alternatives would be hydrogen and biofuels that both can be generated from a number of different sources including a number of non-fossil and renewable sources.

The TRIAS project combined four models (ASTRA, POLES, VACLAV, Regio-SUSTAIN) to analyse the impacts of different policies that would foster the diffusion of alternative fuels into the transport system. The impact analysis covers the fields of transport, energy, environment, technology and economy.

The basic conclusions that can be drawn are that such policies, if they are formulated in an appropriate manner, could stimulate investments and economic development on the one hand and on the other hand would have the potential to generate positive impacts in terms of reductions of CO_2 emissions and increase of security of energy supply due to reduced imports of fossil fuels and the use of a greater diversity of fuels for transport.

1. Introduction

The use of hydrogen as energy carrier for the transport system has been discussed and tested in research niches since many years. Large research networks like the European Hydrogen and Fuel Cell Technology Platform or the US California Fuel Cell Partnership have been set up to overcome the barriers that currently hinder the widespread use of hydrogen for transport, which are especially the fuel cell itself and the hydrogen storage system. The same for biofuels, which in the short to medium-term seem to be the more realistic option than hydrogen as technologies for the first generation of biofuels are available, and for the second generation of biofuels such technologies are reaching the level of demonstration projects, yet.

However, shifting transport towards hydrogen and biofuels is not at all only a technical issue. Instead, it would induce structural economic changes developing a large-scale industry producing hydrogen, trade flow changes reducing trade of fossil fuels and increasing trade of feedstock for hydrogen and biofuels production, offer new employment opportunities and reduce environmental impacts of transport e.g. in the case of hydrogen produced from renewable energy sources.

This paper draws on research work undertaken in the European TRIAS project (http://www.isi.fhg.de/TRIAS/). In TRIAS a baseline scenarios and eight policy scenarios are developed for Europe describing the diffusion of biofuels into the transport markets as well as a shift of the transport system towards hydrogen until 2030 and 2050. The TRIAS project integrates and applies the four models POLES, ASTRA, VACLAV and Regio-SUSTAIN that together cover the multi-facetted impacts of such a large scale change of the transport and energy system.

Policies tested include: a carbon tax funded shift, a shift subsidised by funds from general budget, an accelerated shift where Europe would be the first world region to introduce hydrogen for transport on a large scale, and two regulation policies which would either fix mandatory CO_2 emission limits of cars or fix mandatory quotas of biofuels on the total fuel market. For these scenarios an integrated sustainability impact assessment is carried out providing results for the transport system in terms of changing demand, cost changes, structural change of the vehicle fleets and environmental impacts, for the energy system in terms of energy prices and demand for different energy carriers, for the economic system in terms of growth implications, sectoral shifts and changes of trade flows and for employment.

2. TRIAS baseline scenario

The TRIAS scenarios provide trajectories for the analysed indicators until 2050. We are using different ways of presenting the results e.g. absolute indicators or indices. The most suitable way to present a variety of indicators across different fields is to use indices, which we calculate relative to the base year 2000. Figure 1 shows three different groups of indicators. The first group includes indicators that remain stable or only show very moderate growth until 2050. This includes population and employment, which both show a peak in the period 2025 to 2035 and then decline, but overall remain very close to the level of the year 2000. Transport energy demand, transport CO_2 emissions (life cycle perspective) and passenger performance, which are the other three indicators of this group, increase by up to 50% until 2050. The second group reveals a growth of about 200% until 2050. GDP and freight transport performance belong to this group, which indicates that the models do not foresee a decoupling between freight transport and GDP, but at least a relative decoupling between transport energy demand and GDP, which can be assigned to technological improvements including not only improved energy efficiency of individual technologies but also switches between different technologies. The last group in the figure represented by one indicator only reaches a growth of more than 300%. This includes exports, which reveals that the models expect a continuation of current globalisation trends leading to further specialisation of production in different world regions and hence growing transport activity between different locations of goods production.

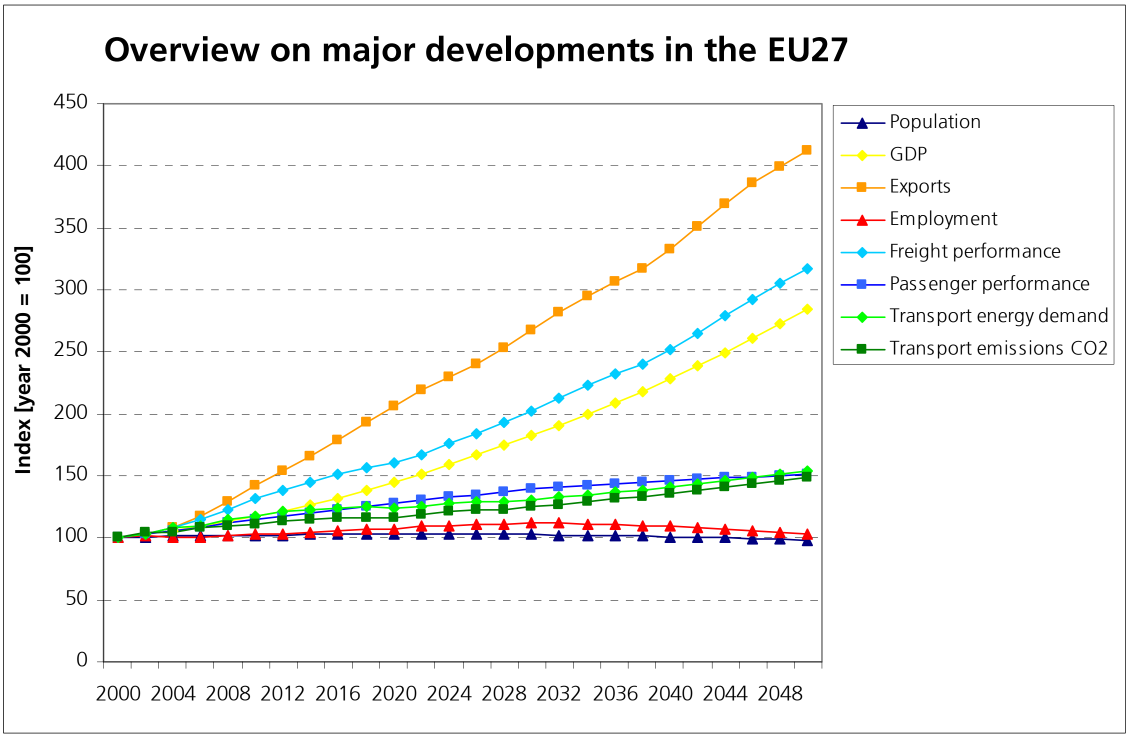

Figure 1. Overview on the TRIAS baseline scenario

Taking a closer look at transport energy consumption by translating the fuel consumption of the different transport fuels into million-tons-of-oil-equivalent (Mtoe) this shows a continuous increase from 2000 until 2050. Starting from 420 Mtoe for EU27 in 2000 the maximum transport fuel consumption reaches 649 Mtoe in 2050, which amounts to an increase of +54% over this period. Excluding truck transport the overall development of fuel consumption shows a growing trend until the year 2026 where a maxim fuel consumption of 351 Mtoe will be reached. Afterwards fuel consumption excluding trucks is estimated to stagnate or even slightly decreases resulting in 347 Mtoe in 2030 and 340 Mtoe in 2050. Influenced by technological development of the vehicle fleets, especially the car fleet, the demand curves per fuel type show different trends. Figure 2 reflects increasing shares of diesel cars leading to a strong growth of diesel fuel demand for cars until 2025, with an even stronger decline of gasoline demand. The high growth rates of freight transport are reflected in particular in the strongly growing demand for diesel fuel for heavy and light duty vehicles. The projections show that diesel fuel consumption for road transport will increase until 2050 reaching a share of more than 72% compared with 46% in the year 2000. As opposed to this trend gasoline consumption reduces to 14% until 2050 compared with 45% in 2000. Concerning the diesel fuel demand it has to be taken into account that ASTRA is not yet considering alternative fuels for freight vans (<3.5t) and trucks. At least for the former the introduction of alternative fuels can be expected.

CNG demand grows until 2024 and reaches a level of 19.1 Mtoe ending up at 13 Mtoe in 2050. In 2028 Bioethanol passes CNG as most important alternative fuel besides the conventional fuel types and results in 20.8 Mtoe in 2050. Together with biodiesel, electric current, LPG and hydrogen the alternative fuels are estimated to have a rather moderate share of only 12% of total fuel consumption by cars in 2050 in the baseline scenario.

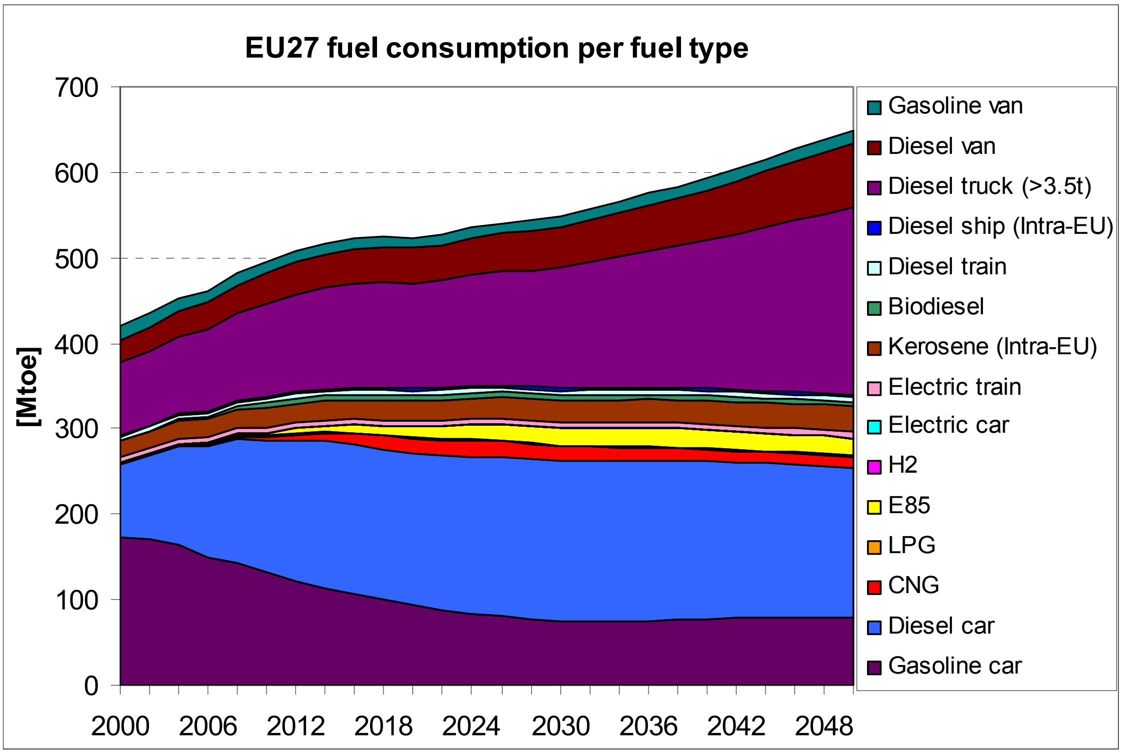

Figure 2. Transport energy consumption for different fuels in TRIAS baseline scenario

3. TRIAS Policy Scenarios

TRIAS has defined in total ten scenarios including a reference scenario, a baseline scenario and eight policy scenarios. The reference scenario represents a virtual scenario excluding any new technologies, which was used for a number of comparisons with the baseline scenario, which e.g. included biofuels. Briefly the ten scenarios are:

- Reference Scenario with no new technologies at all.
- **Baseline** scenario with slow diffusion of biofuels (max 5.75%) and no market entering of hydrogen into transport. The latter seems reasonable as for hydrogen large projects like HyWays (2006) as well as the TRIAS stakeholder workshops concluded that hydrogen will not enter the transport market if it is not supported e.g. by subsidies at the beginning. This is because the entry barriers e.g. in terms of cost of the first fuel cells would be too high.
- **Carbon tax** scenarios to **foster biofuels**, which implements a carbon tax on fuels and uses the revenues for subsidisation of biofuels.
- **Carbon tax** scenario to **foster hydrogen** which implements a carbon tax on fuels and uses the revenues for subsidisation of hydrogen.
- **Subsidies** scenario to **foster biofuels**, which pays subsidies on biofuels from the government budget increasing the debt.
- **Subsidies** scenario to **foster hydrogen** which pays subsidies on hydrogen from the government budget increasing the debt.
- **Combined carbon tax and subsidies** scenario to foster new technologies i.e. both technologies biofuels and hydrogen receive policy support.

On top of the combined scenario:

- **First mover** scenario for **hydrogen** use for transport presupposing that the EU becomes the first world region to produce and use hydrogen cars affecting especially trade of vehicles.
- Mandatory biofuels **quotas** resulting in higher penetration rates **of biofuels**.
- **CO_2 emission limits** for cars defining maximum emission standards of the average car fleet in Europe, which is to some extent equal to regulate fuel consumption.

The policies were introduced earliest in 2008. Some measures like the first mover approach for hydrogen become effective with some delay i.e. policies are introduced around 2012, but impacts are measurable only 4 to 8 years later. In general the picture of all the policies is quite positive, due to a number of synergistic effects.

Looking at GDP of EU27 compared with the baseline development (see Figure 3) the impacts in 2050 lies in the range between close to +0.2% and +1.6% increase of EU27 GDP compared with the baseline scenario. Positive impacts occur for a number of reasons:

1. All policies stimulate additional investments. The stronger the stimulus for investments the more positive is the long-term impact on the economy. Depending on the policies additional investments may occur in:
    a. plants to produce biofuels,
    b. plants and infrastructure to produce and distribute hydrogen,
    c. R&D and manufacturing plants for new type of vehicles (e.g. bioethanol, hydrogen) or improvements of existing technologies (e.g. efficiency of gasoline vehicles to cope with CO_2 emission limits).
2. The counterfinancing of the additional investments by carbon taxes or government subsidies (affecting government debt) leads only to minor cost increases and thus has limited dampening impacts. E.g. average cost of passenger car transport increases by +1 to +2% only in nearly all policies (see Figure 4).
3. Imports of fossil fuels can be reduced, which improves the trade balance of the European countries.
4. In the first mover scenario additional exports of hydrogen vehicles stimulate the economy, as Europe becomes the technology leader and due to this competitive advantage increases its exports of such vehicles to other parts of the world.

Figure 3 reveals that both setting a CO_2 emission limit and trying to get into the first mover position for hydrogen vehicles (presupposing that the technical barriers of fuel cells can be overcome) would be the most promising options. Both policies belong to the policies with the highest investment requirements, but it seems that these could pay-off.

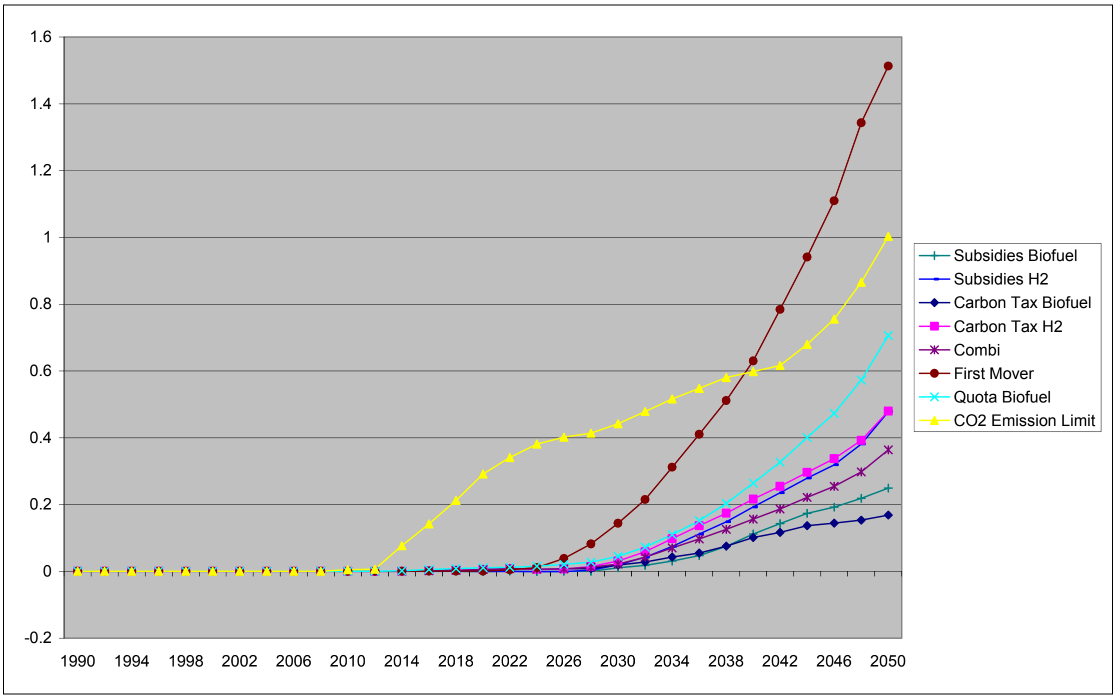

Figure 3. Impact on GDP of EU27 in the eight scenarios as percentage change to baseline

An interesting aspect to notice for the CO_2-emission limits is that these constitute the only policy in which average cost of car transport decrease (see Figure 4). The reason is the significant improvement of fuel efficiency that overcompensates the cost increase induced by the carbon taxes as well as the higher prices of vehicles. The side effect is that modal-share of car transport in this policy can even increase.

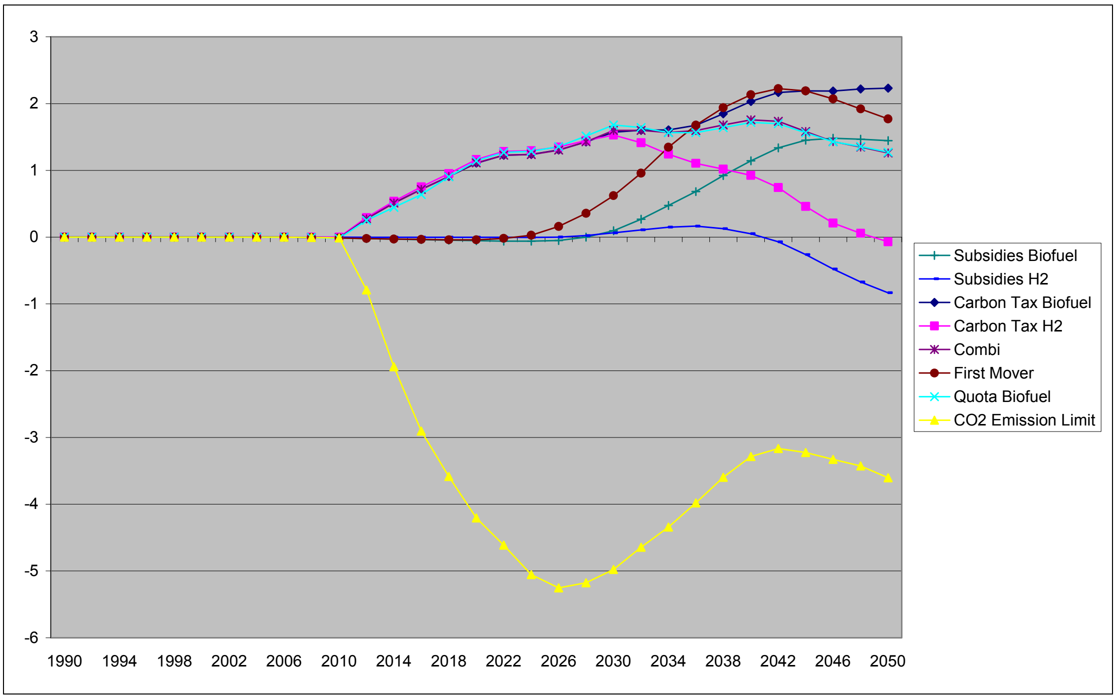

Figure 4. Impact on average cost per pkm by car for EU27 as percentage change to baseline

4. Conclusions

The scenario analysis in the TRIAS project links the developments in the transport sector with the required parallel development in the energy sector. For this purpose the analysis applies eight scenarios with the four models ASTRA, POLES, VACLAV and Regio-SUSTAIN.

The basic idea of the scenarios is to stimulate the diffusion of new technologies into the transport sector, in particular biofuels and hydrogen, with the objectives to reduce the greenhouse impact of transport and to increase the security of energy supply of the European Union. Given the results of the scenarios it is quite obvious that these two objectives can be fulfilled with such policies as CO_2 emissions of transport are reduced in all scenarios and the imports of fossil fuels is also decreased both due to higher fuel efficiency and due to a fuel switch towards alternative fuels. However, since the chosen policy implementation is not very ambitious (e.g. carbon tax levels or subsidies for hydrogen remain at a low level), the measured policy impacts do not reach levels, e.g. as required by recent policy recommendations from the IPCC to reduce CO_2 emissions in developed countries by at least -50% until 2050.

Less obvious but of similar relevance is the question about economic impacts. There is to note that the applied policies did only lead to a moderate cost increase for car transport due to compensating effects like higher fuel efficiency. The technological improvements in terms of efficiency and new technologies for transport required significant additional investments such that together with the reduction of fossil fuel imports the overall economic impact is positive i.e. GDP in all scenarios is increased above the baseline scenario. It was also observed that more ambitious policies e.g. the first mover strategy for hydrogen or strict CO_2 emission limits for cars bear the potential to generate higher positive economic impacts than the rather moderate strategies.

5. References

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