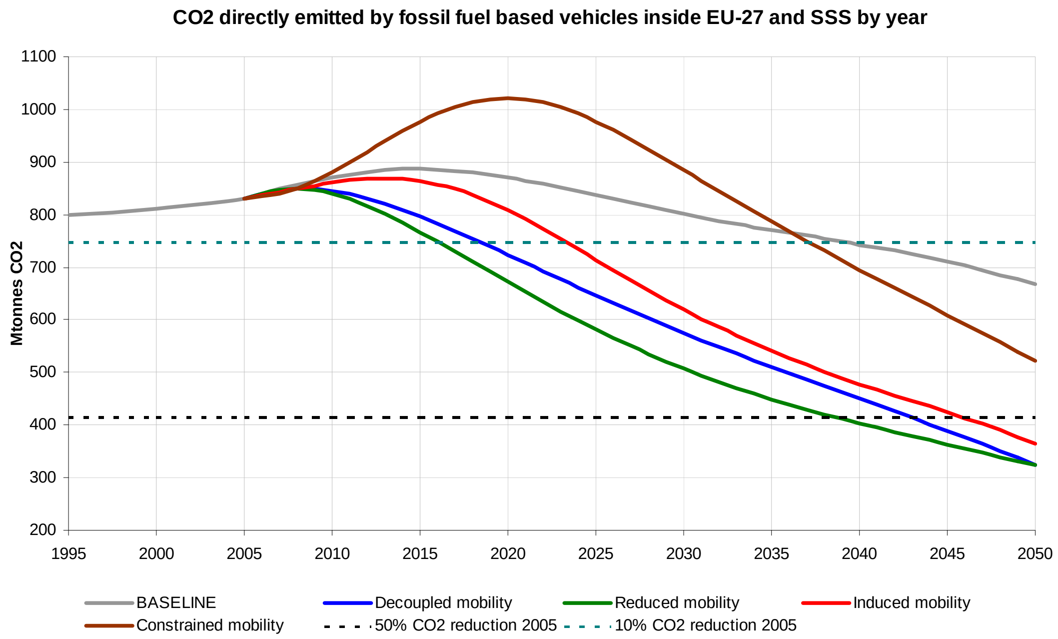
TRANSvisions




# Mobility scenarios towards a postcarbon society.

**TRANSvisions Task 2 Quantitative Scenarios**

FINAL VERSION by MCRIT (Barcelona, SP)

TRANSvisions study was co-ordinated by Tetraplan (DK): Task 1 (by ISIS, IT) and Task 3 (University of Leeds, UK)

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# 1. Introduction

## 1.1. *The questions to be answered*

TRANSvisions' goal is to explore three fundamental uncertainties for the future of European transport from now until 2050:

- Will the strong correlation which has been observed between passenger and freight transport on one side, and GDP and GDP per capita growth on the other side, continue? (For which segments of the market? In which regions of Europe?)

- Will transport growth be decoupled from environmental impacts? (By which modes, or trip purposes? Using which technologies?)

- Which transport policies could be the most effective in reducing $CO_2$ emissions generated by transport activities, facilitating a sustainable and more stable economic development?

TRANSvisions is a foresight exercise including quantitative and qualitative analysis. Foresight is concerned with the long-term look into the future, typically with a time frame of up to thirty years. It could be said that foresight is an overall attempt to prepare for future challenges and changes by trying to assess the challenges faced in the long-term future. Scenario-based methodologies have become widespread over the last few decades to help investigate strategic questions, like the ones just mentioned. The introductory chapter of *Backcasting approach for sustainable mobility* (JRC, IES 2008) provides useful insights concerning these concepts, here just mentioned as a reference.

## 1.2. *The scenario-based methodology applied?*

Scenarios are defined as “consistent and plausible visions of the future”.

Scenarios try to open people minds to unexpected future events and avoid so-called *presentism*. For example, when defining scenarios for a long-term period current dramatic events such as the world financial crisis, the fluctuation of oil prices, the Irak or Afganistan wars, the new importance of religious fundamentalism have to be considered also in a long-term perspective. In some cases they are ephemeral events, while others may correspond with historical patterns or long-term cycles (e.g. according to some analysts the present economic crisis may correspond with the starting point of a new Kondratieff wave signifying a declining economy until 2020, while other analysts tend to believe that ups and downs are less dramatic in mature economies).

Common elements of the methodologies in the various scenarios are:

- Scenarios are a tool for strategic decision making.
- The scenario method emphasizes the construction of plausible alternative futures.
- For this purpose, existing theoretical models should be challenged, and qualitative (“storytelling”, narrative) as well as quantitative (“modelling”) approaches are to be used.[1]
- It is important to know for whom scenarios are made and for what purpose. Credibility, legitimacy, and creativity are important aspects, then, of the process and the result.
- Scenario construction is an exercise in finding key trends, recognising prevalent myths, and imagining attitudes of key players.
- The fundamental aspect of any plausible scenario, is for it to be consistent.

[1] In TRANSvisions Task 1 the qualitative storytelling approach was followed. The quantitative approach was considered in Task 2.

Scenarios may be expressed in two basic forms: qualitative ( “soft”) and quantitative ( “hard”)

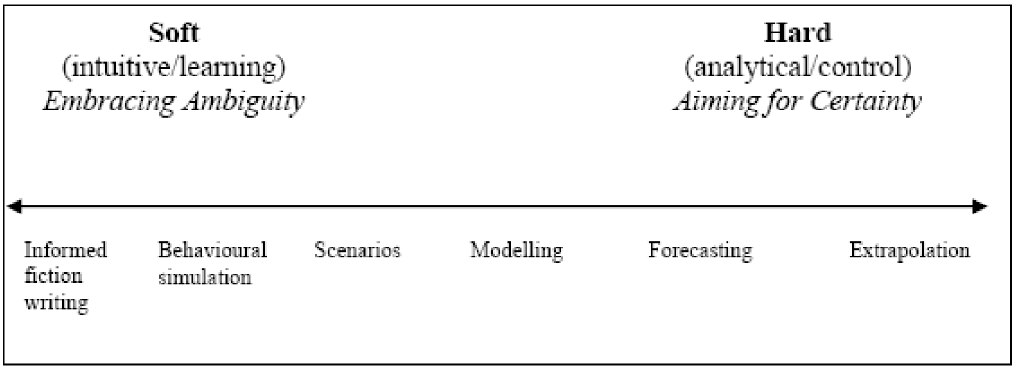



**Figure 1: Practices used in the study or prediction of the future, by Chatterjee and Gordon, 2006.**

In order to make the “soft” qualitative narratives (largely developed in TRANSvisions Task 1) more precise and assure consistency, a “hard” modelling study has been carried out, based on existing official data and TRANS-TOOLS model runs for the 2005-2030 period (based on the latest TRANS-TOOLS version, substantially improved by DTU, November 2009), complemented by ad-hoc meta-models mostly for the 2030-2050 period.

Meta-models are based on 2005 TRANS-TOOLS data, are calibrated with 2020 and 2030 baseline forecasts by TRANS-TOOLS, and validated against other forecasts beyond 2050. TRANS-TOOLS meta-models, complementary to the TRANS-TOOLS core model, estimate continuous trajectories from 2005 up to 2050 for key transport and other strategic indicators not always considered in TRANS-TOOLS. No model can predict a long-term future with full certainty; the goal is mostly to assure the internal consistency of each scenario, and also the relative consistency between them.

The TRANS-TOOLS model and TRANS-TOOLS meta-models are different and complementary tools.

Scenario specification in the TRANS-TOOLS model includes assessing zonal data for about 1,440 different transport zones in Europe, as well as data for about 35,000 road links and 5,000 rail links. Additional cost specifications related to transport modes and specific network links and nodes are part of the specification of scenarios in the model. The TRANS-TOOLS model was designed mainly for analysis of infrastructure development. However, it can also be used for analysis of more general time and cost specifications covering the EU-27.

The TRANS-TOOLS meta-models (TT meta-models) developed and applied in this study were designed mainly for the analysis of policy instruments for the reduction of $CO_2$ emissions, but they are also able to analyse other policy instruments. The specification of scenarios in the TT meta-models is given less importance than in the TRANS-TOOLS.

To present the type of scenarios being defined in TRANSvisions it is worthwhile to consider the next table, which contains a clear summary of key concepts involved in quantitative and qualitative scenario-based studies.

| Scenario category | Quantitative/ Qualitative | Time frame | Main techniques |
|---|---|---|---|
| PREDECTIVE – *What will happen* | | | |
| Forecasts | Typically quantitative, sometimes qualitative | Often short | Surveys; Workshops, Original Delphi method, Time series analysis; explanatory modelling. |
| What if | Typically quantitative, sometimes qualitative | Often short | Surveys; Workshops, Delphi method, Time series analysis; explanatory modelling. |
| EXPLORATIVE – *what can happen?* | | | |
| External | Typically qualitative, quantitatively possible | Often long | Surveys; Workshops, Delphi method modified; explanatory modelling. |
| Strategic | Qualitative and quantitative | Often long | Surveys; Workshops, Delphi methods; explanatory modelling |
| NORMATIVE – *How can a certain target be reached?* | | | |
| Preserving | Typically quantitative | Often long | Surveys; workshops. |
| Transforming | Typically qualitative with quantitative elements | Often very long | Surveys; workshops, Backcasting Delphi. |

**Figure 2: Scenario categories and main techniques, Borjeson et al. 2006.**

These three types of scenarios are applied in TRANSvisions (Predictive, up to 2030; Exploratory, up to 2050; Normative with 2020 and 2050 targets related to reduction of $CO_2$ emissions).

Predictive scenarios (2005-2030):

- The Baseline scenario has been defined as the continuation of existing trends, as defined by the official demographic, economic, transport and energy baselines created by the European Commission.

- The High Growth scenario shares most elements of the Baseline scenario, with a higher population, and GDP.

- The Low Growth scenario has a lower population and GDP.

Exploratory scenarios (2005-2050):

In addition to the Baseline scenario four extreme scenarios have been defined, each one representing a plausible alternative path towards a post-carbon society.

- The organisational path (Decoupled Mobility Scenario), which continues the high-growth 2005-2030 scenario.
- The behavioural path (Reduced Mobility Scenario), which continues the low-growth 2005-2030 scenario.
- The technological path (Induced Mobility scenario), which has the highest growth overall 2005-2050.
- The mandatory path (Constrained Mobility scenario), which has also a high growth from 2005-2030, but then dramatically declines; it captures both an overoptimistic technological vision and a pessimistic view concerning the capacity of public institutions to carry out necessary structural reforms.

Normative scenarios (2005, 2020, 2050):

The policy impacts of infrastructural and pricing policies were assessed for the 2020 period, and backcasting exercises were carried out to explore which policies could be more effective in achieving the $CO_2$ emissions goals in 2050 and 2020 for the organisational and the technological paths (Decoupled and Induced scenarios). This exercise was also carried out for the Baseline scenario.

- The organisational path backwards: 2050-2020
- The technological path backwards: 2050-2020

- Baseline backwards: most effective policy package 2050-2020

The report is organised as follows: first, the context for the definition of the scenarios is discussed, and then the alternative scenarios are defined. Later on TRANS-TOOLS and TT meta-models are briefly introduced. Then, the quantitative results obtained are presented and discussed, this part being the core of the report.

A list of 100 remarks is listed as a final conclusion, providing the answers to the three original questions, obtained by applying the methodology just introduced.

## 1.3. *2005-2050: A transition period*

When defining scenarios for the next decades, it is worthwhile to consider that we are living in a **transition period** (according to many thinkers, e.g. James Martin) towards a post-carbon society, in between 1950 and 2050:

- 1950, five years after World War II, can be fairly considered as a moment where most of current evolutions started from a relatively low level, in some cases from almost zero (e.g. cities as well as infrastructure being rebuilt, very few cars, no tourism, many people still working in agriculture, the process of European political integration had not started and Europe was divided in two politically, with little if any social or economic exchange, etc.). Before 1950, Europe was at war twice, in 1914 and 1940, and therefore it is unthinkable to consider this 50-years period as a reference for 2005-2050. The so-called *First Globalization* (based on railways, maritime transport, and submarine telephone cables) finished around 1914, and the *Second Globalization* (now based on Information and Communication Technologies (ICT), and intercontinental flights) started slowly only after the two wars, around 1950.

- 2050 has been considered by many influential authors (e.g. Ray Kurtzweil) as a *Singularity Point* in human history, since the capacity of computers and electronic communications to manage information will be, if currents trends continue, inconceivable. During the last decade, relevant thinkers have announced “the end of history” (Francis Fukuyama), “the end of distance and

Technological development is faster today than it was in earlier decades, even though someone who lived from 1850 to 1900, the *First Globalization* period, might have the same feeling. In that period, horse transport was replaced by cars and aeroplanes, and electricity and everything powered by it was introduced into homes. But the fact is the highly centralized and hierarchical industrial system developed in the 20th century, largely based on mass production of standardised goods, is slowly changing into a post-carbon society, a decentralised and networked production system able to provide highly customised goods and services. To this effect Richard Sennet has some interesting insights, saying that creativity and craftsmanship is returning. Technological innovations are already creating important social impacts. For example, for the first time in human history, teenagers are generally more familiar with new technologies than their parents or teachers, and numerically enormous virtual communities are emerging.

All things considered, the main driving forces shaping the future of Europe in the next decades are well-known: ageing populations, economic globalization, and technological innovation in energy, biotechnology, nanotechnology and transportation. The rhythms and intensities of these driving forces and their impacts on mobility are however unknown.

Two paramount conclusions can be immediately derived for European transportation planners at the beginning of this transition period:

- *Uncertainty is large since we are in a transition period* (in relation to migration, or the emergence of Asian economies, the market penetration of new energy sources, and transport technologies, etc.)

- *The impact of public policy can also be large*. Political decisions in the next few years may produce an *acceleration* of emerging trends (for instance in relation to the implementation of already existing transport technologies, such as electric vehicles, online pricing, or intelligent traffic management

In order to realise the limits of the state-of-the-art modelling tools available to forecast long-term futures it is enough to consider that many fundamental concepts and indicators we use in advanced forecast models, such as TRANS-TOOLS, may not be relevant in a few decades (e.g. such as "Transport modes", since new transport "modes" may emerge, blurring the lines between private cars and public buses or trains (such as *car-sharing*, using smaller, user-customized, cleaner and more intelligent fleet of electric vehicles, or bikes, *podcars*, and many others). In any case, we must not completely avoid current categories, databases and modelling frameworks in order to explain possible future evolutions, especially for the next ten or twenty years, since existing technologies, consumer behaviour, and policies may remain dominant.

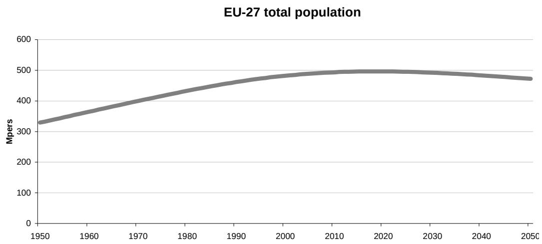
### 1.4. *1950-2050 macrotendencies*

Data of the current situation and long-term evolutions are indispensable in order to further specify the nature of the period to be analysed.

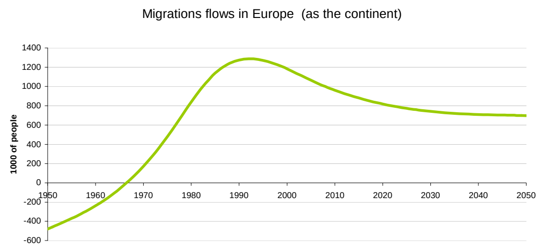
Next, 1950-2050 tendencies for key indicators are presented. Some tendencies are well-known and well-understood, such as the relative stabilisation of population and migration, and ageing, as well as the relative reduction of the economic weight of Europe in the world (as Asian economies, Latin America and African economies are forecasted to grow faster). This will likely lead to the continuing expansion of the European Union as long as it benefits from the integration of neighbouring countries.

Other tendencies, such as the exponential increase of electronic data transfers over the Internet, container traffic, tourism and air traffic are not surprising, but the total growth accumulated by 2050 may be. This is because the non-lineal nature of evolutions can be counter-intuitive: a 3% annual increase over a 50 years period produces a 425% increase, so the absolute value increases more than 4 times in absolute value.

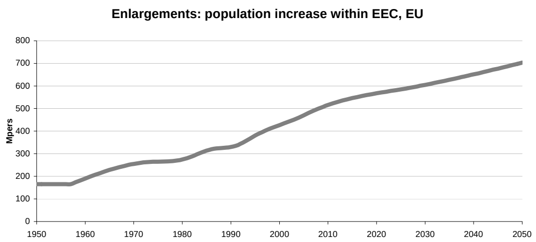
In terms of $CO_2$ emissions due to transport activities, a stabilisation and slow reduction are expected as efficiency gains compensate the increase in mobility.



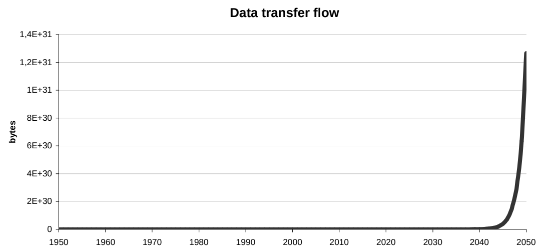

source: Eurostat, United Nations World Population Prospects 2007




source: United Nations World Population Prospects complemented on Eurostat, International Migrations Institute and Transnational Migrant Organisations (TRAMO)




source: Eurostat until 2007

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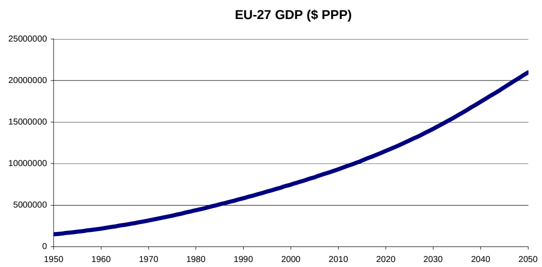
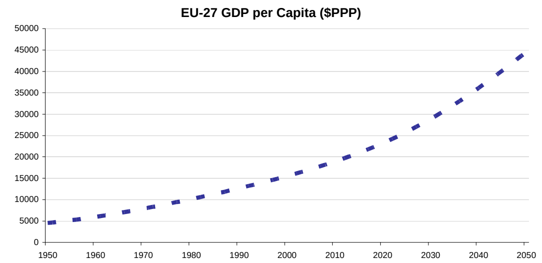



source: Eurostat; A.Maddison, "The World Economy. A Millennial Perspective", OECD, Paris 2001; A.Maddison, "The World Economy, Historical Statistics", OECD, Paris 2003; International Monetary Fund.

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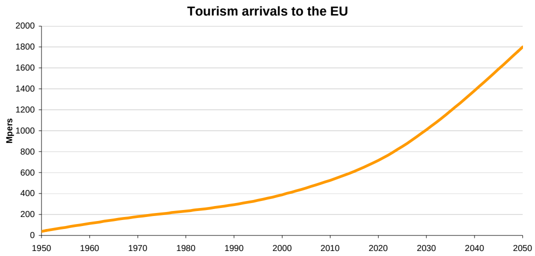
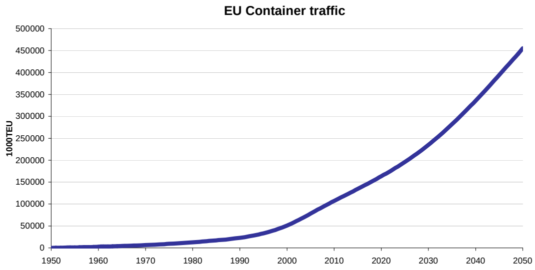
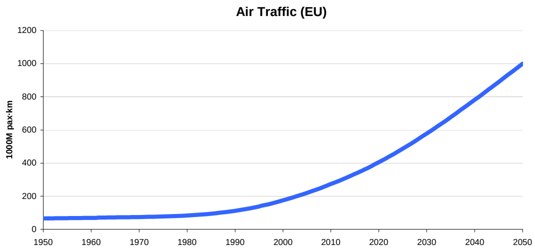


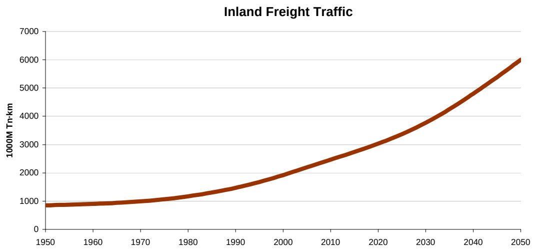

source: "Tourism 2020 Vision", World Tourism Organization (WTO) 2003; Eurostat



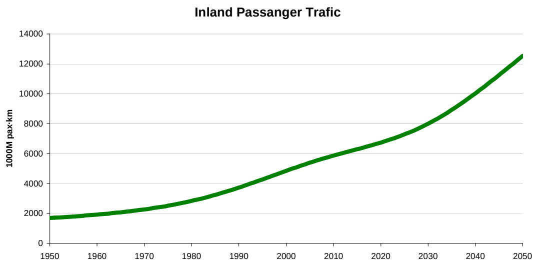

source: T.Nottebom, "The Relationship between seaports and the intermodal hinterland in light of global supply chains", University of Antwerp for OECD and International Transport Forum, 2008; "Regional Shipping and Port Development. Container Traffic Forecast 2007", UNESCAP 2007; Drewry Shipping Consultants; Fearnleys; UNCTAT 2007; Eurostat




source: "Flying by nature. Global Market Forecast 2007-2026", AIRBUS 2007; Eurostat; "European Energy and Transport: trends to 2030 Update 2007", EC 2008, TRIAS 2007.




source: Eurostat; International Transport Forum; OECD, "European Energy and Transport: trends to 2030 Update 2007", EC 2008, PRIMES; "Outlook for Global Transport and Energy Demand", TRIAS Study 2007.

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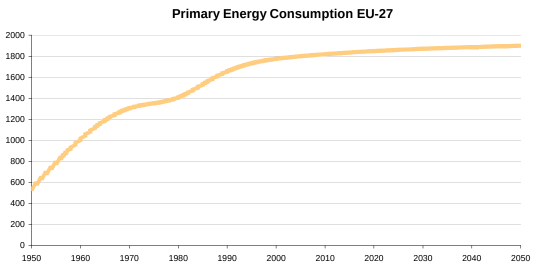
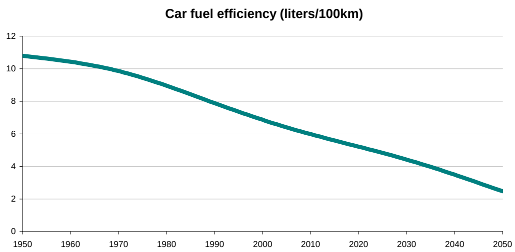
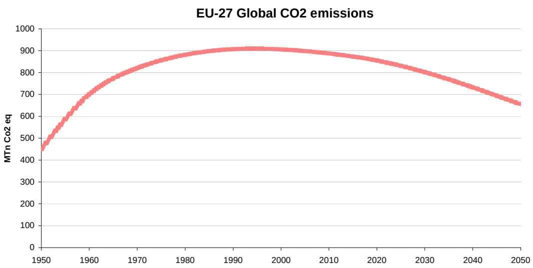



source: BP Statistical Review of the World Energy 2007; "European Energy and Transport. Trends to 2030 - Update 2007", EC 2008; COIAG; BP 2005; IEA 2004; EIA 2004; Carneguie Institution for Science; Marland et al 2005




source: "European Energy and Transport. Trends to 2030 - Update 2007", EC 2008; PRIMES; "Outlook for Global Transport and Energy Demand", TRIAS Study 2007; IEA.




source: "European Energy and Transport. Trends to 2030 - Update 2007", EC 2008; COIAG; BP 2005; IEA 2004; EIA 2004; Carneguie Institution for Science; Marland et al 2005

**Figure 3: 1950-2050 tendencies for key indicators**

## 1.5. *Patterns*

According to most future studies, main patterns, or invariants, for Europe in the next decades could be the following:

- Tendency towards a fertility rate of 2.1 children/woman (or less), as urban population grows. Population becomes more stable.
- Moderate, but relatively stable and continuous economic growth (2% maximum, with significant regional differences). Reduction of regional economic gaps.
- Exponential and cumulative process of growth for technological innovations, with more accelerated waves of innovation.
- Approximately 60 minutes per day of personal mobility (producing an overall increase of mobility if people travel longer distances due to faster vehicles and transport services).
- Approximately 15% of available income (or GDP) devoted to transport expenditures (producing increasing mobility if transport prices decline) .
- Faster and cheaper, and more diversified, transport technologies. Bigger transport ships and aeroplanes.
- Governments represent around 40% of GDP.
- Transport infrastructure investments represent 1-1,5% GDP.

▪ Dense urbanization, compared to other continents, making it more difficult to carry out major territorial transformations and large infrastructure projects.

▪ Attachment to national cultures, restraining the mobility of factors and people, rising concerns in relation to migration.

▪ Maintenance of European social welfare systems.

▪ Environmental quality and sustainability become increasingly important for most Europeans, accepting the internalisation costs that are otherwise transfered to future generations.

▪ Safety concerns become increasingly important.

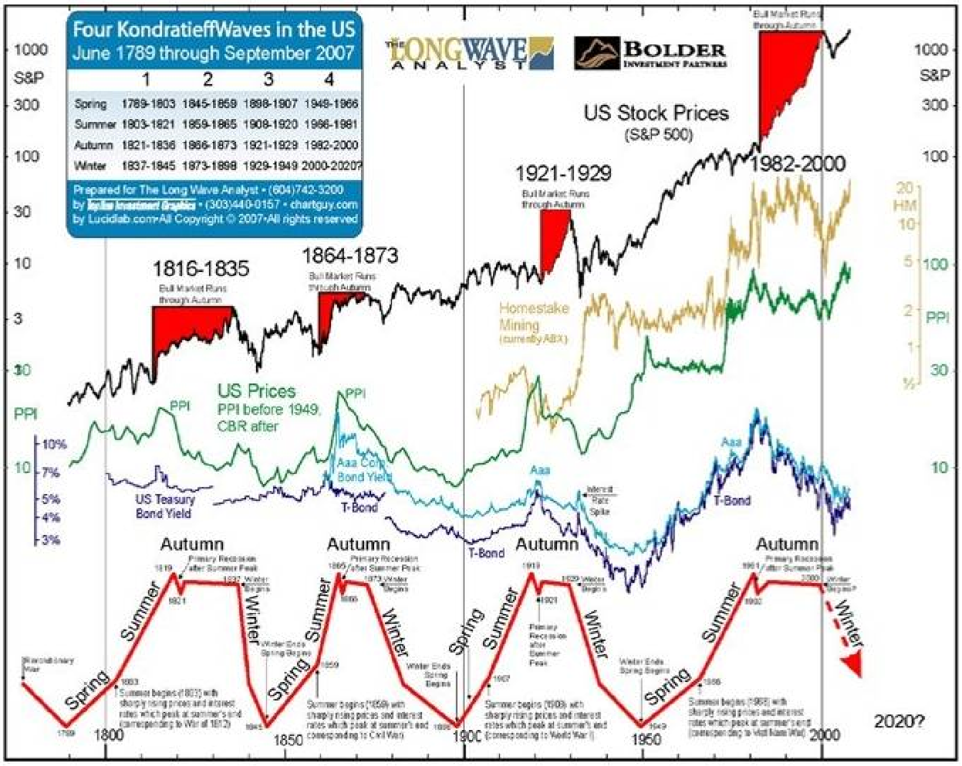



**Figure 4: US patterns on macroeconomic waves according to Kondratieff (source: Lucidlab, 2007)- Note that from 2000 to 2020 an economic decline is expected in the US.**

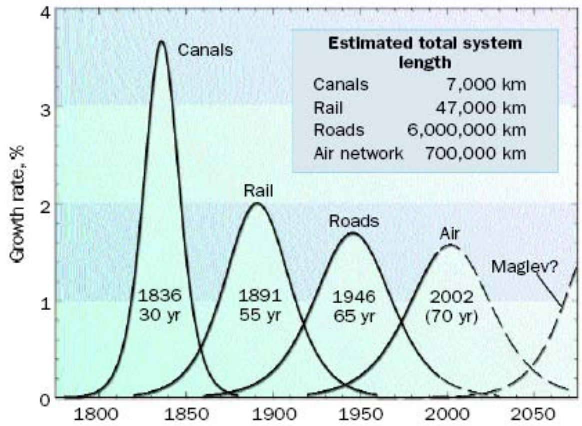



**Figure 3. Smoothed historical rates of growth of the major components of the U.S. transport infrastructure, showing the peak year and the time for the system to grow from 10% to 90% of its extent (conjecture shown by dashed curves).**

**Figure 5: "The evolution of transport", J.Ausubel & C.Marchetti, 2001.**

*Figure 5: Costs of Transportation and Communication*

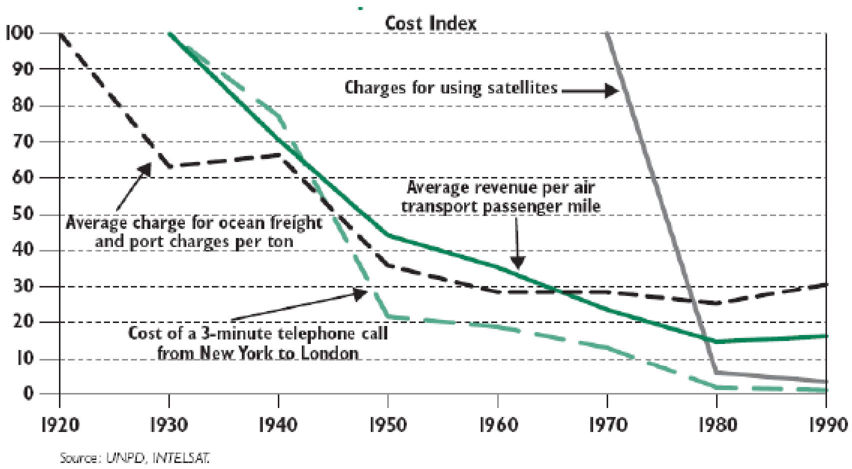



**Figure 6: Source: *UNPD, INTELSAT.***

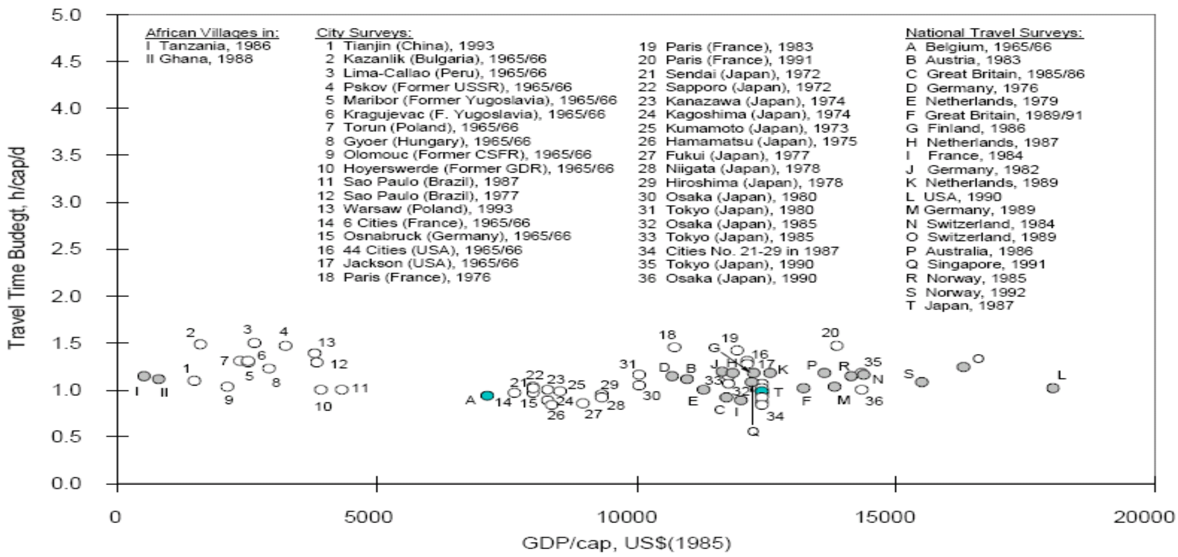



**Figure 7: Patterns on travel time budget (source: ECMT 2002, based on Cesare Marchetti)**

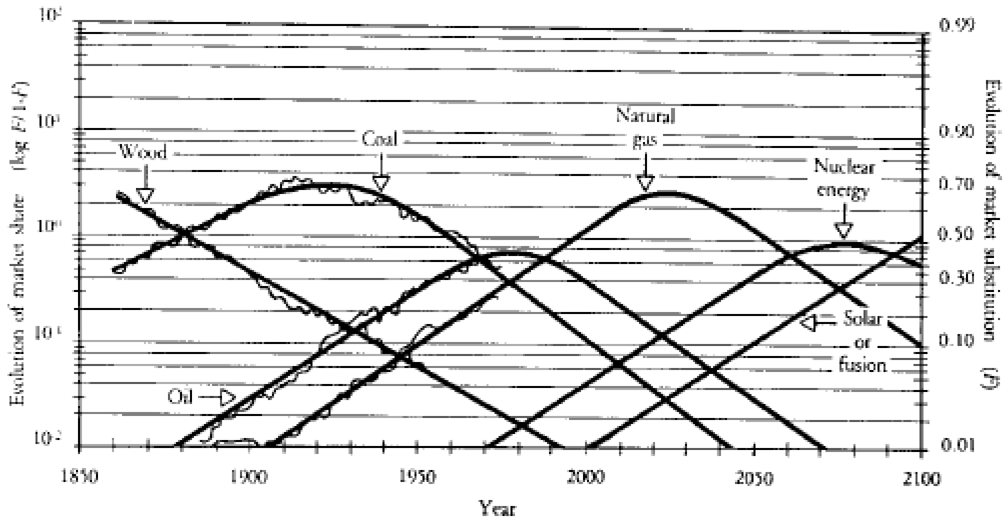



Figure 5. Worldwide use of primary energy sources since 1850. *F* is the fraction of the market (in energy units) taken by each primary-energy source at any given time. The wavy lines represent statistical data. Nuclear energy has not yet penetrated heavily, and the slope is therefore hypothetical. Solar or fusion is hypothetical for both slope and initiation point. Adapted from Marchetti and Nakicenovic, *Dynamics of Energy Systems*. NOTE: For nuclear energy, $F = 0.01$ in 1970 and 0.04 in 2000. For solar or fusion, $F = 0.01$ in 2000 and 0.04 in 2030. Values beyond 1970 are projected.

**Figure 8: "The Future", C.Marchetti, 1988.**

A likely baseline image of Europe in the future

Based on both current trends and general patterns, a likely image of Europe for the future could be:

- Peaceful.
- Stable in demographic terms, within the EU27.
- Ageing population.
- More urbanized.
- Increasing migration from northern countries to southern countries.
- Maintaining social welfare and social inclusiveness.
- Multicultural.
- Enlarged, integrating many neighbouring countries in the East, and South (either becoming "United States of Europe", or a much larger "euro-zone", or both, if a "variable geometry" is adopted).
- In a world with China and India becoming more important players.
- With a public sector staying at its current size, or being marginally reduced.
- With growing pensions, health care and other public services and expenses, making larger infrastructure and research investments.
- Growing exponentially in terms of information exchange.
- Moderate economic growth, with increasing productivity, even if at lower ratios than US and Asia.
- More closely connected to North African countries, where some regions will emerge economically.
- Internal EU policy reforms towards more open markets .

In relation to transport:

- Growing in passenger mobility, especially in all kind of international tourism.
- Growing in freight transport, especially in containers coming from overseas.
- New generations of more specialized vehicles (urban/interurban, private/shared, smaller, cleaner and more intelligent).
- Road as a dominant transport mode, with online pricing and intelligent management systems in place.
- New rail services in dedicated lines linking major ports and logistics areas.
- Increasing volumes of freight from overseas markets.
- Increasing air trips in a more dense network of airports.
- Stable in energy consumption, substituting fossil fuels with renewal sources, while nuclear will increase slightly.
- Reducing $CO_2$ emissions, after a period of stabilization where the improvement of current technologies and traffic management may compensate traffic increases.

# 2. Scenarios towards a postcarbon society

The definition of alternative scenarios is a powerful analytical tool: it provides multiple and contrasting views on the (far) future which is deeply uncertain, while preserving consistency as each scenario is internally consistent.

The quantitative study of TRANSvisions (Task 2), takes qualitative scenarios defined in Task 1 and aims to take into consideration the relatively permanent structural relations and trends shaping the future from the current situation, being well aware of the uncertainty which hides potential problems and opportunities and requires contingent responses.

## 2.1. *Predictive scenarios 2005-2030*

The predictive scenarios considered (up to 2030, as modelled by TRANS-TOOLS) were the following ones:

- Baseline (continuation of existing trends).
- High growth and stable population.
- Low growth and declining population.

Variations of these scenarios to investigate the sensitivity of different policies have also been calculated to measure the impact of infrastructure and pricing policies, in the high-growth and low-growth predictive scenarios.

The description of the scenarios is based on assumptions taken from official forecasts as far ahead as possible; other assumptions are based on previous studies. Different from the exploratory 2005-2050 scenarios introduced later on, predictive 2005-2030 scenarios aim to follow mainstream tendencies in relation to mobility trends and policies, their interest being to consider relatively different social and economic trends, as well as providing a sound foundation to build up the far more risky exploratory scenarios.

### 2.1.1. Baseline

The baseline is essentially a prolongation of existing trends.

The assumptions can be subdivided into socio-economic trends, transport cost assumptions and network assumptions. The socio-economic trends depict the expected development in a number of basic parameters like population, employment, income growth, etc. These are based as much as possible on available sources like EUROSTAT population projections and economic development data from DG ECFIN, and other sources. The transport cost assumptions cover both ongoing policy initiatives as well as possible development paths for variables in the TRANS-TOOLS model reflecting the scenario assumptions. The network assumptions address the infrastructural development.

The baseline assumes a population growth in the EU-27 as indicated in the official population TREND-forecast 2004 from EUROSTAT on NUTS2 level. This forecast is unfortunately rather old, even the basic 2005 figures are changed according to the population censuses already available. The forecasts are also old compared to the UN 2006 forecasts, which are applied outside the EU. The forecasts however are available at the NUTS2 level, which implies taking account of a more diversified development within the countries where NUTS2 forecasts are available. Unfortunately, population forecasts for the UK and France are not subdivided at the NUTS2 level.

In 2005 the total EU population was about 491 million people (Census). In 2020 this is expected to be almost 496m and the population to almost constant up to 2030 (495m). All in all the EU population remains nearly constant. Population in the EU15 will be growing slightly, from 387m to 399m whereas a fall in population is expected in the EU-12 (from 104m in 2005 to 96m in 2030). The highest population growth is foreseen in Ireland, Luxembourg and Cyprus. Outside the EU the forecasts are based on the World Population Prospects 2006 revision from the UN population division. Here, Turkey has the highest population increase and the population in Russia decreases the most.

The population of Europe grows older and the old age group is making up a greater part of the total population. This has the effect that a productive population, which is decreasing, has to feed a fast-increasing non-productive population. In the EU-27 the above 64 age group increases almost 50% up to 2030, while the age group below 18 decreases by 14%, and the productive age group decreases by 7%. There are major differences among the different countries.

The economic development up to 2030 is based on the DG-ECFIN Note 253 of June 2006. The economic development by GDP per capita is fastest in the eastern part of Europe and less in the western part. This is also in line with the development experienced in the last 10 years. The GDP per capita in the EU-15 in 2005 was about 24,000 EUR in constant 2000 prices, expected to increasing to about 37,000 EUR in 2030. In the EU-12 the GDP per capita was about 5,000 EUR in 2005. This is expected to increase to about 13,000 EUR in 2030. The ratio between GDP per capita in the EU-15 and in the EU-12 decreases from 4.7 to 2.9.

Car ownership increases continuously, however with a slightly decreasing growth rate. In the EU-15 the level grows from 483 cars per 1000 inhabitants in 2005 to 553 in 2020 and 594 in 2030. In the EU-12 the rate per 1000 inhabitants increases from 337 in 2005 to 402 in 2020 and 447 in 2030. Car ownership in terms of passenger cars per 1000 inhabitants is estimated based on a car ownership model developed from statistical analysis of the correlation between GDP growth and car ownership development in different countries. This model was established in the TENconnect project and provides a uniform basis for estimating car ownership in the coming years.

It is expected that the world oil price will follow the development indicated by the US Energy Information Administration in their forecast from spring 2008. The price per barrel of oil is expressed in 2006 US$ per barrel which comes out to less than 70€ on average from 2005-2030.

For road transport following cost items are estimated:

- Vehicle operating costs, which is approximated with fuel costs.
- Distance-based costs related to the use of infrastructure.
- Distance-based costs related to internalisation of external costs.

Further travel time is estimated as part of the Level of Service calculation.

A modest improvement of vehicle efficiency is assumed to be about 0.5% per year. These two aspects lead to an expected increase in vehicle operating costs of passenger cars of 7% measured in 2005 prices.

It is assumed that emission-free vehicles will constitute only small proportions of the vehicle fleets, mostly in the major urban areas in the EU-15. It is also assumed that the fuel costs for the emission-free vehicles will follow the cost development for the emitting vehicles.

The use of Intelligent Traffic Systems (ITS) will be widespread, and its applications will help ensure an increase in safety and a better utilisation of congested road systems.

Vehicle operating costs for heavy goods vehicles are combined from many different cost items, like fuel and lubricants costs, maintenance, drivers' salaries, insurance and administrative costs. Time-related costs make up about 2/3 of the costs and the remainder is distance related. The time-related costs are linked to the time level of service data. Fuel costs make up about 1/3 to 1/2 of the distance-based costs. Technological development, improved efficiency both in terms of better utilisation of trucks and more efficient load planning, and finally competition are all reasons for the assumption that distance costs for trucks increase about 4% by 2030 measured in fixed prices.

On top of the time and distance costs different charges and fees are applicable to truck transport, including internalisation fees and motorway charges. The digital tachograph and more efficient enforcement of driving and resting time regulations have lead to more equal competition between transport modes.

It is worth stressing that the TRANS-TOOLS model applies to only two types of road vehicles, passenger cars and trucks. Therefore, cost items related particularly to trucks need to be evaluated, taking into account that the composition of truck fleets is quite different in the different European countries. Charges, as in the example of the German Maut, can also depend on the type of truck. EURO V trucks have a lower km charge than EURO I trucks, and there are also different applicable weight limits. In Germany trucks above 12 tonnes are subject to the Maut, but in Austria the weight limit is 3.5 tonnes.

In the Baseline scenario, infrastructure charging in terms of a cost per kilometre in the road network is limited to the motorway system plus additional major pieces of infrastructure, such as bridges and tunnels. For passenger cars the 2005 charging regime is assumed to be valid also in 2030, that is, the use of the motorway system is generally not charged in Finland, Sweden, Denmark, Germany, Benelux, UK and the Baltic States, whereas charges are applied for using the motorway system in the remaining countries either in terms of vignettes or by direct payment. For road freight, it is assumed that internalisation of external costs is applied throughout Europe in 2030, and motorway charges are applied as a distance cost in most countries. In the vignette countries charges for using the motorway system is paid in terms of a vignette. The vignette countries are the countries mentioned above excluding Germany, which uses a km-charge.

The internalised costs are applied to all links in the road network the internalised costs are only applicable to trucks. It is assumed that the external costs of heavy goods transport is being internalised, taking into account noise, air pollution and congestion. The applied costs were originally developed in the IMPACT project, and made operational by Joint Research Centre (JRC) in the vignette impact study carried out in 2008. The costs applied by JRC has been updated to 2005, and applied in the Baseline scenario.

Consumer prices for rail transport in EU25 have been increasing by 9% in real prices between 1999 and 2006, and consumer prices for bus transport have been increasing at a rate of 17% in the same period. GDP, in constant prices, rose by 17% in the same period. Since TRANS-TOOLS is dealing with rail transport as the public transport mode it is assumed that rail prices in real terms will increase at 50% of the growth in GDP. The fares however, are not assumed to grow by more than 50%. In border-crossing traffic the average growth of the two neighbouring countries is taken as the basis for the fare assessment.

Transport costs for rail freight depend heavily on the capacity costs, such as the cost of administration, cost of networks, and costs of interoperability. For reasons related to competition the development in rail transport costs has followed the development in truck transport costs. In the Baseline scenario it is anticipated that improvement in interoperability of safety systems, internationalisation of drivers' education, improvement of terminal operations and improved utilisation of tracks will all lead to a decrease in freight transport costs by rail of 10%.

Air transport has been the mode with the most modest price increases in the last seven years. In the Baseline scenario, where oil prices are expected to increase only slightly, it is expected that improvements in efficiency, the consolidation of the air transport industry, and the introduction of more efficient aircraft will result in the same airfares in 2030 as in 2005 measured in real prices. This is also a based on the introduction of the Emission Trading Scheme for air transport by 2012

Inland waterway operating costs are assumed to remain constant in fixed prices as are the charges related to use of locks and canals, as well as the costs of using rail terminals is assumed to remain constant in fixed prices.

For maritime transport the costs depend on the developments in areas such as ship acquisition, maintenance, operation, fuel and lubricants. These different cost items have considerably different weights depending on the dimensions and types of the ships. Since TRANS-TOOLS operates with maritime as one mode regardless of the ship, it has been assumed that cost development in the Baseline scenario will follow the development of truck costs, which is an increase of 4% compared to 2005 in real prices.

In order for the TRANS-TOOLS model to function properly, improvement of links of both national and international importance needs to be integrated in the TRANS-TOOLS network. The links proposed to be included in the analysis of the axes are set out below. Extensions and changes to the existing 2005 road and rail network are included.

Transport networks include the links and nodes to which the traffic of the different transport modes is assigned. The networks are also used for calculating the travel/transport time and transport distances between all zones in the TRANS-TOOLS transport model for the different transport modes. An improvement of a link in one of the networks will therefore lead to an improvement in time and/or distance for the transport mode under consideration.

In the Baseline scenario links which have been constructed between 2005 and 2008 and links which are currently under construction or already planned for construction are included. A number of member states have provided input to the maps. Where no direct communication with member states occurred, the national plans have been used as the basis for appointing the projects. It has however been quite difficult to assess if a project has reached a final status. Therefore, the baseline is a conservative estimate of what could be accomplished. The many projects considered priority projects, such as Pan-European Corridors, but not yet finalised have been included in the High Growth scenarios.

The roads indicated on the maps are road projects improving the main road network. Two different types of road works are foreseen; new construction and changes of existing infrastructure. All changes assumed are depicted.

Most of the changes are related to roads changing class or speed. A class change changes the attributes on a road link, e.g. moving from ordinary two-lane road to expressway or motorway standard, or moving from a four lane motorway to a motorway with six or more lanes. Although it is obvious that a motorway is not constructed in exactly the same alignment as an existing two lane road, it is assumed that the change in length is negligible. If roads are constructed in completely new alignments this is termed “New Roads”.

The road and rail networks assumed in the Baseline scenario are indicated in the following maps.

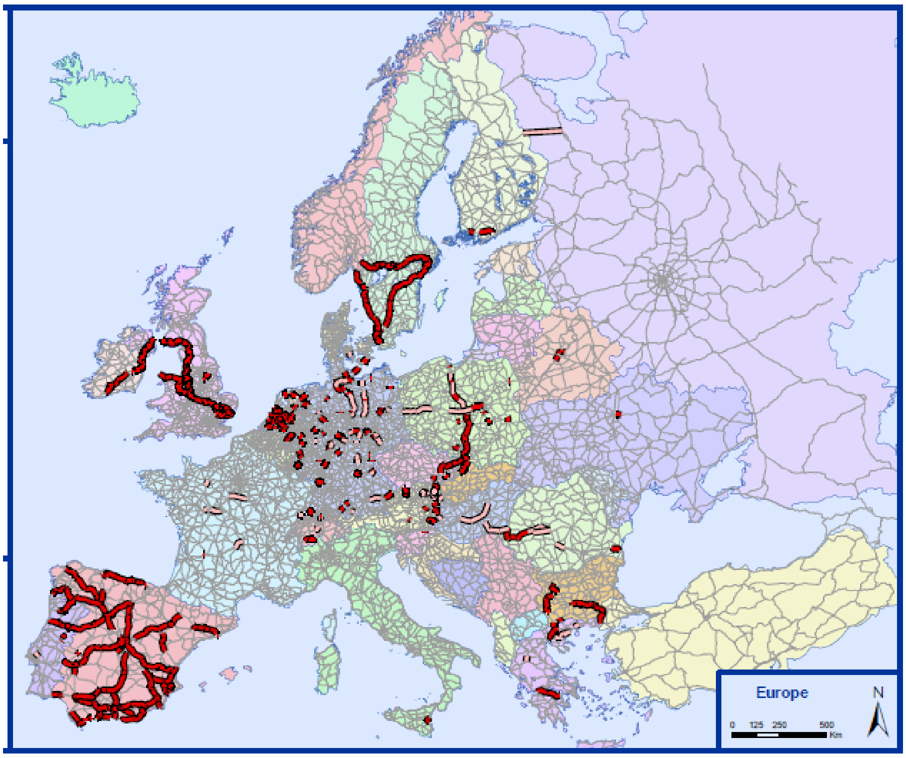


**Figure 9: New and upgraded Road infrastructure development in Baseline, 2030**

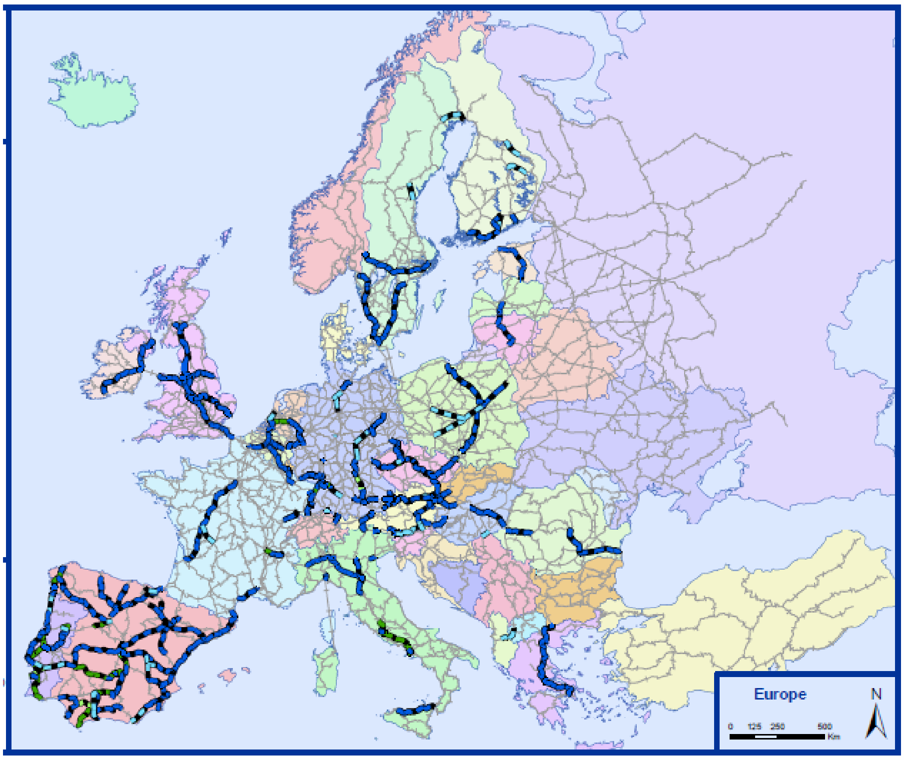



**Figure 10: New and upgraded rail infrastructure development in Baseline, 2030**

## 2.1.2. High Growth scenario

The High Growth scenario is based on elements giving priority to cohesion (higher economic growth, and improvement of infrastructure particularly in the EU-12) and elements based on competition (each mode of transport paying its own costs). The scenario, thus, is a combination of local and global interests which work together with environmental and social interests to create a sustainable Europe.

It is assumed that the population development will follow the 2004 EUROSTAT forecast on NUTS2 level with high population growth. This means that the population of Europe will grow with approximately 5% above the baseline up to 2030 (523m in the EU-27). The distribution by age group is quite different from the baseline, in particular the "below 18" segment is increasing compared to the 2030 baseline.

Economic development will be supported both by cohesive measures, which will ensure faster economic development in the cohesion countries, as well as global development which will provide for an increased economic growth in the centrally located member states. Economic development, measured in GDP per capita, will therefore grow to about 33,000 EUR and about 38,000 EUR in the EU-15 in 2020 and 2030 respectively. In the EU-12 the development will result in a GDP per capita of 10,000 EUR and 14,000 EUR in 2020 and 2030 respectively.

Due to the increase in population and the increase in GDP car ownership is expected to grow from 483 passenger cars per 1,000 inhabitants in EU-15 to 556 in 2020, and 601 in 2030. In the EU-12 the growth is faster, going from 337 in 2005 to 405 in 2020, and 458 in 2030. Car ownership per country is indicated in the figure below compared to the 2030 baseline.

The price of oil is expected to remain at the high level observed in 2008. At the same time, however, the payment regime related to the environmental and social dimension in the EU is expected to be implemented, and this is extended with a climate change-related charge on $CO_2$ emissions.

Concerning transport costs, which are here in 2005 prices, in the High Growth scenario the fuel efficiency of passenger cars is actively being improved through a research and development strategy, which increases fuel efficiency with about 40%. In the high growth alternative the price of oil is expected to be higher than in the baseline because higher economic growth puts more strains on resources. It is assumed that the overall effect is a fuel cost for passenger cars which remains at the level of 2005.

For road transport the following cost items are estimated:

- Vehicle operating costs, which is approximated using fuel costs.
- Distance-based costs related to the use of infrastructure.
- Distance-based costs related to internalisation of external costs.

Increased travel time is estimated as part of the Level of Service calculation. For passenger transport, the value of transport time is endogenously forecasted using the level of GDP increase in each country. For goods transport, value of time is included in the distance costs referred to below.

Technological innovation also makes vehicles such as trucks more efficient, which has a considerable impact on fuel consumption. However, the cost of freight transport depends on other cost items too, but increasing driver and operating costs are counteracted by efficiency gains mainly due to intelligent transport systems and application of systems that increase the utilisation of vehicles. In some countries the 60-tonne modular hauling truck is introduced, which also produces efficiency gains. For trucks the VOC is assumed to be at the same level as in 2005, measured in constant prices.

In the High Growth scenario it is assumed that the tolls and charges applicable to road traffic in 2005 are still applicable in 2030. Infrastructure charging based on cost recovery is assumed to have been introduced in the vignette countries for heavy trucks. The level of charges is 50% of the German Maut, corresponding to 0.06 Euro per km on motorways. The vignette countries are the UK, the Netherlands, Belgium, Luxembourg, Denmark, Sweden, Finland, Estonia, Latvia and Lithuania.

Internalisation of external costs is also assumed in the High Growth scenario, for both commercial trucks and passenger cars. The internalisation for passenger cars is introduced because the high economic growth produces more mobility and thus more adverse effects on climate, urban environment, safety, etc., and therefore passenger cars will have to contribute to the payment of these costs.

Internalisation is based on internalising the cost of noise, air pollution, congestion and $CO_2$. A uniform rate of 0.04 Euro per km is applied for heavy goods vehicles for the $CO_2$ internalisation. For vehicles, internalisation is assumed to be 5% of the external costs of noise and air pollution of heavy goods vehicles, and on top of that the external costs for passenger cars related to congestion are internalised. For $CO_2$, a contribution of 0.01 Euro per km is applied. The 5% passenger car internalisation for noise and air pollution is about the same that can be found in the IMPACT study handbook.

It is also assumed that more than 10% of the European car fleet will be emission-free or using bio-fuels in 2030.

For rail passenger fares the assumptions made in the Baseline scenario are also valid for the high-growth predictive scenario.

For rail freight transport, the costs will be influenced by a higher cost-recovery charge. This is assumed to make the rail freight transport cost equal to the cost in 2005, measured in fixed 2005 prices.

In the high growth alternative, fuel prices are higher than in the baseline, and economic activity is also higher. The air transport industry is fuelled by a considerable growth in tourism both within the EU and from abroad, but particularly from the countries with emerging economies into Europe. In spite of a high level of research and development, the economic conditions and demand for air transport favour a higher price, and this is reflected in a 20% increase of the airfares in real prices compared to 2005.

It is assumed that for maritime transport costs will increase by 15%.

For inland waterways no changes in transport costs are foreseen.

On the other hand, in the High Growth scenario a more comprehensive infrastructure development than foreseen in the baseline is assumed. The 30 priority projects are assumed finished as are a number of other projects of importance for the unity of Europe.

The road and rail networks assumed in the High Growth scenario are shown in the following figures:

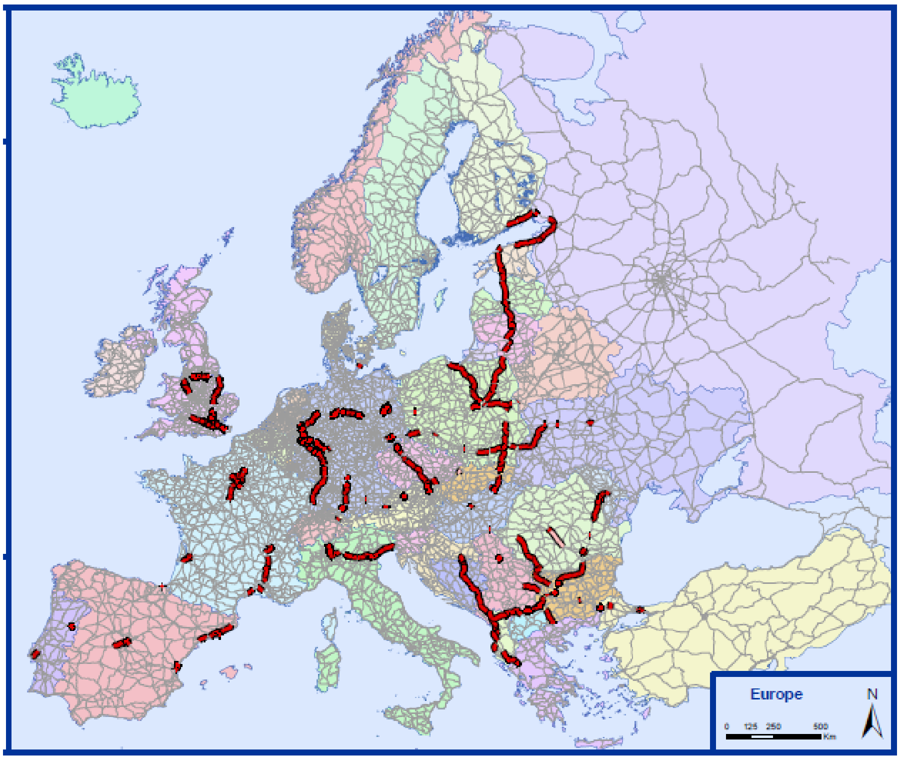



**Figure 11: Road infrastructure development in the High Growth scenario compared to baseline, 2030**

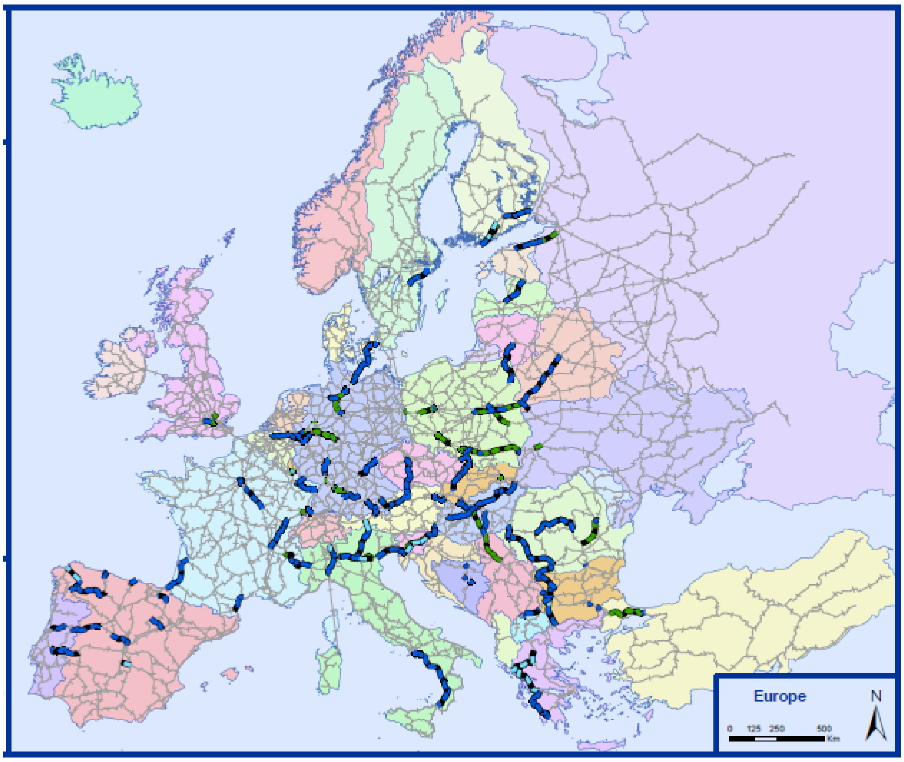



**Figure 12: Rail infrastructure development in the High Growth scenario compared with Baseline, 2030**

### 2.1.3. High Growth scenario with higher infrastructure investment

A policy scenario based on the High Growth scenario has been developed assuming a further development of the infrastructure in the EU and neighbouring countries. This goes for both roads and railways. All other assumptions made for the High Growth scenario are unaltered.

The development of the road and rail networks in this maximum infrastructure scenario is shown in the following maps.

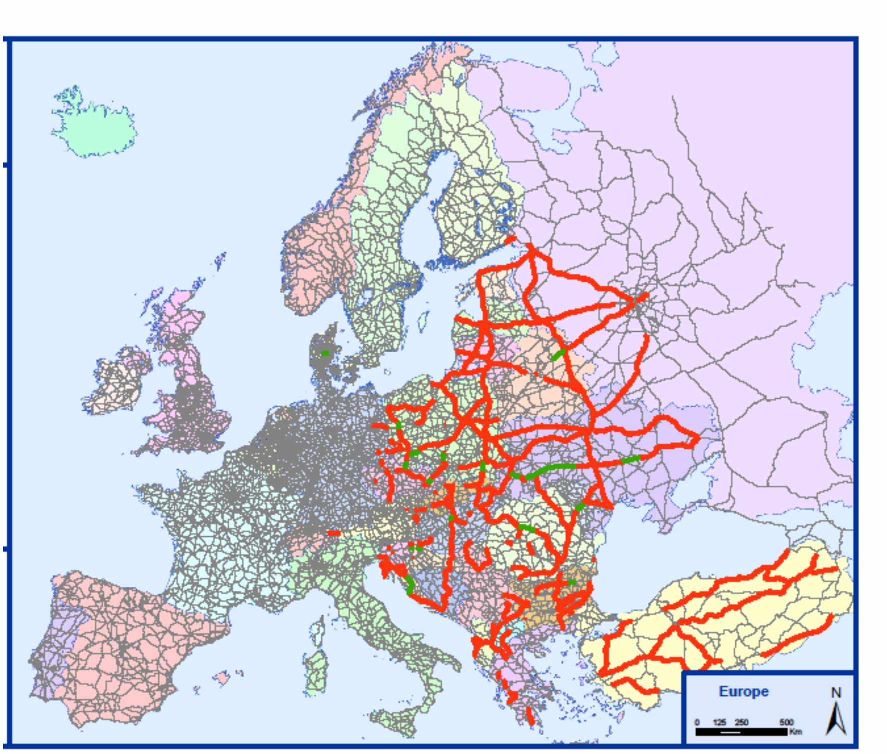



**Figure 13: Road infrastructure development in High Growth policy-scenario compared to High Growth scenario, 2030 (in red new road capacity increases, green road upgrades)**

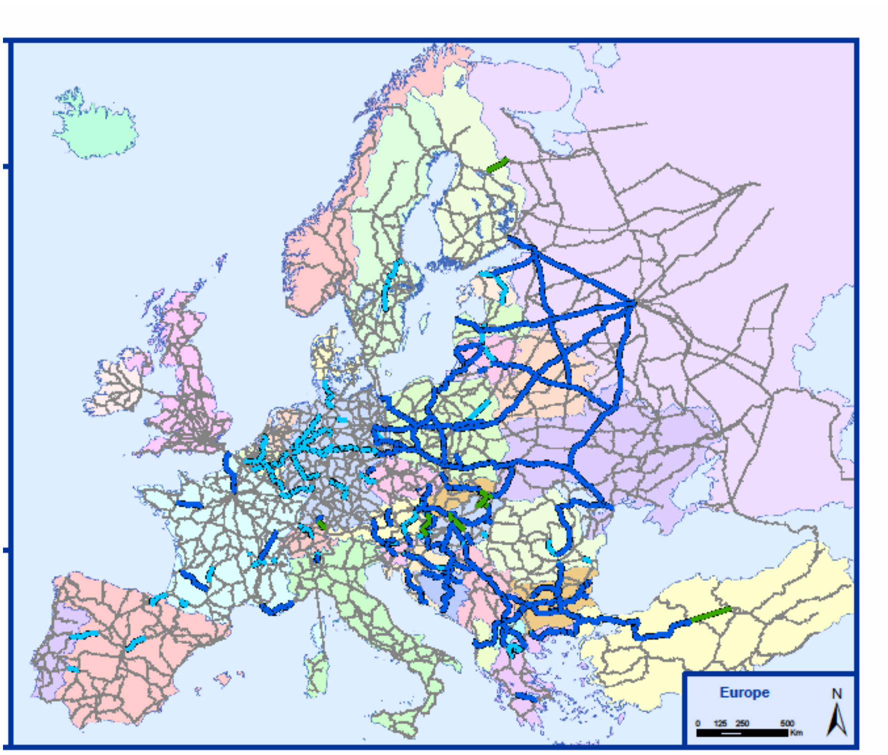


**Figure 14: Rail infrastructure development in High Growth policy-scenario compared to High Growth scenario, 2030 (in dark and pale blue rail upgrades for passenger and freight lines respectively).**

### 2.1.4. The Low Growth scenario

The Low Growth scenario is characterised by low economic development, further emphasized by negative population growth. Low growth is experienced due to the increasing costs of energy—particularly oil. Europe’s answer to increasing energy costs is mobility reduction because of higher operating costs they incur.

It is assumed that the population development will follow the 2004 EUROSTAT forecast on NUTS2 level with low population growth. This means that the population of Europe will decrease by approximately 6% in relation to baseline up to 2030 (464m in the EU-27).

The age group development by EU country compared to the Baseline scenario is indicated in the following graph. Population in all age groups in all member states declines but the biggest decline is seen in the age group 1-18, where there is a total decline of 17% in EU-27. The productive age group declines by 4% and the old age group by 3%.

The economic development per capita is assumed to reach 40% of the high growth level. Moreover, with the declining population this means a total increase in GDP in the EU-27 of 20% in real prices up to 2030. In comparison, the increase in the Baseline was 61% and in the High Growth scenario 77%.

Consequently, car ownership is also considerably less in the Low Growth scenario. In the EU-27 the level is assumed to be 490 compared to 552 in the Baseline scenario.

The price of oil in fixed terms is assumed to increase to a high level. This has an impact both on the general economy but particularly on the transport sector.

Research and development initiatives are in line with the baseline, but the fuel cost for passenger cars is expected to be at a level 35% higher than in 2005, in constant 2005 prices. In addition, it is assumed that distance-based transport costs for heavy goods vehicles increase by 20% in constant 2005 prices.

It is assumed that the network is the same as in the Baseline scenario. However, cost recovery for heavy goods vehicles is being anticipated in the vignette countries, at the same level as indicated in the High Growth scenario. The introduction of cost recovery is assumed a necessity in order to carry out necessary maintenance and reconstruction of the network under low growth conditions.

Internalisation is also anticipated in the Low Growth scenario at the same level as in the Baseline scenario. Therefore the Low Growth scenario assumes internalisation of noise, air pollution and congestion with the same values per km as indicated in the Baseline scenario.

Passenger rail fares are expected to be the same as in the Baseline scenario. For rail freight the rail transport costs are assumed to increase mainly because the improvements in rail technology and cross border operations are not advancing as fast as in the Baseline scenario. An increase in rail transport costs of 10% has been assumed.

The air transport industry is under strain because of high oil prices and a slow economic development. In order to ensure profitability of the business the 2005 airfares are assumed to have increased by 30%, measured in real terms.

For freight transport by inland waterways the transport costs are unchanged compared to the Baseline scenario.

It has also been assumed that maritime transport will develop along the same path as truck transport, which means that maritime transport costs are assumed to increase by 20% in real terms.

It is assumed that passenger cars are also contributing to cost recovery on motorways. The cost recovery is 0.02 Euro per km, and it is only applicable in the vignette countries and Germany. The internalisation of external costs is also introduced for passenger cars, at a level of 5% of noise and air pollution costs for heavy goods vehicles plus congestion costs for passenger cars.

### 2.1.5. Low Growth policy-scenario, with higher road pricing

A policy scenario based on the Low Growth scenario has been developed assuming higher road pricing. All other assumptions made for the High Growth scenario are unaltered.

In conclusion, the fundamental hypothesis for the predictive scenarios to be modelled by TRANS-TOOLS can be summarised in the following table:

| Scenario | Baseline | Baseline | High-growth | High growth with infrastructure policy | Low growth | Low growth with road pricing policy |
|---|---|---|---|---|---|---|
| Year | 2020 | 2030 | 2030 | 2030 | 2030 | 2030 |
| **Transport cost relative to 2005:** | | | | | | |
| - Rail and bus fare | 50% GDP (max. 30%) | 50% GDP (max. 30%) | 50% GDP (max. 30%) | 50% GDP (max. 30%) | 50% GDP (max. 30%) | 50% GDP (max. 30%) |
| - Passenger car fuel cost | 7% | 7% | 0% | 0% | 35% | 35% |
| - Air fare | 0% | 0% | 20% | 20% | 30% | 30% |
| - Truck driving cost | 4% | 4% | 0% | 0% | 20% | 20% |
| - Rail freight cost | -10% | -10% | 0% | 0% | 10% | 10% |
| - IWW freight cost | 0% | 0% | 0% | 0% | 0% | 0% |
| - Maritme transport cost | 4% | 4% | 15% | 15% | 20% | 20% |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Zonal data relative to 2005:** | | | | | | |
| - Population | 0,6% | -0,2% | 7,2% | 7,2% | -6,4% | -6,4% |
| - Employment | 0,0% | -1,1% | 6,2% | 6,2% | -7,2% | -7,2% |
| - GDP, Europe | 44,2% | 75,6% | 92,5% | 92,5% | 37,3% | 37,3% |
| - GDP, Overseas | 55,8% | 129,0% | 129,0% | 129,0% | 129,0% | 129,0% |
| - Carownership (average) | 18,6% | 29,4% | 32,1% | 32,1% | 19,8% | 19,8% |
| - CAP | 0% | 0% | 0% | 0% | 0% | 0% |
| **Networks:** | | | | | | |
| - Road | Baseline 2030 | Baseline 2030 | High growth 2030 | High growth var 2030 | Baseline 2030 | Baseline 2030 |
| Passenger km cost | as in 2005 | as in 2005 | as in 2005 | as in 2005 | as in 2005 | as in 2005 |
| Passenger km internalisation | 0 | 0 | 25% of truck intern | 25% of truck intern | 0 | 25% of truck intern |
| Passenger km cost recovery vignette countries | 0 | 0 | 0 | 0 | 0 | 0,02 Eu on motorways |
| Truck km cost | as in 2005 | as in 2005 | as in 2005 | as in 2005 | as in 2005 | as in 2005 |
| Truck km internalisation | IMPACT table | IMPACT table | IMPACT table + 0,04 Eu | IMPACT table + 0,04 Eu | IMPACT table | IMPACT table |
| Truck km cost recovery vignette countries | 0 | 0 | 0,06 Eu on Motorways | 0,06 Eu on Motorways | 0,06 Eu on Motorways | 0,06 Eu on Motorways |
| - Rail passenger | Baseline 2030 | Baseline 2030 | High growth 2030 | High growth var 2030 | Baseline 2030 | Baseline 2030 |
| - Rail freight | Baseline 2030 | Baseline 2030 | High growth 2030 | High growth var 2030 | Baseline 2030 | Baseline 2030 |
| - Air | 2005 | 2005 | Extra low cost lines | Extra low cost lines | Extra low cost lines | Same as low growth |
| - IWW | 2005 | 2005 | 2005 | 2005 | 2005 | Same as low growth |

**Table 1:Overview of assumptions in the TRANSvisions' Reference scenarios**

The mid-term predictive scenarios are integrated into a long-term 2005-2050 exploratory framework, as explained in the next chapter.

## 2.2. *Exploratory scenarios 2005-2030*

Four alternative exploratory scenarios have been defined to analyse extreme but plausible paths towards a post-carbon society:

- **The organisational path ("Moving Together" or Decoupled Mobility scenario)** This is the continuation of the predictive scenario "*High growth and stable population* ", combining relatively high economic growth with strong social sustainability. **Balanced policies are applied**, with emphasis on pricing and modal shifts, as well as public-private partnerships. There is an overall optimism in the capacity of public institutions to implement cost-effective policies, and adapt themselves according to the *subsidiarity principle*. There is a gradual process to reduce $CO_2$ that has no negative impact on GDP.

- **The behavioural path ("Moving Less" or Reduced Mobility scenario)**. It is the continuation of 2030 scenario "*Low growth and declining population*"), combining weak economic growth with strong social and environmental sustainability. **Behavioural policies that reduce demand for motorised transport are applied**. Strict speed limits on roads and land-use regulations lead to an increase in public transport. Long-distance traffic is reduced in relation to short-term trips. There is a fast process to reduce $CO_2$ from the early stages, but also a relative economic decline measured in terms of GDP.

- **The technological path ("Moving Alone" or Induced Mobility scenario)**. High growth and a small increase in population due to immigration from 2005 to 2050. Combines strong economic growth with weak social sustainability. **Policies have an emphasis on technology, supply-side management and spontaneous market self-organisation**. $CO_2$ emissions are reduced mostly because of new technologies, and therefore $CO_2$ still grows during the first years.

- **The mandatory path ("Stop Moving" or Constrained Mobility scenario)**. Very high growth and an increase of population due to migration until 2030, and then a "**bottleneck**" is reached because of structural reasons. Examples are a lack of public investment in infrastructure or failure to implement new technologies in vehicles or traffic management, leading to an economic decline. It is attached to a pessimistic vision regarding the capacity of European institutions to carry out structural reforms. From 2030 to 2050, the scenario combines weak economic growth with weak social sustainability. **Non-cost-effective regulations and bans are applied to constrain mobility, in order to release congestion and reduce emissions, such as strict and expensively priced Emission Trading Markets**. The economy is depressed, and taxes cannot be raised. This scenario can be understood as a failure on the technological path ("Moving Alone" or Induced Mobility scenario).

### 2.2.1. Comparison between exploratory scenarios

The next graphic represents the political and social values emphasised by each scenario, simplified as "happy/unhappy" for social aspects and "growth/decline" for economic aspects. Please note that all axes are relative to the baseline, which does not mean that the Baseline scenario favours all political emphases equally, just that the other scenarios are pictured relative to the baseline values.

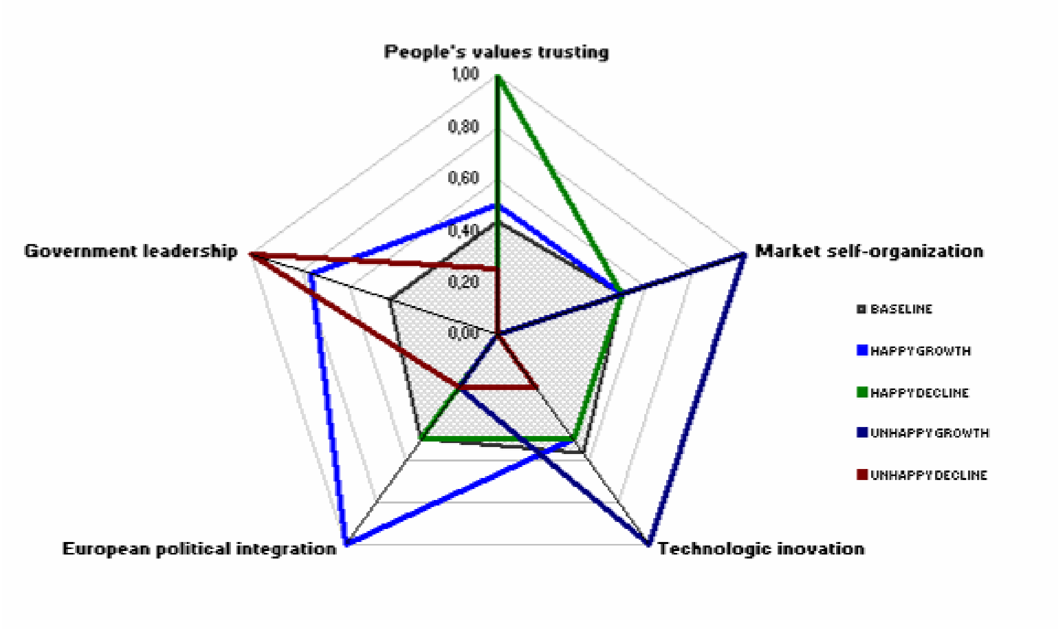



**Figure 15: The exploratory scenarios pictured in the TRANSvisions asset pentagon**

In order to define the alternative exploratory scenarios, scenarios defined in recent studies have been reviewed. Most of them are related to the European context, although some are broader.

| | | |
|---|---|---|
| UK OFFICE SCIENCE & TECHNOLOGY | | Perpetual Motion |
| | | Urban Colonies |
| | | Tribal Trading |
| | | Good Intentions |
| FORWARD STUDIES UNIT "Five different futures for Europe" | | Triumphant Markets |
| | | The Hundred Flowers |
| | | Shared Responsibilities |
| | | Creative Societies |
| | | Turbulent Neighbourhoods |
| CPB, "4 FUTURES 4 EUROPE" | | Strong Europe |
| | | Transatlantic Market |
| | | Regional Communities |
| | | Global Economy |
| EMCC. "Trends and drivers of Change in the EU transport and logistics sector:scenarios" 2008 | | Take the A-Train |
| | | I'm in love with my car |
| | | Riding the rainbow |
| | | Moonlight ride in a Diesel |
| ESPON 3.2. | | Pro-active Europe |
| | | Cohesion-oriented (Danubean Europe) |
| | | Competitiveness-oriented (Rhine-Rhone Europe) |
| UN GEO-3 | | The Markets First |
| | | Policy First |
| | | Security First |
| | | Sustainability First |
| MEDACTION | | Knowledge is King |
| | | Big is beautiful |
| | | Convulsive Change |
| GLOBAL SCENARIO GROUP | | Market Forces |
| | | Policy Reform |
| | | Great Transitions |
| | | Fortress World |
| MILLENIUM PROJECT SCENARIOS | | S&T develops a Mind of its Own |
| | | The World Wakes Up |
| | | Please, turn off the Spigot |
| | | Backlash |
| JAMES MARTIN | | Fortress America |
| | | The Strong Nation Clubs |
| | | Triage |
| | | Compassionate World |
| GLOBAL FUTURE ANALYSIS | | Doing nothing |
| | | Extending the past |
| | | Reinventing prosperity |

**Figure 16:** Reference scenarios**.**

The next two graphics map all these scenarios in terms of economic performance versus social welfare in one case, and environmental awareness on the other. Different scenarios are coloured similarly according to affinities between them: technology and economic performance-driven scenarios are red, ecologically driven scenarios are green, welfare scenarios are blue and decadence scenarios are grey.

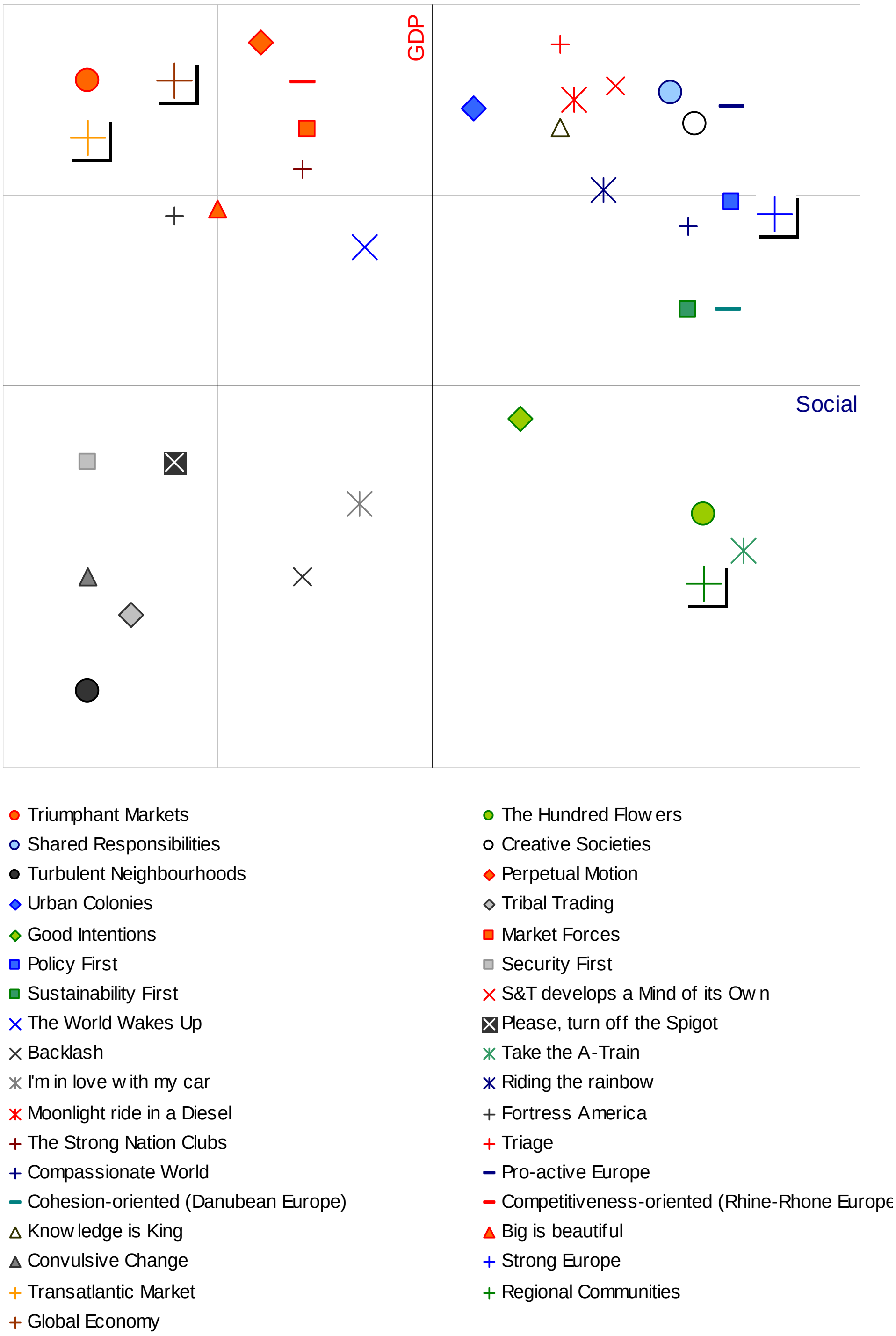



**Figure 17: Scenarios mapped on economic and social axes**

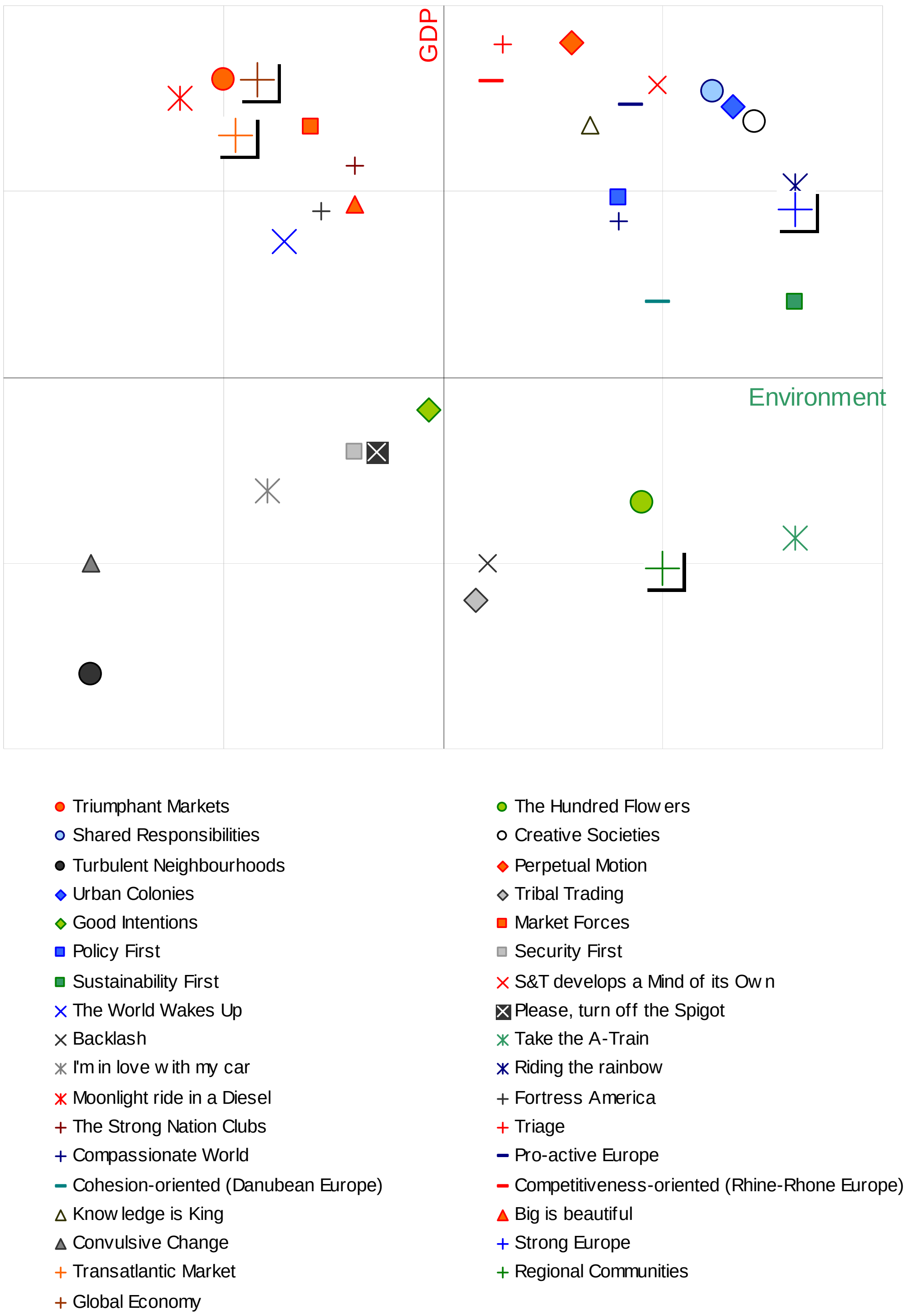



**Figure 18: Scenarios mapped on economic and environmental axes**

The exploratory scenarios are now described further, as working-hypotheses to be validated/adjusted later on by the quantitative forecasts. All four scenarios are defined as alternative paths towards a post-carbon society, so in the end all four share the same environmental values, even if they diverge in terms of social and economic values.

### 2.2.2. The behavioural path: "Moving Less" or Reduced Mobility

*Scope*

- Environmental concern: $CO_2$ has to be reduced as much as possible in the shortest time.
- Changes in behaviour: policies aiming to modify users and firms' mobility decisions are effective, complemented by restrictive policies whenever needed.

*Similar scenarios*

- "The Hundred Flowers" (Forward Studies Unit)
- "Regional Communities" (CPB)
- "Take the Train" (EMCC)
- "Sustainability First" (UN GEO-3)

*Population dynamics*

- Decrease of total population.
- Low level of immigration.
- Very strong ageing.
- Cities become more compact. Some detached self-sufficient communities.

*Socio-economy and technology dynamics*

- Technology improvements are limited, focused on environmental and safety conditions, as well as on organisational aspects.
- Productivity gains are limited.
- Companies do more local business, following the consumer's increasing environmental awareness.
- Low relative growth of trade, due to the increasing protection of imports to encourage local production.
- Tourism grows more locally.
- Unemployment is marginal, since work is distributed across active population. Less working-hours per day.

- Increase of ecological taxes, and reduction of income-based taxes.
- GDP decreases, but global well-being may increase due to the internalisation of the environmental externalities of economic development.
- GDP gap across European regions is slightly reduced.
- The structure of regional economies becomes more balanced.

*Transport, energy and other mobility-related policies*

- Efforts on environmental education to reduce unnecessary mobility.
- Pricing and regulation to induce self-organisation in mobility demand.
- Better maintenance and management of existing infrastructure, giving priority to public transport.
- Moderate increase in local infrastructure, especially in clean public transport.
- Strict land-use policies to avoid urban sprawl.
- Large tax increases on fossil fuels and subsidies for renewable energy.
- Technology development focused mostly on safety and environmental efficiency.

*Mobility and energy*

- GDP elasticity of passenger transport decreases because of land-use policies and behavioural attitudes.
- GDP elasticity of freight transport decreases because markets grow mostly locally.
- Average trip length decreases, because the relative decline of long-distance trips increase in relation to short-distance.
- Transport prices increase, especially in the short term on roads.
- More use of renewable resources, even if not economically efficient, as well as electric and hydrogen-powered vehicles. No nuclear facilities are built. Oil is progressively less used, even before it reaches what would be its natural peak. Solar energy grows in the long-term. More decentralised production facilities and self-sufficient activities.
- Congestion increase in the short term, due to the lack of road and airport infrastructure capacity increases, decreasing notably afterwards when behavioural changes occur.
- Vehicle occupancy increases, since trips are optimised.
- Emission factors improve because technology is oriented to achieve this goal.

*Storyline*

- 2010-2020: Behavioural policies have implementation problems. Diversification of energy sources. Emphasis on land-use and mobility regulation. $CO_2$ emissions grow at a lower ratio. Decline in GDP.

- 2020-2030: Emphasis on pro-active policies to reinforce behavioural policies. Land-use policies start to be effective. Important reduction of $CO_2$ emissions. Increasing importance of local markets. Increase in renewable technologies. GDP becomes stabilised.

- 2030-2040: Continuation and intensification of the previous trends. Emergence of new technologies bringing sustainable economic growth. Zero-carbon economy practically achieved.

- 2040-2050: Stable and sustainable growth is maintained.

### 2.2.3. The technological path: "Moving Alone" or Induced Mobility

*Scope*

- Exponential growth of technology: substitution of oil by more efficient and clean energy sources leads to $CO_2$ reductions in the long term.
- Technology reaches a "singularity" in 2045, leading to unlimited information (following the exponential increase in computer processing power) and unlimited and cheap energy (from petroleum-based to fusion and solar).
- Focus on economic growth.

*Reference scenarios*

- "Perpetual Motion" (UK office of Science and Technology)
- "Triumphant Markets" (Forward Studies Unit)
- "Global Economy" (CPB)
- "Transatlantic Market" (CPB)
- "Moonlight Ride in a Diesel (EMCC)
- "Rhine-Rhine, Competitiveness-oriented" (Espon 3.2)
- "The Markets First" (UN GEO-3)
- "Big is Beautiful" (MedAction)
- "Market Forces" (Global Scenario Group)

*Population dynamics*

- Moderate increase of total population.
- High increase of immigration, especially skilled workers.
- Marked ageing, but limited due to immigration.

- Emigration from north to southern “Sun Belt” regions.

*Socio-economy and technology dynamics*

- Technology increases productivity, thus boosting economy measured as GDP.
- High economic growth allows financing more research and spurs innovation.
- Globalisation process continues, with companies tending to delocalise production factors.
- External trade grows in volume and value, following globalisation patterns.
- Overseas tourism increases, both in volume and length of trips as transport costs are reduced relative to income levels.
- Unemployment levels are kept at about 10%, lifestyle changes force reforms in the labour market that delay retirement age.
- Economic disparities across regions become more marked as GDP gap increases.
- Regional specialisation.
- Enlargement of EU continues in the Balkans and Eastern Europe.

*Transport, energy and other mobility-related policies*

- Transport development follows demand.
- Increase of infrastructure stock, for both roads and public transport.
- Better management and more intelligent transport systems.
- Online pricing is generally available for all transport modes.
- European policies are reformed towards a more intensive liberalisation.

*Mobility and energy*

- The GDP elasticity of passenger transport increases as urban sprawl continues and personal wealth grows.
- GDP elasticity of freight transport increases because globalisation patterns continue, as well as regional specialisation.
- Support of R&D to develop cheaper and more efficient just-in-time global transport.
- Transport prices decrease as new technologies allow the abandonment of carbon-based fuels and moving to cheap $CO_2$-free energy sources.
- Support of renewable resources that have high economic efficiency.
- Congestion increases in the short term as well as $CO_2$ emissions, but investments in capacity increase and new energy sources allow a mid and long-term reduction of congestion and $CO_2$ emissions, even though traffic levels keep increasing.
- New vehicles provide faster, cheaper and cleaner transport.

- Continuous growth of ICT leads to increasing social and economic relations worldwide, leading to more personal and freight trip demand.
- Vehicle occupancy decreases following the individualism of society, mainly because of the need of flexibility and transport price reduction.
- Increase in average trip length due to delocalisation.
- Increases in wealth and in travelling speeds leading to longer or more frequent trips.

*Storyline*

- 2010-2020: A very efficient market economy overcomes institutional constraints, or forces institutions to adopt structural reforms, more open and flexible markets, resulting in high growth of the GDP. Emerging technologies increase the productivity of the economy, also in relation to the transport sector. Ongoing congestion levels and uncertainty in oil prices stimulates the support of research in new energy sources and increases the infrastructure stock. A mix of nuclear energy, clean coal and renewable energy supply, as well as the first introduction of cleaner fuel technologies (e.g. hydrogen fuel cells), assures energy provision. Existing transport vehicles are improved and reduce their $CO_2$ emissions, but do not compensate for the growth in traffic, especially on roads. Intelligent traffic management systems have a significant importance in relieving congestion and increasing speed.

- 2020-2030: The diversification of energy sources, complemented by an open market policy allows for the continuous growth of the economy and traffic levels. European regions tend to specialise and economic and social disparities may increase. Emergence of new technologies in the transport sector, such as electric and hydrogen cars or the implementation of online pricing. There is a huge improvement of the efficiency of existing car engines. Renewable resources become more efficient. Huge productivity gains achieved thanks to ICT. Public investments strictly follow cost-benefit analyses (CBA). More public-private partnerships in the construction and management of transport infrastructures. Use of the most cost-effective technologies to reduce emissions.

- 2030-2040: Continuation of the previous liberalisation trends, with creation of economic poles. Retirement age increases but labour becomes more flexible. Welfare is not well balanced among people. Increasingly stressful and exciting way of life. Emergence of new energy sources, such as solar and/or nuclear fusion, providing cheaper, unlimited energy. There is a high travel demand, 24/7 “always on” society. Computers reach a capacity beyond that of humans.

- 2040-2050: The development of IT with virtually infinite capacity and almost free energy boosts GDP and traffic levels. Zero-carbon economy practically achieved.

### 2.2.4. The mandatory path: “Stop Moving” or Constrained Mobility

*Scope*

- Economic failure due to a very slow process of technological implementation and lack of capacity of public administration to undertake structural reforms. The necessity of peak-oil or energy shortages is not felt.
- Welfare systems break down partially due to governments’ incapacity to face increasingly expensive pensions and health expenses. Long-term investments on research and infrastructure are reduced, leading to decreasing productivity rates.
- Changes in travelling patterns: strong regulation and legislation on mobility with heavy taxation and implementation of expensive carbon credits.

*Similar scenarios:*

- “Good Intentions” (Office of Science and Technology, UK study)
- “Turbulent Neighbourhoods” (Forward Studies Unit)
- “I’m in Love With my Car” (EMCC)
- “Security First” (UN GEO-3)
- “Convulsive Change” (MedAction)
- “Fortress World” (Global Scenario Group)

*Population dynamics*

- Very low increase of total population.
- Very low immigration.
- Marked ageing of population.

*Socio-economy and technology dynamics*

- GDP follows a short-term high growth pattern, but the lack of long-term sustainability planning leads to a sudden decline of the economy.
- Productivity gains are very low and decline over time.
- Trade levels grow marginally, mainly due to stagnation of economy.
- Tourism becomes more locally-oriented and sees very few increases.

- Unemployment grows as economy gets worse.
- GDP gap is reduced due to the introduction of carbon entitling system.

*Transport, energy and other mobility-related policies*

- Very low productivity due to the lack of public investments as well as the very low market implementation of new technologies.
- Strong taxation of GHG emissions and lack of non-carbon energy sources, as well as GDP decline, producing a mid-term reduction of traffic.
- Pricing and regulation intend to reduce high congestion levels and $CO_2$ levels.
- Very strict land-use regulation leads to more compact urbanisation and thus reduces mobility needs.
- Increase in local public transport infrastructure.
- Little investment in R&D.
- Important application of $CO_2$ sequestration facilities to cut down possible causes of global warming.

*Mobility and energy*

- Lack of long-term planning with insufficient financing of new projects and maintenance leads to the deterioration of infrastructure.
- Long distance traffic will increase for a short time, and then decline.
- Short distance traffic increases at a low rate, because of strong regulations.
- GDP elasticity of passenger transport decreases because of mobility constraints.
- GDP elasticity of freight transport decreases.
- The average length of trips decreases as urban sprawl is cut down and people become more mobile at a local level.
- Lack of sufficient R&D of energy source development makes it difficult to reduce dependence on carbon-based energy, and the peaking of oil from conventional sources boosts prices, leading to a global economic decline.
- Congestion levels increase due to the lack of infrastructure capacity, but decrease afterwards when mobility is reduced.

*Storyline*

- 2010-2020: Continuation of existing trends. Ongoing congestion levels and increases in oil prices pose difficulties for economy to grow. $CO_2$ restrictions bypassed. Inefficient public institutions, that are unable to implement the structural reforms needed to open markets to healthy competition and to promote and finance technological innovation.

- 2020-2030: The carbon trading system is developed to mitigate greenhouse gas emissions as well as limit transport demand. The economy suffers as private investments are less productive (because a reduction on public stock of physical capital and lack of flexibility on labour markets), and GDP goes down. Ageing is causing an important burden to public finances through public pension systems, reducing the funds available for the economic infrastructure and then reducing the overall productivity of the economy. As mitigation of ongoing climate change, an important effort is made in applying $CO_2$ sequestration methods, partially used to facilitate drilling deeper oil fields.

- 2030-2040: Travel has become an expensive commodity, but the change has been very abrupt and the lack of long-term measures to solve the energy problem means the GDP level keeps decreasing. Carbon credits are now an important currency that has allowed less developed regions to catch up with the richest ones. More effective $CO_2$ sequestration technologies are applied. Public finances start to find a better balance. Need for strict regulations in order to comply with $CO_2$ targets in 2050.

- 2040-2050: Reduction of economic and transport growth together with minor policies aiming at energy efficiency result in a high reduction of $CO_2$ emissions, but the price has been a global slowing of growth patterns. As a result, communities have become more local, and technology has not fulfilled the expectations raised at the beginning of the 21st century.

### 2.2.5. The organisational path: “Moving Together” or Decoupled Mobility

*Scope*

- Strong decoupling between economic development and traffic is gradually achieved due to well-balanced policies, favourable to the implementation of cleaner and more effective technologies as well as to the increase of transport productivity due to better infrastructure and demand management. Moderate increase in GDP.
- $CO_2$ is reduced quickly, but in a harmonious way, without hampering economic development.
- Changes in behaviour: policies aiming to modify users and firms’ mobility decisions are effective to some extent.

*Similar scenarios*

- “Urban Colonies” (UK Office of Science and Technology)
- “Shared Responsibilities” (Forward Studies Unit)
- “Creative Societies” (Forward Studies Unit)

- "Strong Europe" (CPB)
- "Riding the Rainbow" (EMCC)
- "Danubean-Europe, Cohesion-Oriented" (Espon 3.2)
- "Knowledge is King" (MedAction)

*Population dynamics*

- Large increase in total population mainly due to vegetative growth.
- Moderate immigration.
- Moderate ageing.

*Socio-economy and technology dynamics*

- In the short-term, the GDP increases at a lower rate than in the Induced and Constrained Scenarios, but it is more stable.
- Unemployment is strongly reduced thanks to the constant growth of the economy and flexible work regime policies.
- Support of R&D of renewable energy and distributed energy production technologies.
- Important development of new forms of personal services related to "tourism" (business, health, education, etc.).
- Income inequalities are reduced across European regions.

*Transport, energy and other mobility-related policies*

- Reduction of unnecessary trips thanks to technology (internet shopping, telecommuting, IT convergence).
- Better management of infrastructure to improve transport efficiency.
- Increase in urban infrastructure stock to encourage short distance trips.
- Internalisation of social and environmental impacts of transport activities.
- Pricing systems and incentive schemes in transport, including taxation, to encourage long-term behavioural changes.
- Land-use policies aimed at reversing the tendency towards urban sprawl help reduce travel needs.
- Enlargement of the EU towards the east, the Balkans and Turkey, and close cooperation with all other neighbouring countries.

*Mobility and energy*

- GDP elasticity of passenger transport (trips within Europe) decreases, but Europeans continue to devote to transport the same time and budget (so, trips to abroad have a dramatic increase).

- Elasticity of freight transport decreases slightly because economy turns to less material commodities. More trade with non-European economies.
- Average trip length is reduced.
- More intensive use of public transport in urban areas.
- Part of long distance traffic becomes short distance traffic.
- Shift towards slower and more environmentally friendly modes of transport.
- Transport price increases due to taxation, especially those relying on carbon-based energy.
- Optimisation of capacity, increasing the size of vehicles and occupancy ratios.
- Emission factors improve because technology is oriented to achieve this goal.

*Storyline*

- 2010-2020: $CO_2$ emissions keep growing while the mix of policies is being implemented, but at a slower pace. During this period, the GDP grows because no radical measures are being considered to reduce global warming. Continuation of the process of economic liberalisation.

- 2020-2030: Slow introduction of behavioural policies. Land-use policies have led to an important reduction of urban sprawl, reducing the need to travel by car. Development of distributed energy generation, rise of renewables, while vehicle improvements in the form of hybrids and electric cars and a shift towards more ecological transport modes triggers a reduction of $CO_2$ emissions. Introduction of online road pricing encourages a reduction in road transport use.

- 2030-2040: The transition to non-fossil fuels is almost complete and thus the economy does not suffer from high oil prices. While global mobility decreases, short distance trips increase because urban areas have become very dynamic with the help of highly-developed urban transport infrastructures. Taxation moves from being oil-based to the use of infrastructure.

- 2040-2050: Societal inequalities are further reduced, having a positive impact on the economy. $CO_2$ emissions continue to be reduced.

In conclusion, these four scenarios illustrate that there are different paths towards a post-carbon society. It may be possible to achieve higher sustainability and economic growth together, if a balanced development of technology or of social organisation is achieved or if there is a voluntary reduction of mobility.

Failure along the way is also possible. There is a fourth scenario which shows the risks of not achieving a technological fix, nor the necessary structural reforms to facilitate its implementation.

Next section provides a political reading, which is still qualitative, of these scenarios.

## 2.3. *Policy-aims of the scenarios*

The next table provides an overall illustration of the broad political emphasis considered in the scenarios. The first table displays how emphases on different type of policy aims and instruments may change over time for the Baseline scenario, using 10-year periods. The second compares predictive and exploratory scenarios. The aim of these representations in the process of quantifying the scenarios is simply to help visualise the policy emphases attached to the scenarios, still qualitatively.

BASELINE SCENARIO. INDICATIVE EVOLUTION OF POLICY-AIMS EMPHASIS

| | WB2001 | RWB2006 | WB2010 | WB2020 | WB2030 | WB2040 |
|---|---|---|---|---|---|---|
| **Policy-aims (*)** | | | | | | |
| Territorial Cohesion/Integration | 5 | 5 | 4 | 3 | 1 | 1 |
| Environmental sustainability | 9 | 8 | 8 | 6 | 3 | 2 |
| Economic competitiveness | 6 | 7 | 9 | 6 | 5 | 4 |
| Safety/Social and cultural aspects | 5 | 5 | 7 | 9 | 10 | 8 |
| Governance/Subsidiarity | 5 | 5 | 6 | 7 | 8 | 10 |
| **Policy instruments** | | | | | | |
| Opening of markets | 6 | 6 | 9 | 6 | 4 | 2 |
| Better infrastructure management | 3 | 4 | 6 | 10 | 8 | 7 |
| Increase stock long-distance roads | 4 | 5 | 6 | 5 | 4 | 3 |
| Increase stock ports | 7 | 7 | 8 | 7 | 6 | 6 |
| Increase stock of logistics | 7 | 8 | 8 | 7 | 6 | 6 |
| Increase stock airports | 7 | 7 | 8 | 7 | 6 | 6 |
| Increase stock long-distance rail/PT | 10 | 8 | 6 | 5 | 4 | 3 |
| Incresase stock regional infrastructures (PT) | 4 | 5 | 6 | 6 | 8 | 8 |
| Public support to R+D on technology | 6 | 6 | 7 | 8 | 10 | 7 |
| Bans and regulation | 6 | 6 | 7 | 6 | 5 | 2 |
| Effective pricing | 8 | 8 | 8 | 9 | 8 | 8 |
| Other behavioural incentives | 2 | 2 | 5 | 6 | 8 | 10 |
| Strict land-use regulations | 2 | 2 | 5 | 6 | 7 | 8 |
| Taxation | 5 | 7 | 7 | 8 | 6 | 4 |

(*) Aims reduce their relative importance overtime as they are achieved or internalised into other aims.

**Table 2: Evolution of policy aims in the Baseline scenario. The relative values measuring "emphasis" are defined between 1-10 but should be understood just as a categorical classification. Quantitative values have only an instrumental interest: assuring that the total value of each column in the table is just the same, so what is measured across time is relative emphasis.**

| | Induced | High growth Decoupled | Moderate Baseline | Low Growth Reduced | Constrained |
|---|---|---|---|---|---|
| Economic growth | VERY HIGH | HIGH GROWTH | MODERATE | LOW GROWTH | VERY LOW |
| Population growth | HIGH GROWTH | VERY LOW | LOW DECLINE | HARD DECLINE | LOW DECLINE |
| Technologic development | VERY HIGH | HIGH | HIGH | LOW | VERY LOW |
| Mobility growth | INDUCED | DEC&SHIFTED | DECOUPLED | REDUCED | CONSTRAINED |
| European enlargment (€-ZONE) | VERY HIGH | HIGH | LOW | LOW | VERY LOW |
| **Policy-aims** | | | | | |
| Internal Territorial Cohesion | 3 | 6 | 7 | 6 | 3 |
| Political integration at EU level | 5 | 6 | 6 | 4 | 3 |
| Environmental sustainability | 6 | 7 | 6 | 10 | 8 |
| Economic competitiveness | 9 | 6 | 5 | 3 | 9 |
| Safety/Social and cultural aspects | 7 | 5 | 6 | 7 | 5 |
| **Policy instruments** | | | | | |
| Opening of markets | 10 | 6 | 6 | 4 | 4 |
| Better infrastructure management | 8 | 7 | 6 | 7 | 6 |
| Increase stock long-distance roads | 6 | 4 | 5 | 2 | 7 |
| Increase stock ports | 7 | 7 | 7 | 3 | 6 |
| Increase stock on logistics | 7 | 6 | 6 | 3 | 6 |
| Increase stock airports | 7 | 6 | 6 | 3 | 6 |
| Increase stock long-distance rail/PT | 2 | 6 | 9 | 4 | 6 |
| Incresase stock urban infrastructures (PT) | 7 | 6 | 6 | 6 | 6 |
| Public support to R+D on technology | 9 | 6 | 6 | 7 | 4 |
| Bans and regulation | 2 | 5 | 6 | 9 | 9 |
| Effective pricing | 8 | 8 | 6 | 7 | 6 |
| Other behavioural incentives | 2 | 5 | 4 | 9 | 3 |
| Strict land-use regulations | 2 | 4 | 3 | 10 | 6 |
| Taxation | 5 | 6 | 6 | 8 | 7 |
| **Strategic evaluation** | | | | | |
| Economic development (GDP) | 8 | 6 | 5 | 4 | 4 |
| Social Welfare (Social gaps) | 2 | 6 | 5 | 6 | 3 |
| Technological development (Productivity) | 9 | 6 | 5 | 4 | 3 |
| Environmental sustainability (CO2) | 5 | 6 | 5 | 9 | 5 |
| Safety (Accidents) | 6 | 6 | 5 | 7 | 5 |

**Table 3: Comparison of policy instruments in different scenarios**

Since there is no preference between the Induced, Reduced and Decoupled scenarios (there is no "desirable" scenario in the exercise) the strategic evaluation gives the same value, adding partial evaluations. On the other hand, there is a "undesirable" scenario, which receives a worse evaluation (the Constrained scenario).

The following graphics illustrate the same concepts using a different graphical symbolism.

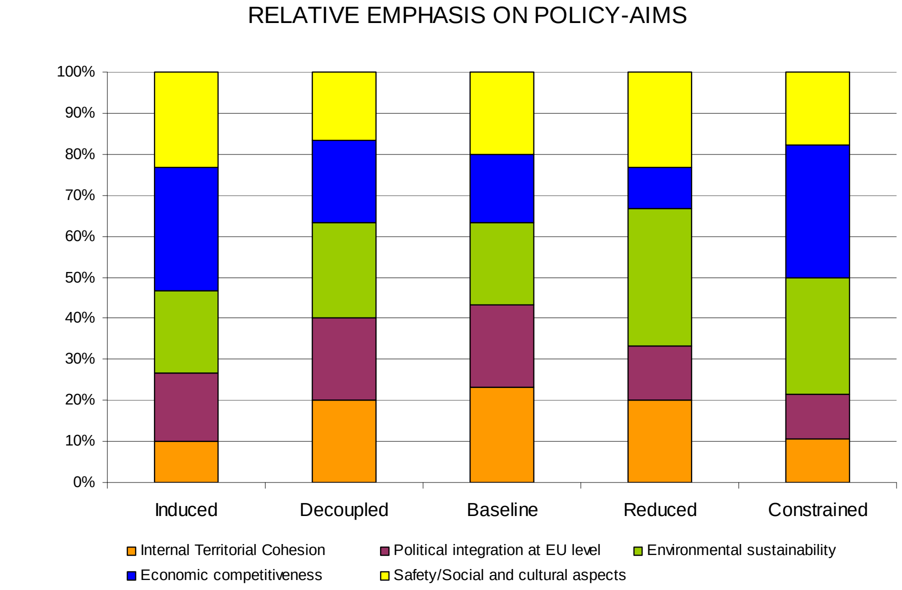



**Figure 19: Relative emphasis on policy-aims**

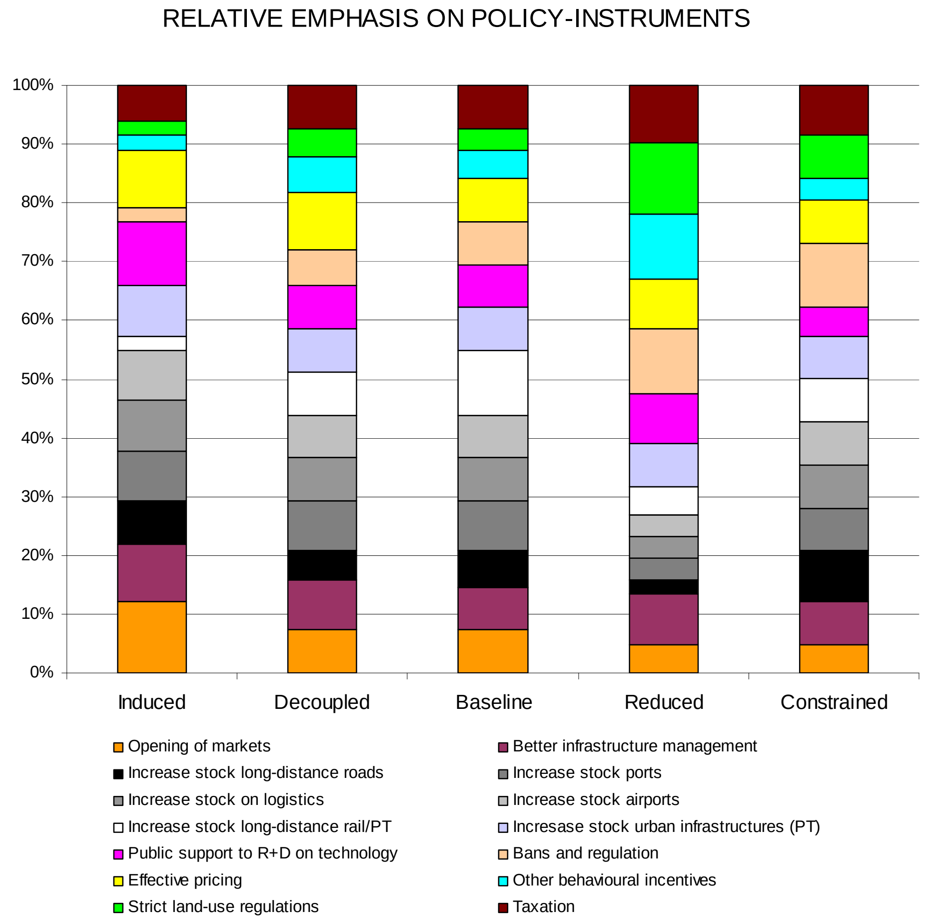



**Figure 20: Relative emphasis on policy-instruments**

# 3. Modelling tools

Quantitative scenarios provide numerical information based on forecast models, based on various scientific theories and computer techniques. Needless to say, forecast models have to be well adapted to the kind of scenarios being studied or, if feasible, especially programmed for the purpose.

## 3.1. *The limits of models*

A word of caution is always needed before applying forecast models. Compared with other scientific fields, such as the natural sciences or physics, transport modelling as well as the social sciences in general are far from having authoritative explanatory theories and predictive models. It is reasonable to doubt if social sciences ever will, because the comprehension and prediction of human behaviour by other humans is almost an ontological impossibility. For instance, social and personal experimentation involves ethical aspects which are not present in natural sciences and physics. In this form of research, the group studied generally also includes the researcher, making true objectivity impossible.

Is not surprising, then, that for many decision-makers transport models not only provide poor or already well-known predictions, but they also use obscure formulations based on oversimplified assumptions, and there is not much hope that future changes in research may significantly improve the situation.

Even if forecast models are not as good as we would like at predicting the future, they are probably the best methodology available to carry out a systematic check of our intuitions, which are very often inconsistent and largely unable to capture the non-lineal nature of complex events. Developing and applying forecast models based on sound methodologies and real data is also useful, if not indispensable, in providing objective references to be used in multi-party negotiation processes, as well as in facilitating a learning process in scientific fields where real experimentation has to be substituted by simulations.

Generally speaking, a “model” is just an algorithm which predicts unknown data, often forecasting uncertain futures. A “model” is nothing but an intelligent simplification of reality: the paramount goal of constructing models is to represent reality with the maximum simplicity and the minimum error, because science is primarily focused on discovering the simple laws governing reality. Said succinctly, models can be clustered around three major paradigms: statistically-based (then data becomes an indispensable starting point), theoretically-based (then the abstract formulation, based on scientific analogies, is the starting point and data is used mostly to validate) or expert-based (using rules of thumb, heuristics, then comparative cases and experts’ panels are key modelling procedures). In social sciences, almost every model has a component belonging to each one of these paradigms.

All considered, accurate predictions and transparent meaningful explanations alone are not the most important requirements for using transport models in decision-making processes. If the model has to be used as planning assessment tool, it has to also provide for robust results, in the sense that each run with the same input data yields the same results, and marginal changes in input variables do not produce significant variations.

Contrary to intuition, the “predictive” and the “explanatory” attributes of scientific models do not always coincide: better explanations do not necessarily produce more accurate predictions. An “accurate prediction” is usually obtained using statistically-based paradigms, supported by large volumes of data, and it is even possible “to let the data speak for itself” and give the computer the capacity to “learn by itself”. However, accurately predicting short-term trends based on statistic adjustments does not always provide meaningful explanations.

The European Transport System is becoming a “complex system”: it involves an increasingly large number of heterogeneous agents, such as EU, national, regional and local administrations, carriers, users, etc., which are both intelligent and adaptive and make their decisions based on local rather than global information. This complexity produces unexpected behaviour and surprises, often against common sense and intuition.

The main tool used in TRANSvisions has been TRANS-TOOLS model (version 2 developed by DTU in TEN_CONNECT, November 2008).

TRANS-TOOLS has been complemented by meta-models to forecast 2030-2050, as well as the more extreme scenarios, distant from mainstream tendencies covered by TRANS-TOOLS from 2005-2030.

Meta-models are needed given the impossibility of TRANS-TOOLS to forecast scenarios distinct from mainstream tendencies or beyond 2030. Given the limited accuracy that any long-term forecast may offer, TT meta-models results always have to be considered in relative terms, rather than as accurate, absolute predictions.

TRANS-TOOLS and TT meta-models share the same data for 2005 and are calibrated for 2020 and 2030, but they are different in nature:

- While TRANS-TOOLS follows a conventional state-of-the-practice 4-step transport forecast modelling formulation, meta-models are foresight tools based on highly disaggregated indicators for all sectors, growth factors and elasticity functions that include internal feedback and consistency checks, very much similar to a dynamic-system formulation.

- While TRANS-TOOLS was calibrated with 2005 real data, meta-models share TRANS-TOOLS 2005 estimated data and have been calibrated with TRANS-

TOOLS 2020 and 2030 results, and finally validated by comparison with other official databases and forecast studies for 2005-2050.

## 3.2. *The TRANS-TOOLS model*

TRANS-TOOLS is the best state-of-the-practice, transport-oriented 4-step forecast model available at EU level, which includes specific socioeconomic modules based on complementary modelling paradigms.

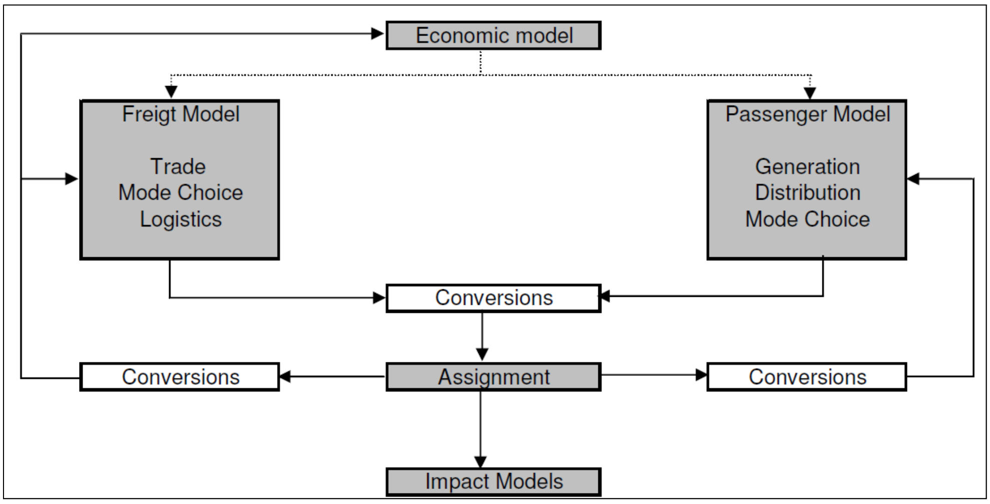



**Figure 21: TRANS-TOOLS main modules**

The modelling capabilities of TRANS-TOOLS are related directly to input variables describing the infrastructure networks and aspects related to the networks as e.g. transport costs or transport times, as well as flows between NUTSIII and NUTS II. Therefore, the TRANS-TOOLS model is also able to offer answers on policy questions indirectly affecting transport costs and transport times, as well as the evolution of demand.

The aim of this section is not to describe TRANS-TOOLS in depth (detailed descriptions are available in the TRANS-TOOLS website), but the advantages and problems of TRANS-TOOLS in the context of TRANSvisions:

- It is a 4-step transport equilibrium model (version November 2008, developed by DTU and others in TEN_CONNECT), calibrated against 2005 data. The 2005-2009 evolution, in many aspects changes previous trends, and is therefore not included.
- Provides results only for 2020 and 2030, or any fixed year, does not give evolutions over time.
- Policies are translated into generalised user costs in 2030, either in values of time or in costs of vehicle operation.
- Covers the EU-27 and neighbouring countries (refined for Eastern European countries). northern Africa is not included.
- The new road assignment procedure implemented (SUE, Stochastic User Equilibrium, local traffic generated and preloaded, assignment by periods of the day) allows a detailed analysis of congestion on roads and therefore the impact of transport policies such as speed limits.
- The new trade model facilitates the analysis of import/export freight.
- Passenger trips with origin or destination outside the EU-27 are included but not explicitly modelled (except for neighbouring countries, but not northern Africa).
- In the case of aviation, trips with origin or destination outside the EU-27 are not modelled (EU-27 trip segments included, in non-direct flights).
- Freight trips with origin or destination outside the EU-27 are included as if they had their origin or destination in a European port (except for neighbouring countries).
- Air freight is not included.
- No explicit modelling of ferries when used as road and rail links.
- There is no policy-interface, producing a synthesis of the 2 GB of results produced in each scenario run (leading to a very time-consuming process of analysis).

## 3.3. *TRANS-TOOLS META-MODELS*

TRANSvisions has adopted a methodological approach based on developing meta-models especially programmed for the exercise that are complementary to TRANS-TOOLS..

Generally speaking, meta-modelling, can be understood in two different ways:

- It can be considered as the definition of a semantic model for a family of related domain models. In this sense, meta-modelling becomes very much related to Ontological Engineering. We can define an ontology as being the explicit representation of domain concepts. Under this definition, the process of building an analysis domain model in a standard object-oriented methodology can be understood as meta-modelling as long as the resulting model is precise and general enough as to be used to model different systems apart from the one under study.

- In System Engineering, meta-modelling is understood in a quite different sense. A meta-model is here a simple approximation, usually mathematical, of a complex model. The meta-model requires less computer resources and can be run intensively under controlled parameters to reveal what affects system performance.

In TRANSvisions, meta-modelling is understood close to the System Engineering approach, but is not based on duplicating an existing model with an easier statistically-based formulation, but somehow extending its area of knowledge to other sectors and time horizons.

Meta-models have been calibrated with TRANS-TOOLS results for 2005, 2020 and 2030 for three scenarios (Baseline, High Growth and Low Growth) and validated against other forecast studies for 2020 and 2050.

The purposes of TRANSvisions meta-models are the following:

- First, to validate the consistency of qualitative scenarios, as well as the educated guesses made by participants in the Delphi process in relation to the tendencies of key indicators.

- Second, to provide a quantitative forecast of scenarios far away from the current situation (from 2030 to 2050), both forecasted and backcasted.

Therefore, the goal of meta-models is to provide a bridge between qualitative and quantitative approaches. It is worth mentioning that the 2005-2050 scenarios defined in TRANSvisions contain complete storylines, used as reference to consistently define all independent variables and parameters included in the formulation of TT meta-models, and to check the results. In some cases, particularly for the Constrained scenario, storylines were then adjusted to be consistent.

Meta-models here then are therefore TRANS-TOOLS meta-models developed to complement TRANS-TOOLS, according to the specific requirements of TRANSvisions. For example, to be able to analyse the 2030-2050 period, and analyse scenarios far from mainstream tendencies for 2005-2050.

### 3.3.1. Modelling procedure applied

The procedure for modelling the qualitative-predictive and exploratory scenarios followed these steps:

1. The Baseline, Decoupled and Reduced Mobility scenarios were first calculated by TRANS-TOOLS for 2005, 2020 and 2030.

2. The TT meta-model, based on 2005 data from TRANS-TOOLS, was then calibrated to be able to reproduce these scenarios in 2030 for key indicators. Results were calibrated against 2030 TRANS-TOOLS results as well as the 2005 DG TREN statistical pocketbook and 2020 and 2030 results of the Energy Strategic Review, for the different scenarios.

3. The TT meta-models were used to validate the consistency of 2030 assumptions for the Induced and Constrained Mobility scenarios, respecting the differences between these two scenarios and the Decoupled and Reduced Mobility scenarios (as given in their qualitative scenario construction).

4. The TT meta-models were used to check the consistency in 2050 of four exploratory scenarios, producing quantitative values for all variables.

5. The TT meta-models were used for constructing pathways showing how the future evolves between the present and 2050 for each exploratory scenario[2].

[2] Trans-Tools is not able to produce pathways.

6. The TT meta-models were applied to estimate the impact of alternative transport policies in different scenarios, in order to achieve $CO_2$ targets such as a 10% reduction of emissions due to transport activities within the EU-27 in 2020, and 50% in 2050.

### 3.3.2. Information sources

The main sources of information used (in addition to TRANS-TOOLS) to develop the meta-models were:

- EUROSTAT (COMEXT)
- DGTREN (Transport Pocketbook)

A review of existing statistics was carried out, which covered the following datasets:

- Socio-economic data
- Comext Scenes
- SABE
- Gisco
- Corine land cover
- World Bank Data & Statistics (by country)
- IMF Directory of Trade Statistics (DOTS)
- WTO World Trade Organisation.
- OECD Main Economic Indicators
- World fact Book (CIA database)
- COMEXT Trade by mode; Eurostat
- NewCronos Transport data; Eurostat
- Trade data; UN
- Intermodal data; UIRR
- Intermodal data; ICF
- Cross Alpine Freight Transport, CAFT

For long-term forecast studies the following sources were used, among many others:

- TRIAS Sustainability Impact Assessment of Strategies Integrating Transport, Technology and Energy Scenarios, European Commission – DG Research, ISI, 6th Research Framework Programme (2007)
- Quantifying Four Scenarios for Europe, CPB Netherlands Bureau for Economic Policy Analysis, Arjan Lejour (2003)
- Backcasting Approach for Sustainable Mobility, JRC (2008)
- Forecasts for Motor Vehicle and Oil Demand to 2030 and 2050, International Energy Agency (2008)
- ESPON 3.2 SCENARIOS, DGREGIO European Comission (2007)
- Global Future Analysis (Plank, 2008)

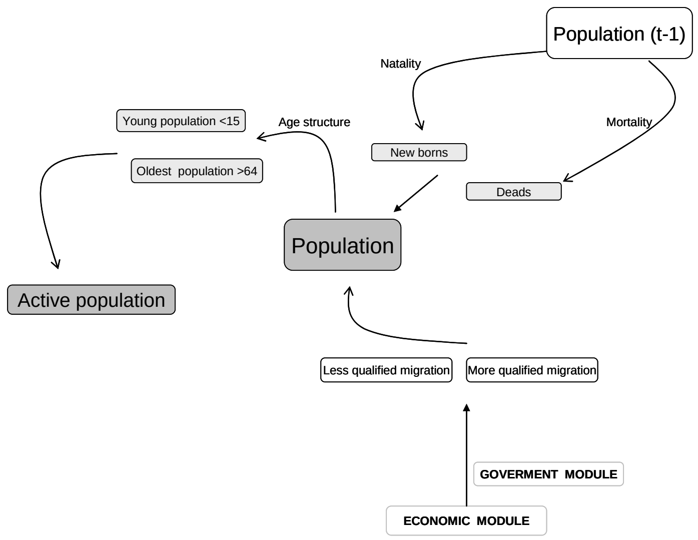
The next section briefly presents the formulation of the TT meta-models.

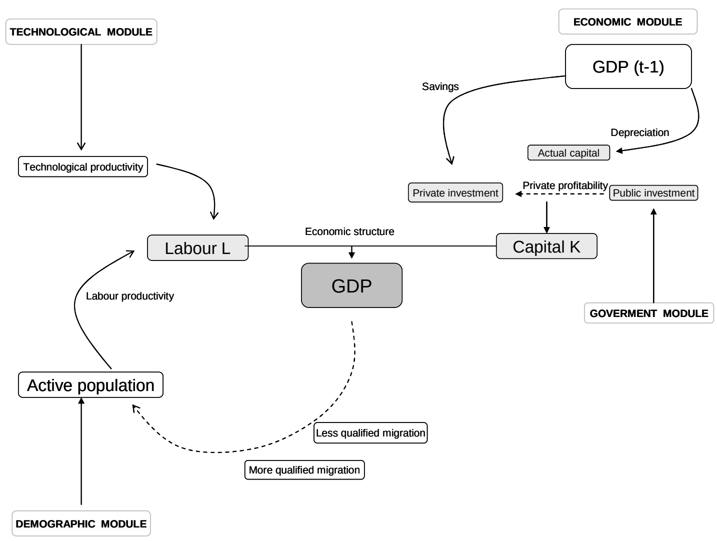
### 3.3.3. TRANS-TOOLS meta-model formulation

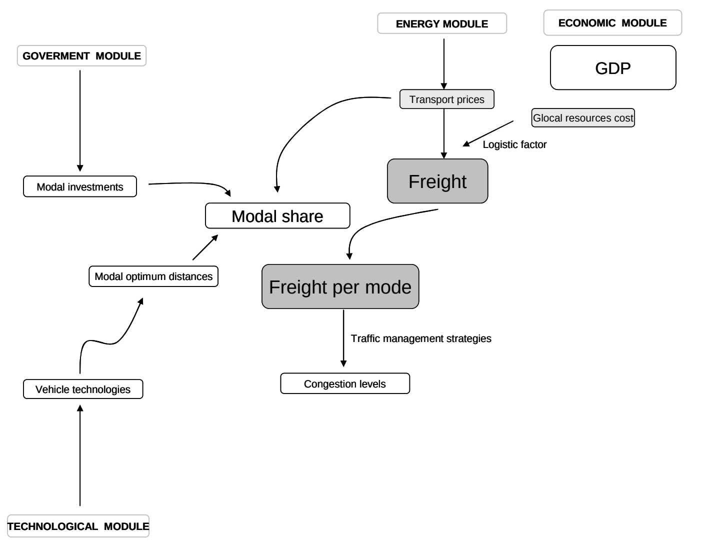
The formulation of the meta-models, supported by unsophisticated software applications (Microsoft Excel enhanced by Visual Basic, and Microsoft Access), follows a rather simple mathematic structure. Transport demand is generated for passengers and freight from socio-demographic and macroeconomic indicators aggregated at European level, then, transport demand is distributed by local, regional and long-distance and by macro-zones (North and Centre, East and South), and overseas, by trip purposes and modal division. The resulting passenger transport demand is adjusted considering a fixed income per person allocated to transport, and the freight transport demand in relation to economic growth. Through occupancy and load-factor ratios in all modes the demand in terms of vehicles, trains, planes and vessels is calculated. Furthermore, the energy consumed is calculated based on the technologies used by vehicle fleets. Emission factors of each technology influence the final result of directly and indirectly generated emissions, according to the mix of energy sources defined in each scenario. This main formulation is complemented by independent modules dealing with passenger and freight traffic, in order to further regionalise transport demand according to different types of trips (such as short-distance , cross-border, between capital cities, etc.). The main objective of the TT meta-models is, then, to find the level of $CO_2$ emissions in the 2050 scenario, and trace back the path combining trends and policies leading to this result.

Next, diagrams are presented that will illustrate the main concepts included in the different sub-modules of the meta-models. These main concepts are disaggregated into approximately 300 indicators, linked together by growth factors and elasticity functions mostly based on TRANS-TOOLS, as well as by feedback and constraints. For example, with passenger transport demand a fixed relative budget allocated to transport is assumed, and the total expenditure on transport activities balances the transport consumed in terms of pax-km.

The evolution over time of the independent variables or parameters is defined according to the narrative of each scenario, and TT meta-models calculate dependent variables annually.


Population (t-1)
Natality
Mortality
New borns
Deads
Age structure
Young population <15
Oldest population >64
Population
Active population
Less qualified migration
More qualified migration
GOVERMENT MODULE
ECONOMIC MODULE


TECHNOLOGICAL MODULE
ECONOMIC MODULE
GDP (t-1)
Savings
Depreciation
Actual capital
Technological productivity
Private investment
Private profitability
Public investment
Economic structure
Labour L
Capital K
GDP
Labour productivity
GOVERMENT MODULE
Active population
Less qualified migration
More qualified migration
DEMOGRAPHIC MODULE


ENERGY MODULE
ECONOMIC MODULE
GOVERMENT MODULE
GDP
Transport prices
Glocal resources cost
Logistic factor
Modal investments
Freight
Modal share
Modal optimum distances
Freight per mode
Traffic management strategies
Vehicle technologies
Congestion levels
TECHNOLOGICAL MODULE

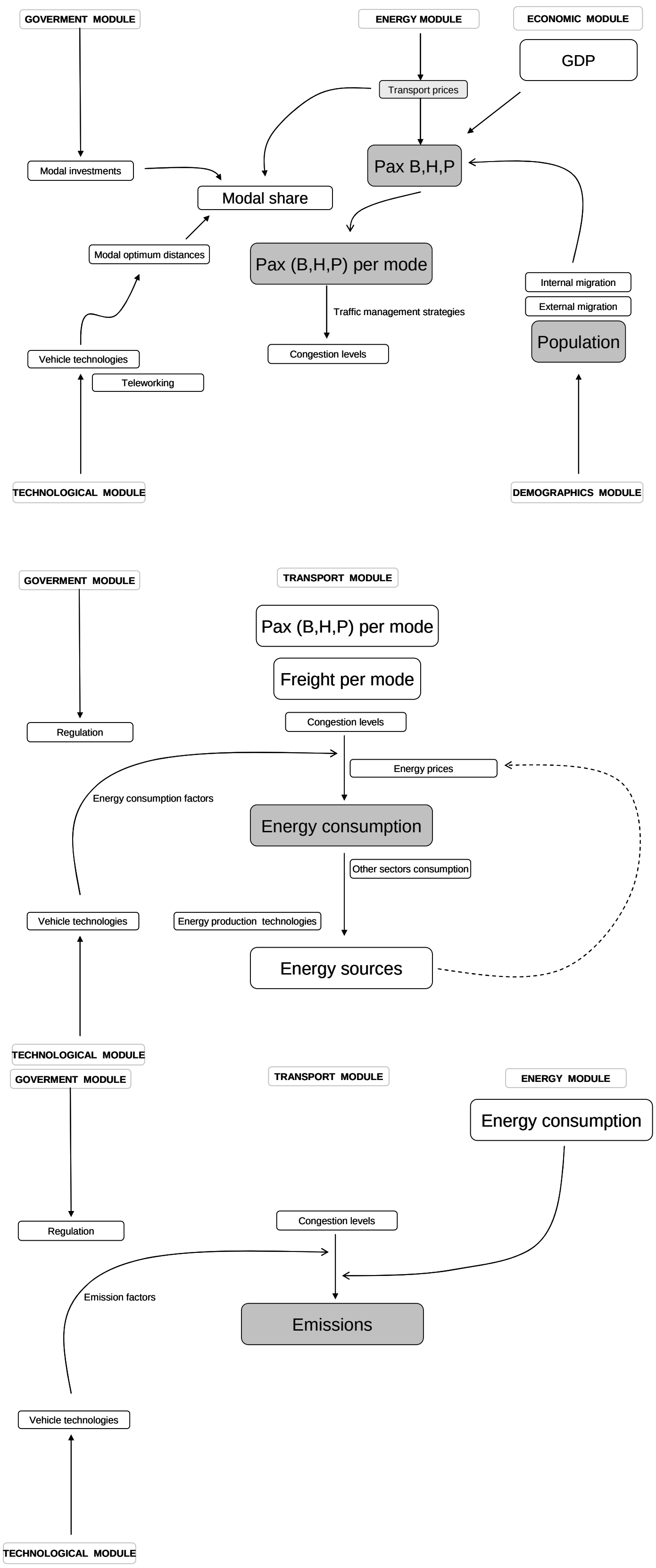



**Figure 22: Diagrams of the different modules with the main concepts**

### 3.3.4. Meta-models interface

Next, an image of the main interface of the meta-model is presented. It has been designed as simply as possible, in order to make user interaction easier.

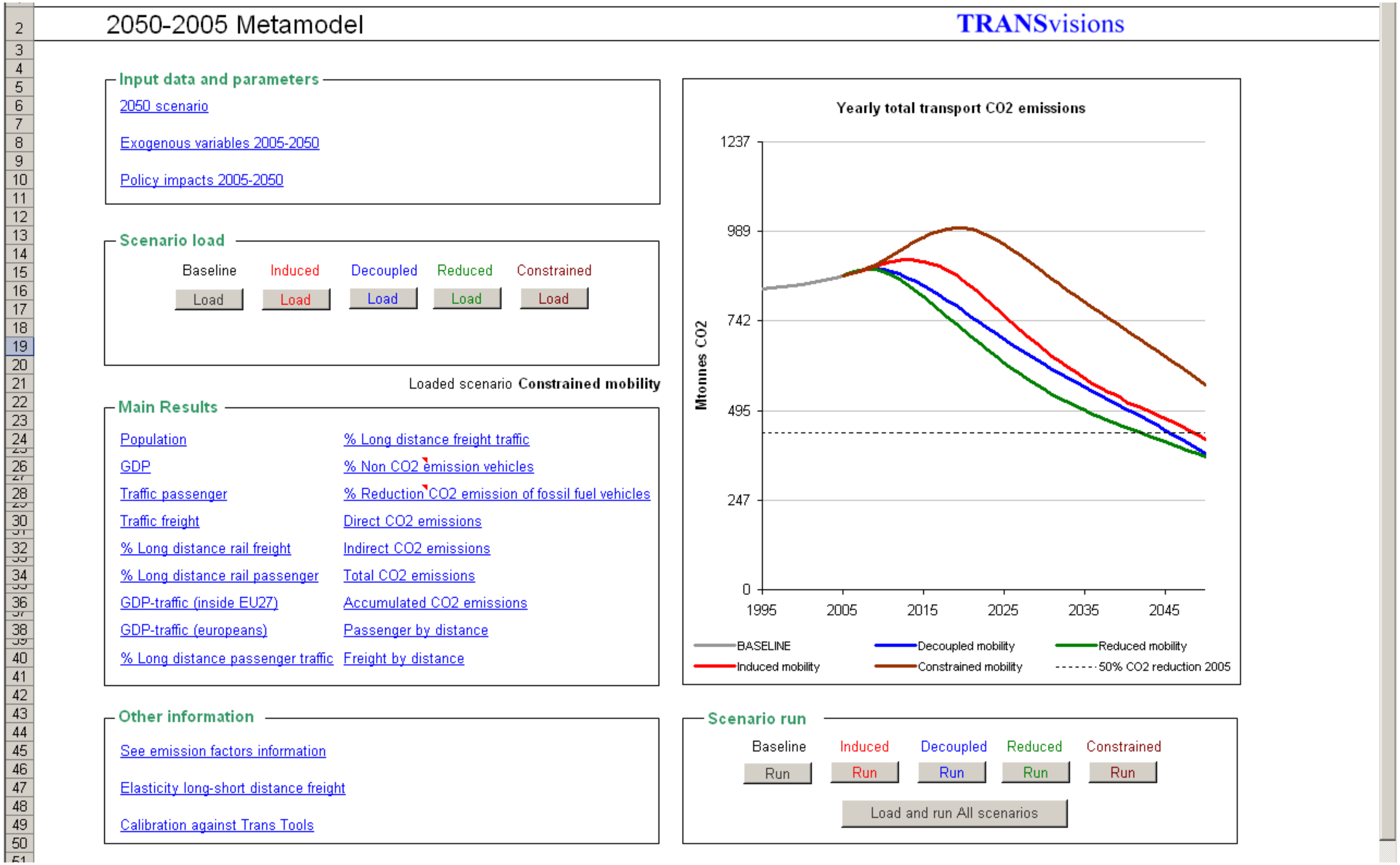



**Figure 23: Main interface of TV meta-models**

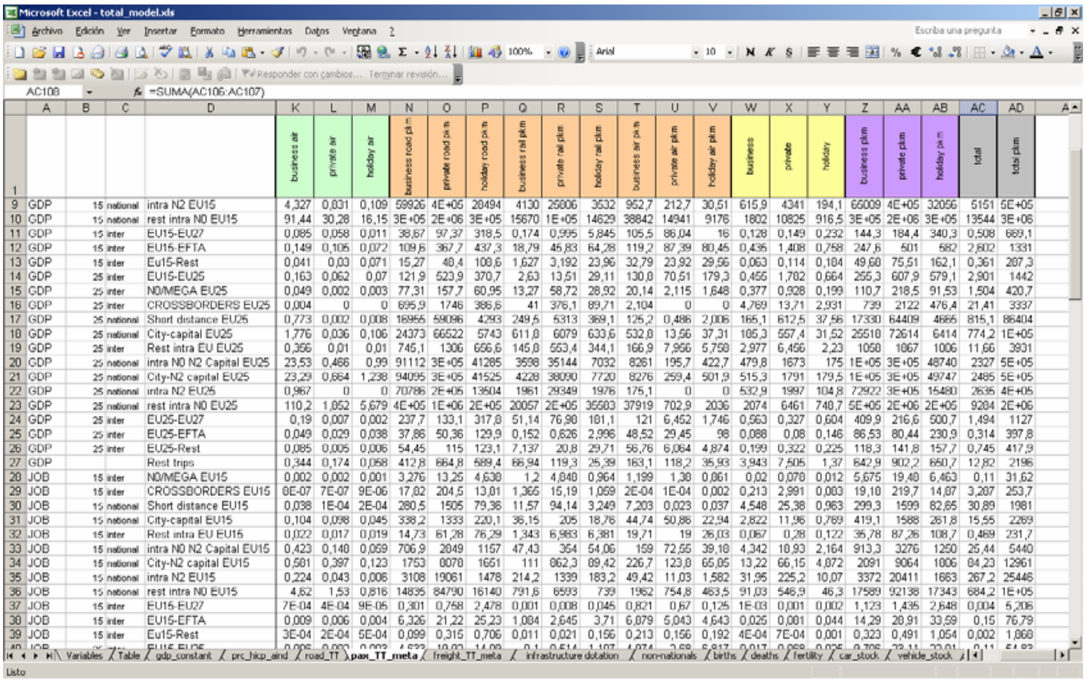


**Figure 10: Interface of the Passenger meta-model submodule**

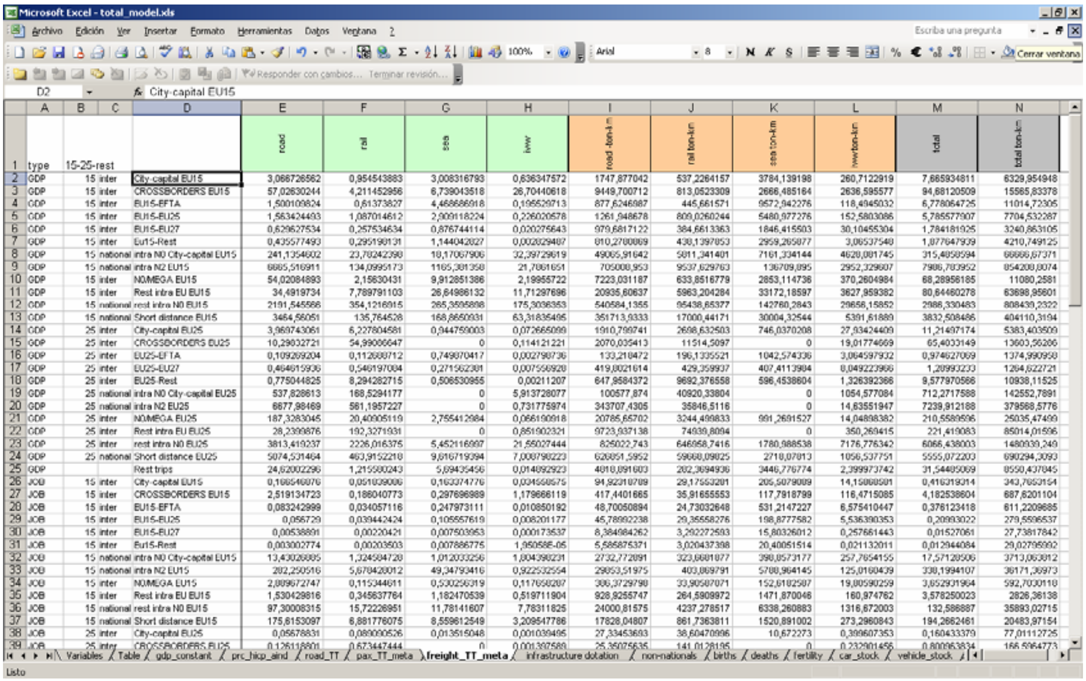


**Figure 11: Interface of the Freight meta-model sub-module**

## 3.4. Calibration process

The key indicators to be calibrated and/or validated are the absolute values of traffic by mode, for passengers and transport as well as $CO_2$ emissions in 2005, 2020 and 2030. This is done assuming the same values in relation to socioeconomic variables, average population and economic growth in the territory covered by the TRANS-TOOLS model.

While TRANS-TOOLS produces results for a given time horizon (e.g. 2020, or 2030), meta-models produce results for every year during the whole period of study. This means that while for TRANS-TOOLS it is enough to know the absolute growth of independent variables such population or GDP between 2005 and 2020 or 2030, for the meta-models there is the need to define the evolution of independent variables over time, consistently with the narratives of the scenarios.

The calibration process consists precisely in defining evolutions over time for all independent variables in the meta-models to match the average growth values of TRANS-TOOLS for all key indicators.

### 3.4.1. Calibration of traffic by mode

These steps were followed in the calibration process:

- The year 2030, being the most distant prediction TRANS-TOOLS can make reasonably reliably, was considered as the reference year to calibrate the meta-model for the Baseline scenario, the Organisational/Decoupled and Behavioural/Reduced scenarios.

- Results provided by TRANS-TOOLS in 2020 were also considered for further validation in relation to the Baseline scenario.

- Results for 2020 provided by other forecast models (in orders of magnitudes, since each forecast is based on its own scenarios and methods and therefore not directly comparable) were also considered for validation.

- The TRANSvisions Baseline scenario was validated against other available forecasts for 2050.

- The $CO_2$ emissions in 2005 produced by TRANS-TOOLS and TT meta-models was validated against the DG TREN statistical pocketbook considering different technological strategies. TRANS-TOOLS provides $CO_2$ figures for non-local inter-NUTS3 traffic, so additional emissions were included in the meta-models to provide a global vision of the impact of transport regarding GHG.

It is worth mentioning that because the TT meta-models are a foresight tool to be applied for 2030-2050; their calibration required a process of validation of concepts, indicators and figures, in addition to an adjustment by simulation. This was done instead of a purely statistical calibration of parameters. If the goal instead were to replace TRANS-TOOLS in the 2005-2030 for a range of variation of a given number of parameters, the calibration would have required many runs of TRANS-TOOLS from 2005 to 2030 to analyse its sensitivity to the different parameters, and then statistically calibrate a meta-model, by applying neuronal network techniques, for instance.

The next graphic shows the temporal evolution of annual variation in GDP, 2005-2050, for the Baseline scenario in TRANS-TOOLS, and the continuous evolution for the meta-models.

Since TRANS-TOOLS only provides the absolute values of GDP in 2005, 2020 and 2030 to define the Baseline scenario, in the next graphic (figure 16) the average value in between these periods is represented with green and grey straight lines.

The continuous evolution provided by the TT meta-models has been adjusted in order to get both absolute values at the end of each period as well as to assure a realistic transition in the first years with previous 1990-2005 trends. The actual annual variation of GDP may oscillate much more than the theoretical curve used in the exercise. Needless to say, the prediction of annual oscillations of GDP growth is far beyond the scope of the models used in TRANSvisions; our main concern is adjusting the average growth during the different periods.

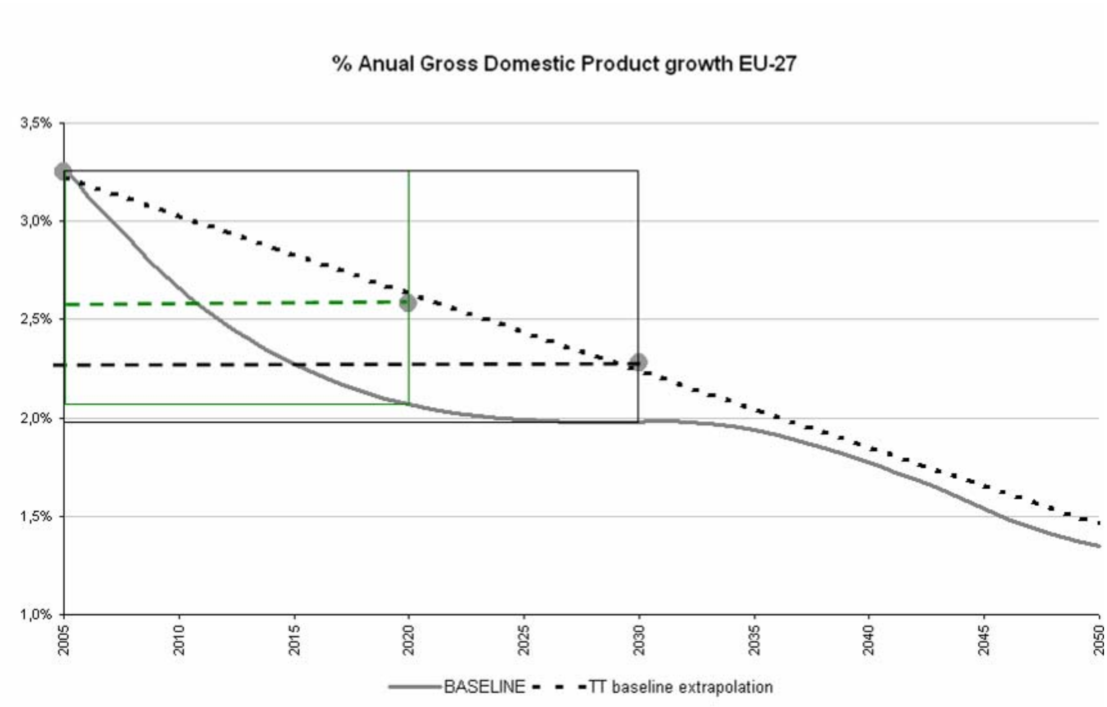



**Figure 24: Calibration of the annual change of GDP.**
**Given the fact that the actual GDP growth for the 2005-2010 period is lower than the one assumed, the average ratio of GDP growth for 2010-2020 should be higher.**

The next graphic includes all the other scenarios (GDP in absolute values).

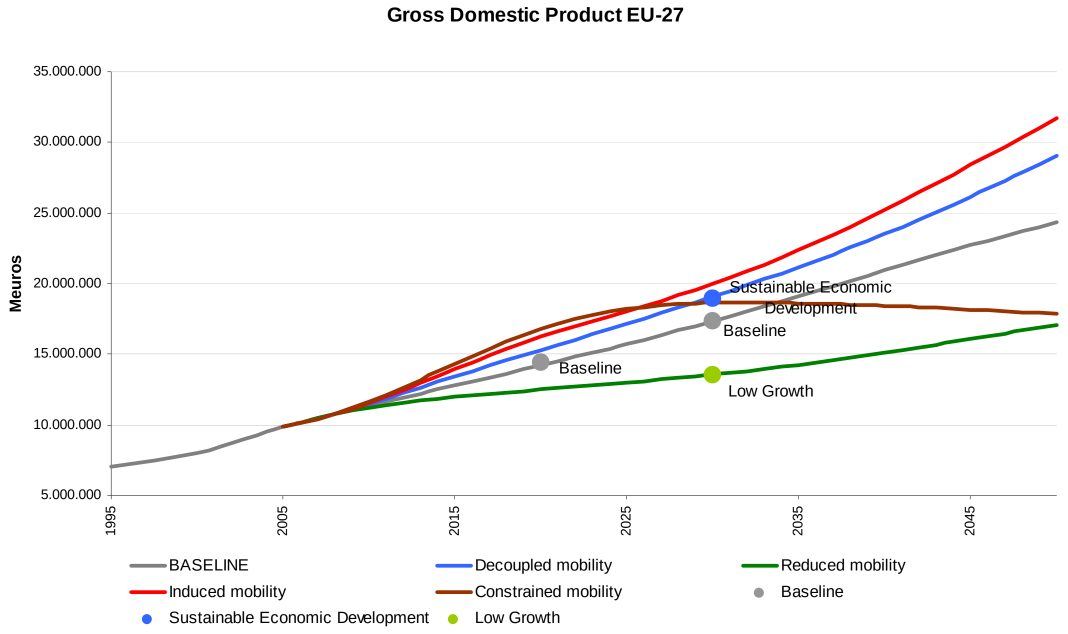



**Figure 25 Calibration of GDP**

The next graphics present the calibration results for the other key indicators:

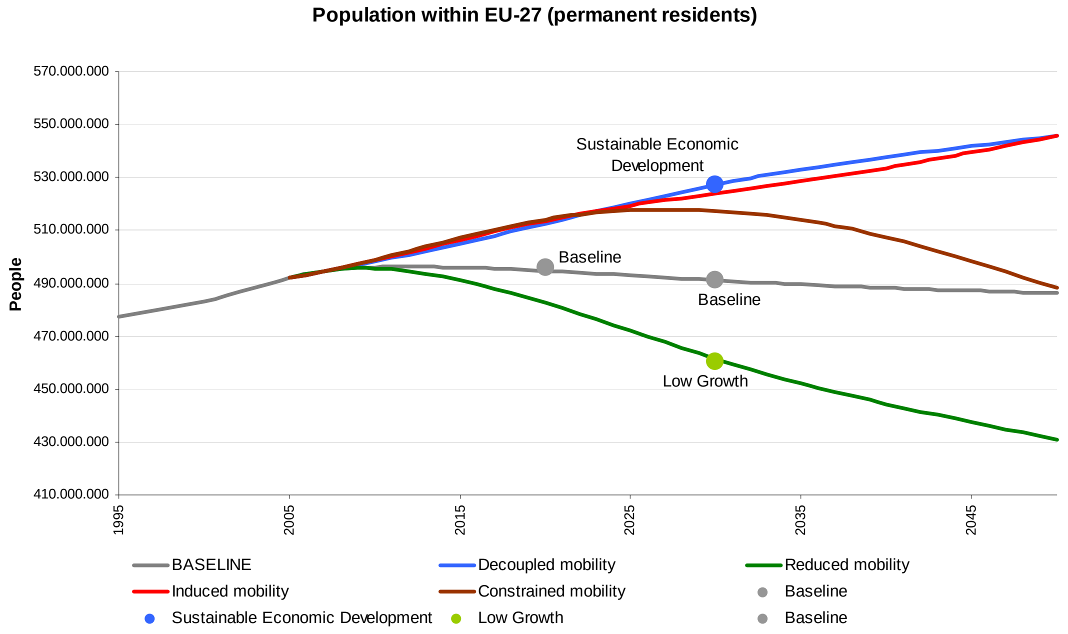



**Figure 26: Calibration of population**

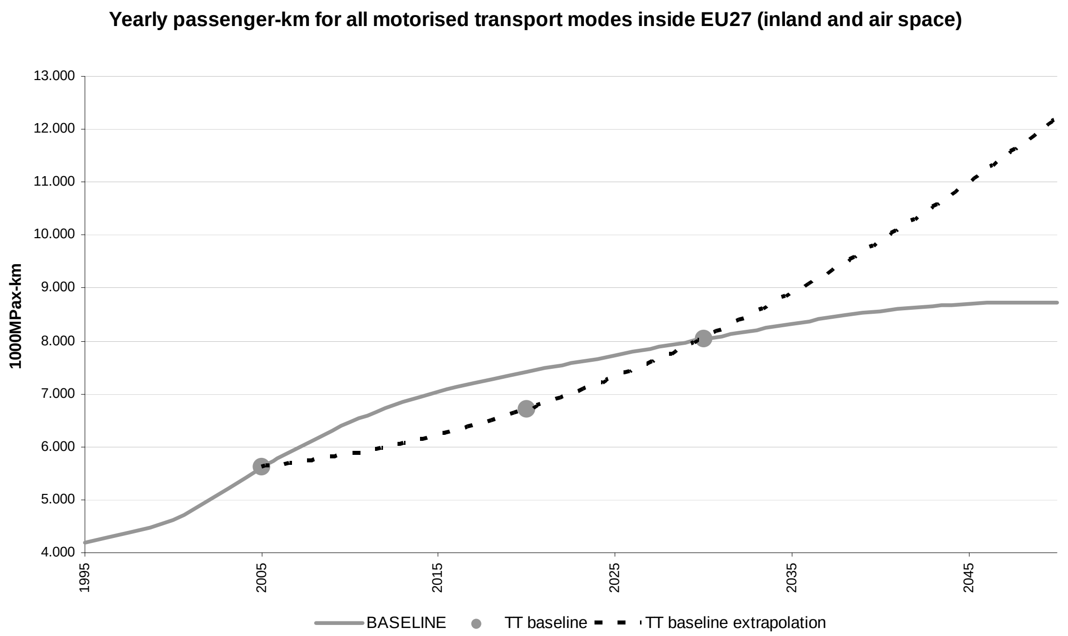



**Figure 27: Baseline calibration for passenger traffic**

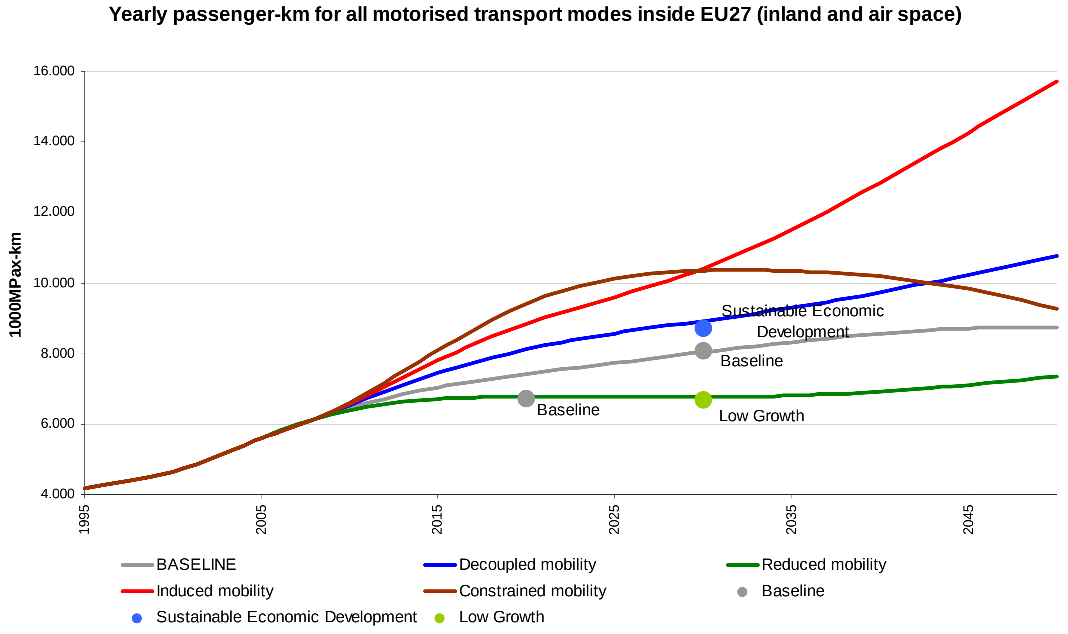



**Figure 28: Calibration of Passenger traffic. All scenarios**

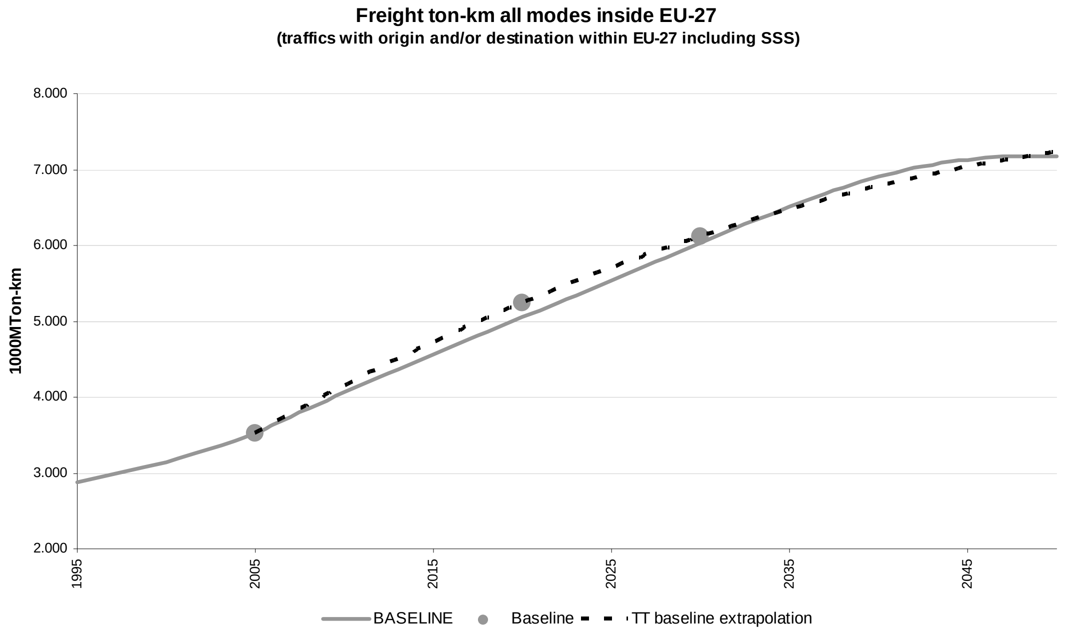



**Figure 29: Baseline calibration for freight traffic**

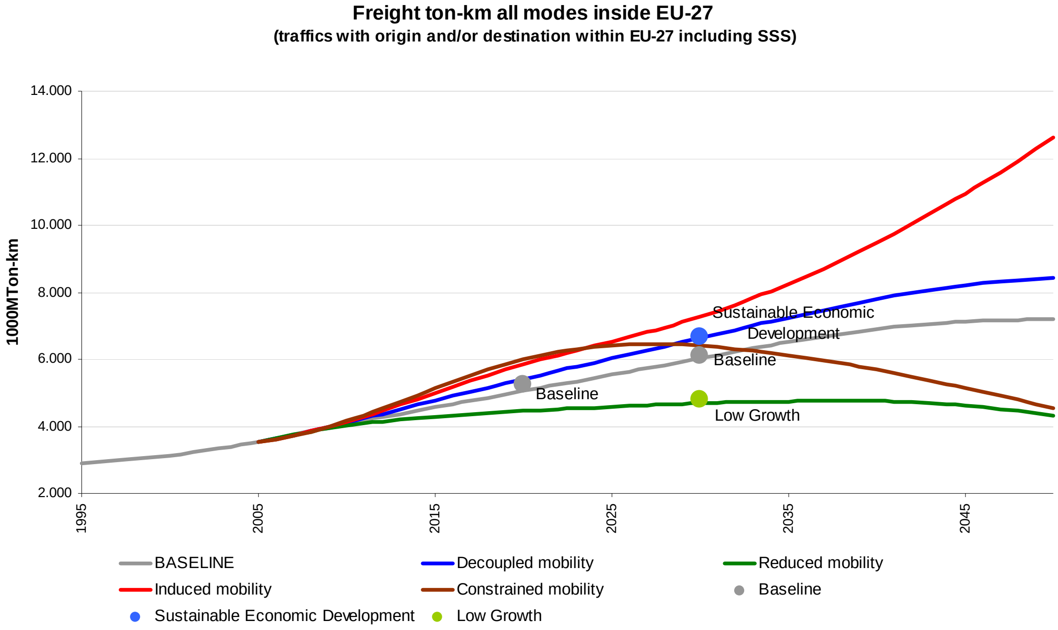



**Figure 30: Calibration of freight traffic**

In quantitative terms:

| | 2020 TransTools | 2020 Meta-models | Difference |
|---|---|---|---|
| Road pax-km | 5.444 | 6.153 | 13% |
| Rail pax-km | 512 | 491 | -4% |
| Air pax-km | 382 | 368 | -4% |
| **Total pax-km** | **6.338** | **7.012** | **11%** |
| Road ton-km | 2.191 | 2.063 | -6% |
| Rail ton-km | 662 | 644 | -3% |
| Maritime ton-km | 2.259 | 2.223 | -2% |
| **Total ton-km** | **5.112** | **4.930** | **-4%** |

**Table 4: Calibration figures for year 2020**

| | 2030 TransTools | 2030 Meta-models | Difference |
|---|---|---|---|
| Road pax-km | 6.593 | 6.569 | -0,4% |
| Rail pax-km | 657 | 659 | 0,3% |
| Air pax-km | 298 | 298 | 0,0% |
| **Total pax-km** | **7.548** | **7.526** | **-0,3%** |
| Road ton-km | 2.453 | 2.442 | -0,4% |
| Rail ton-km | 797 | 796 | -0,1% |
| Maritime ton-km | 2.653 | 2.645 | -0,3% |
| **Total ton-km** | **5.903** | **5.883** | **-0,3%** |

**Table 5: Calibration figures for year 2030**

### 3.4.2. Validation of $CO_2$ emissions

The following technological strategy was first considered for the Baseline scenario (TS1) in order to validate $CO_2$ data for 2005:

- The 2005 values refer to EURO 3 technology.
- The 2030 values refer to EURO 5 technology, diesel and petrol, medium size car for passenger and heavy goods vehicle (HGV) diesel for freight. For HGV travelling in motorways, we have considered a representative vehicle >18 ton, and for HGV travelling across urban areas, a HGV <18 ton has been considered.
- Emissions coefficients and fuel consumption factors have been taken from the TREMOVE database v. 2.7.

The results in terms of $CO_2$ provided by TRANS-TOOLS and TT meta-models for 2005 are as follows:

| 2005 | TT+MM Within EU-27 | MM Outside EU-27 | Total |
|---|---|---|---|
| **Transport** | **1038,0** | **864,3** | **1902,2** |
| - Road Transport within EU-27 | 925,0 | 0,0 | 925,0 |
| - TOTAL Civil Aviation | 42,0 | 121,9 | 163,9 |
| - Trips within EU-27+ NCT+Segment of trips to overseas within EU-27 airspace | 42,0 | 0,0 | 42,0 |
| - Segment of trips to overseas outside EU-27 airspace | 0,0 | 121,9 | 121,9 |
| - TOTAL Navigation | 46,0 | 742,4 | 788,4 |
| - SSS EU-27+ NCT | 46,0 | 0,0 | 46,0 |
| - International overseas trips with O or D in EU-27 | 0,0 | 742,4 | 742,4 |
| - Railways (including indirect emissions) | 25,0 | 0,0 | 25,0 |

**Table 6: $CO_2$ emissions for TRANS-TOOLS and Meta-models 2005**
* NCT: Neighbouring countries considered in TRANS-TOOLS

The DG TREN statistical pocketbook data used for validation purposes is presented next:

| 2005 | Pocketbook |
|---|---|

| 2005 | Pocketbook |
|---|---|
| **Transport** | **1273,5** |
| - Road Transport | 917,5 |
| - TOTAL Civil Aviation | 151,6 |
| - Civil Aviation | 25,6 |
| - International Bunkers | 126,0 |
| - TOTAL Navigation | 185,4 |
| - Navigation | 21,9 |
| - International Bunkers | 163,5 |
| - Railways | 8,4 |
| - Other Transport | 10,8 |

**Table 7: DG TREN statistical pocketbook $CO_2$ data 2005**

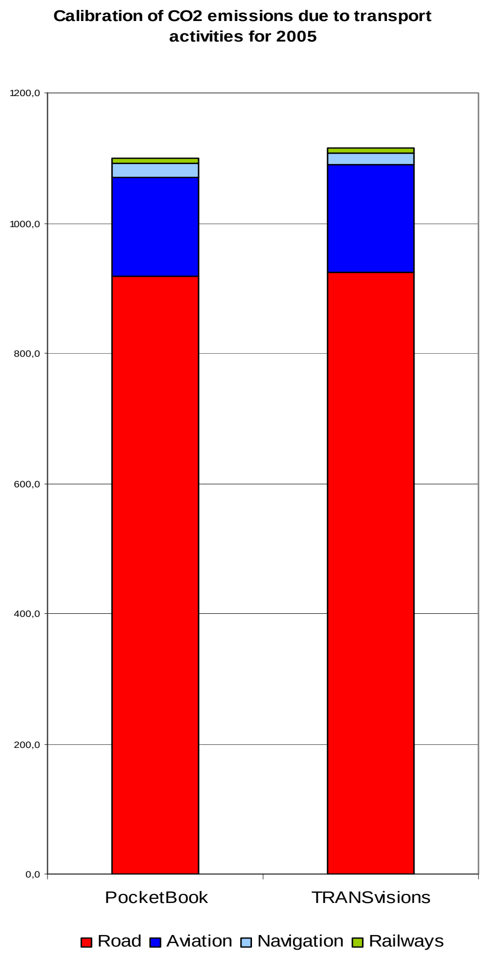
These figures cannot be directly compared, since indicators are not exactly the same, and some adjustments need to be made to make them more homogeneous and therefore comparable.

These adjustments are presented in the next table:

| | Pocketbook | TRANS visions | | Absolute differences | Relative differences | Relative differences over total |
|---|---|---|---|---|---|---|
| Total | **1099,3** | **1115,7** | | **16,4** | **1,5%** | **1,5%** |
| Road | 917,5 | 925,0 | (1) | 7,5 | 0,8% | 0,7% |
| Aviation | 151,6 | 163,9 | | 12,3 | 8,1% | 1,1% |
| - Civil Aviation | 25,6 | 27,3 | (2) | 1,7 | 6,6% | 0,2% |
| - International Bunkers | 126,0 | 130,3 | (3) | 4,3 | 3,4% | 0,4% |
| Navigation | 21,9 | 19,3 | (4) | -2,6 | -11,7% | -0,2% |
| Railways | 8,4 | 7,5 | (5) | -0,9 | -10,5% | -0,1% |

**Table 8: Comparison of DG TREN statistical pocketbook-TRANSvisions $CO_2$ emissions**

(1) 0.8% difference because traffic is estimated by TRANS-TOOLS
(2) Considering 20% of veh-km are international and 15% to NCT
(3) Adding the veh-km segments over EU-27 airspace
(4) Considering 58% of veh-km are to NCT (according to TTools)
(5) Considering that 30% emissions are due to diesel trains




| | Pocketbook 2005 | TRANSvisions 2005 |
|---|---|---|
| **$CO_2$ EMISSIONS (in kt $CO_2$)** | **1.099.311** | **1.115.661** |
| Road | 917.469 | 924.961 |
| Aviation | 151.580 | 163.880 |
| Navigation | 21.884 | 19.320 |
| Railways (not including indirect $CO_2$) | 8.377 | 7.500 |

**Table 9: Comparison of $CO_2$ emissions by modes**

In conclusion, $CO_2$ emissions are reasonably consistent in both estimates for 2005.

In order to evaluate the 2020 and 2030 results provided by TRANS-TOOLS and meta-models, another alternative technological strategy was applied for the Baseline scenario (TS2):

- The 2005 values refer to EURO 3 technology.

• The binding rules actually under discussion are considered and, stretching it a bit, the 95 gr/km for new cars by 2020 as a binding measure to be adopted by 2013. Then, the average emission rate in the 2030 baseline is 152g/km for fossil-fuel cars, with a 7% for non-fossil-fuel.

The 2030 results, for both the continuation of TS1 and TS2, are as follows:

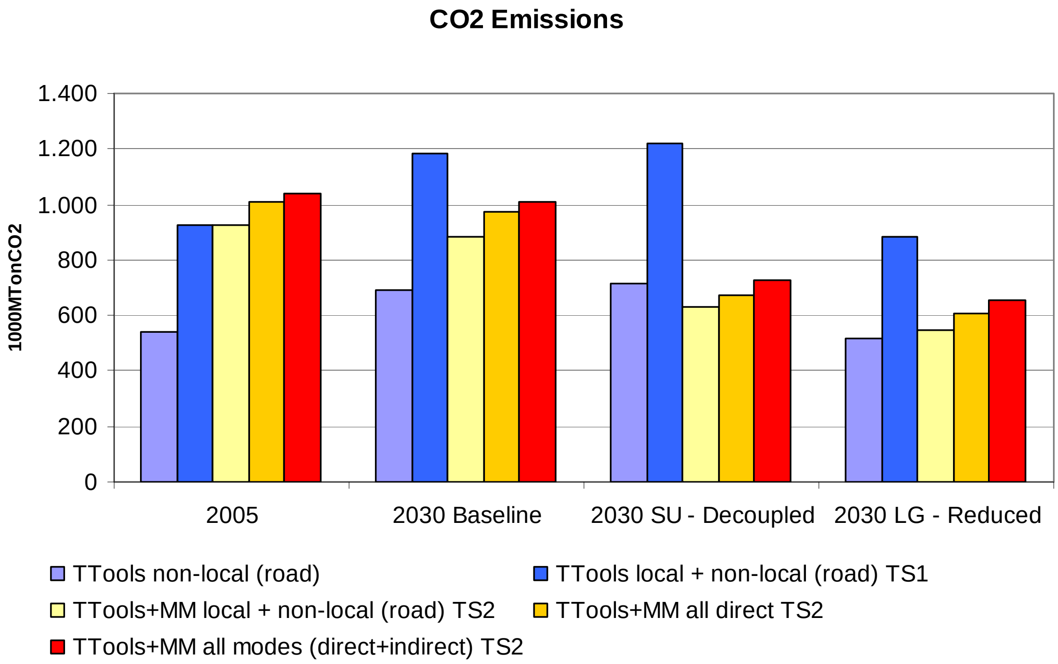



**Figure 31: $CO_2$ emissions comparison TRANS-TOOLS - Meta-models. As always, non-local refers to inter-NUTS3 traffic.**

The continuation of the 2005 TS1 technological strategy up to 2030 would result in an increase of 30% of direct $CO_2$ emissions in the 2030 Baseline scenario. This increase is even higher in the Decoupled scenario (given traffic is also higher than in the baseline), and it becomes a small reduction in the Reduced scenario, as it has less traffic.

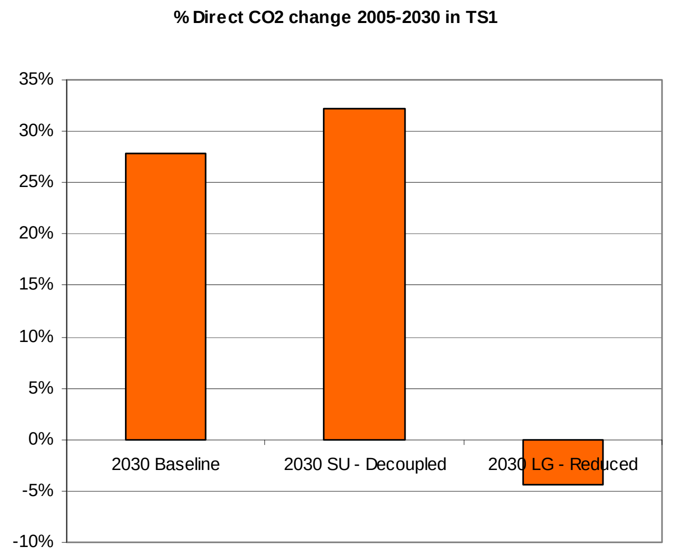



**Figure 32: % Direct $CO_2$ emission reduction with TS2 2005-2030**

| | Pocketbook 2005 | TRANSvisions 2005 | TRANSvisions 2020 | % variation 2005-2020 | TRANSvisions 2030 | % variation 2005-2030 |
|---|---|---|---|---|---|---|
| **$CO_2$ EMISSIONS (in kt $CO_2$)** | **1.099.311** | **1.115.661** | **1.223.816** | **10%** | **1.135.648** | **2%** |
| Road | 917.469 | 924.961 | 975.340 | 5% | 885.520 | -4% |
| Aviation | 151.580 | 163.880 | 225.944 | 38% | 227.982 | 39% |
| Navigation | 21.884 | 19.320 | 22.532 | 17% | 22.146 | 15% |
| Railways (not including indirect $CO_2$) | 8.377 | 7.500 | 5.850 | -22% | 4.125 | -45% |

**Table 10: Comparison of $CO_2$ emissions by modes**

The implementation of the TS2 technological strategy would produce a reduction of 4.9% in direct $CO_2$ emissions in the 2030 Baseline scenario. This reduction is higher for the Decoupled and Reduced scenarios, as was expected.

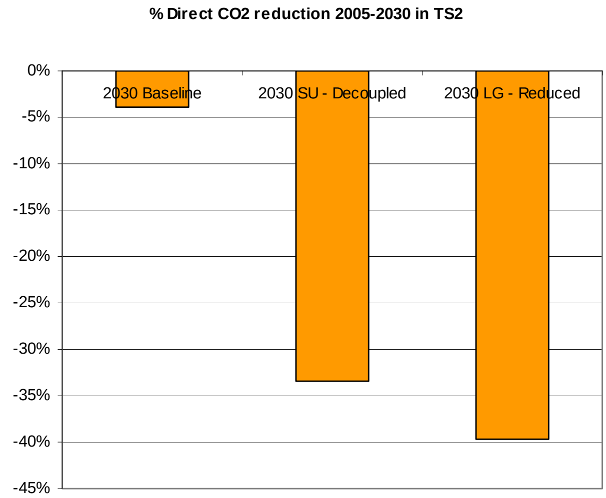



**Figure 33: % Direct $CO_2$ emission reduction with TS2, 2005-2030**

### 3.4.3. Comparison with other forecasts

The comparison with other forecasts is useful to notice differences and analyse relative magnitudes, but it is not easy to derive conclusions concerning the consistency of predictions since different studies are based on different assumptions and modelling tools.

The Baseline scenario upon which all other scenarios are built has been validated taking into consideration two different periods: 2000 to 2020, and 2000 to 2050, which are the main target years for most of the existing studies.

For the period 2000 to 2020, the TRANSvisions Baseline scenario is in line other studies (each one based on their own scenarios and geographic coverage), although the modal split for rail is more favourable in the TRANSvisions scenarios.

| Freight Growth 2000-2020 | Short-sea | Rail | Road | Total |
|---|---|---|---|---|
| IMPACT baseline | 53% | 53% | 47% | 50% |
| TREMOVE baseline 2020 | | 9% | 47% | |
| TREMOVE baseline 2020 non-urban | | 9% | 48% | |
| PRIMES | | 20% | 46% | |
| ASSESS | 58% | 12% | 55% | 47% |

| | | | | |
|---|---|---|---|---|
| IMPACT int. w/ taxes | 53% | 52% | 47% | 49% |
| IMPACT int. w/ tolls | 72% | 125% | 40% | 55% |
| TRANSvisions Baseline | 72% | 79% | 60% | 68% |
| TRANSvisions Decoupled | 82% | 98% | 71% | 79% |
| TRANSvisions Reduced | 51% | 60% | 41% | 48% |
| TRANSvisions Induced | 97% | 104% | 88% | 94% |
| TRANSvisions Constrained | 100% | 112% | 95% | 99% |

**Table 11: Freight traffic growth 2000-2020 for different studies (EU-27 for TRANSvisions, EU-15 for others)**

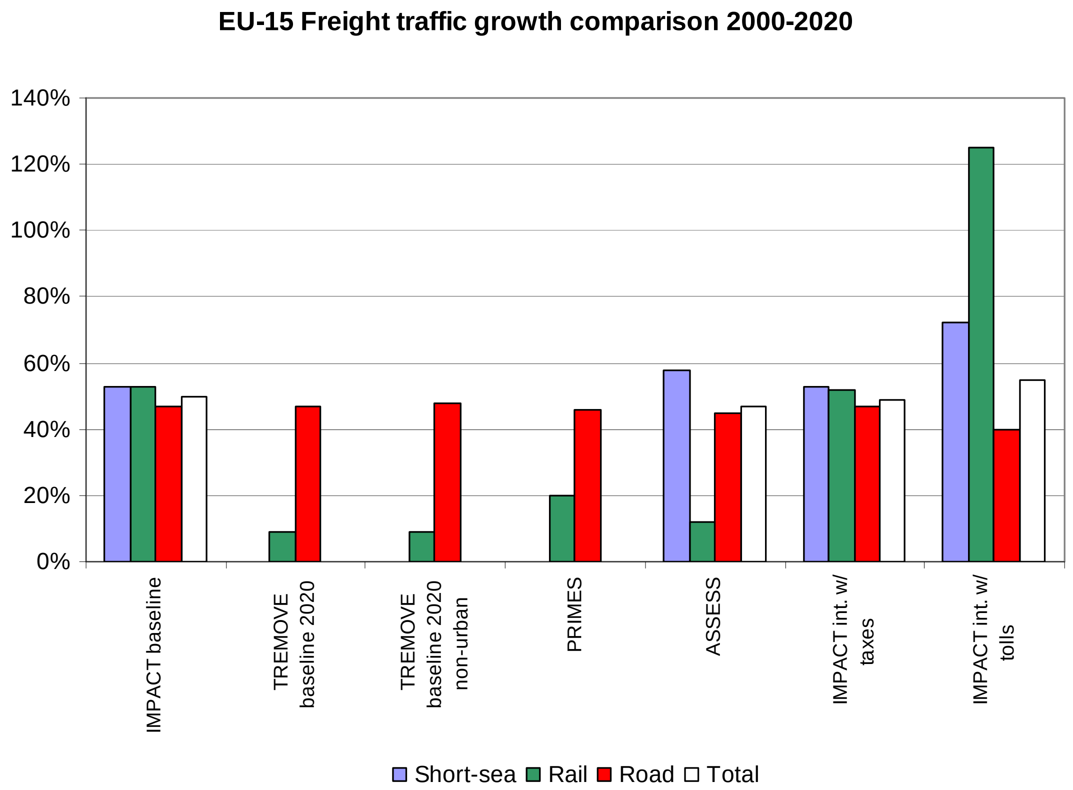



**Figure 34: Freight traffic growth comparison, 2000-2020**

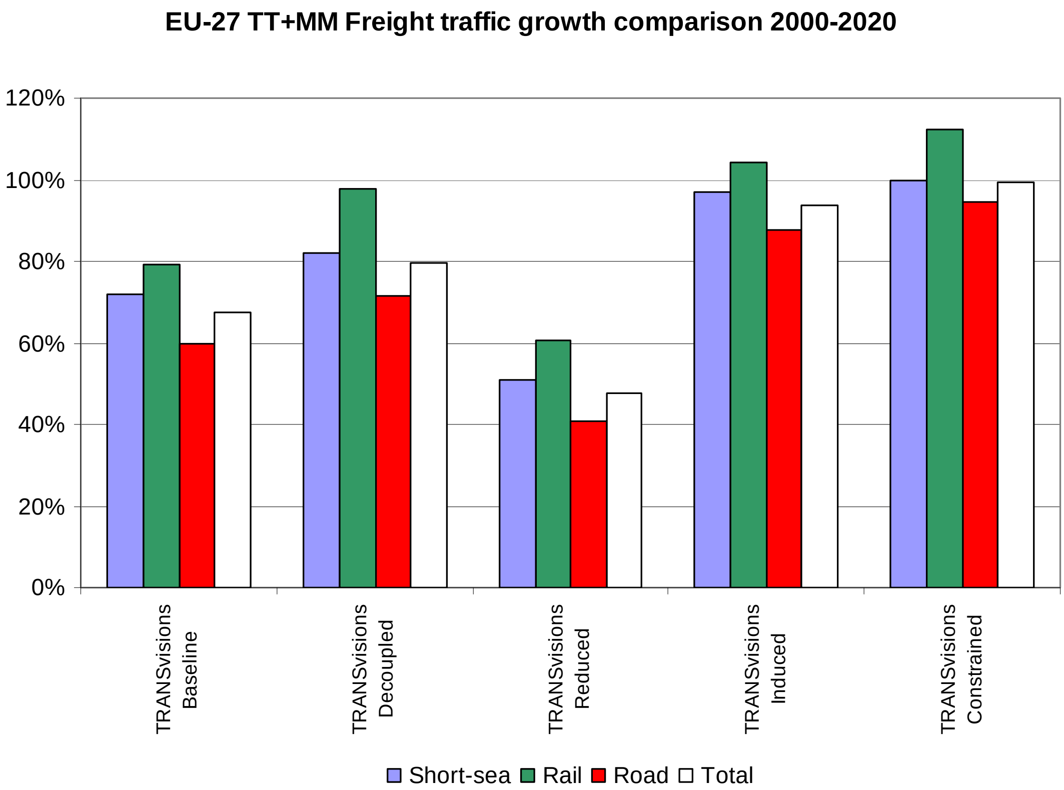



**Figure 35: Freight traffic growth TRANS-TOOLS with Meta-models, 2000-2020**

| Passenger Growth 2000-2020 | Air | Rail | Road | Total |
|---|---|---|---|---|
| IMPACT baseline | 25% | 10% | 13% | 14% |
| TREMOVE baseline 2020 | 106% | 23% | 32% | 36% |
| TREMOVE baseline 2020 non-urban | 106% | 22% | 30% | 36% |
| PRIMES | 92% | 32% | 32% | 37% |
| ASSESS | 104% | 22% | 32% | 37% |
| IMPACT int. w/ taxes | 25% | 11% | 13% | 14% |
| IMPACT int. w/ tolls | 24% | 39% | 21% | 22% |
| TRANSvisions Baseline | 57% | 158% | 43% | 50% |
| TRANSvisions Decoupled | 52% | 189% | 56% | 63% |
| TRANSvisions Reduced | 23% | 186% | 32% | 40% |
| TRANSvisions Induced | 89% | 123% | 73% | 77% |
| TRANSvisions Constrained | 105% | 151% | 83% | 88% |

**Table 12: Passenger traffic growth 2000-2020 for different studies. (EU-27 for TRANSvisions, EU-15 for others)**

Results for TRANSvisions are relatively different in relation to rail travel, and have similar magnitudes for the other modes, with the reason for this being the increase in long-distance trips by rail, which adds a high number of pax-km, even if the absolute number of passengers is small.

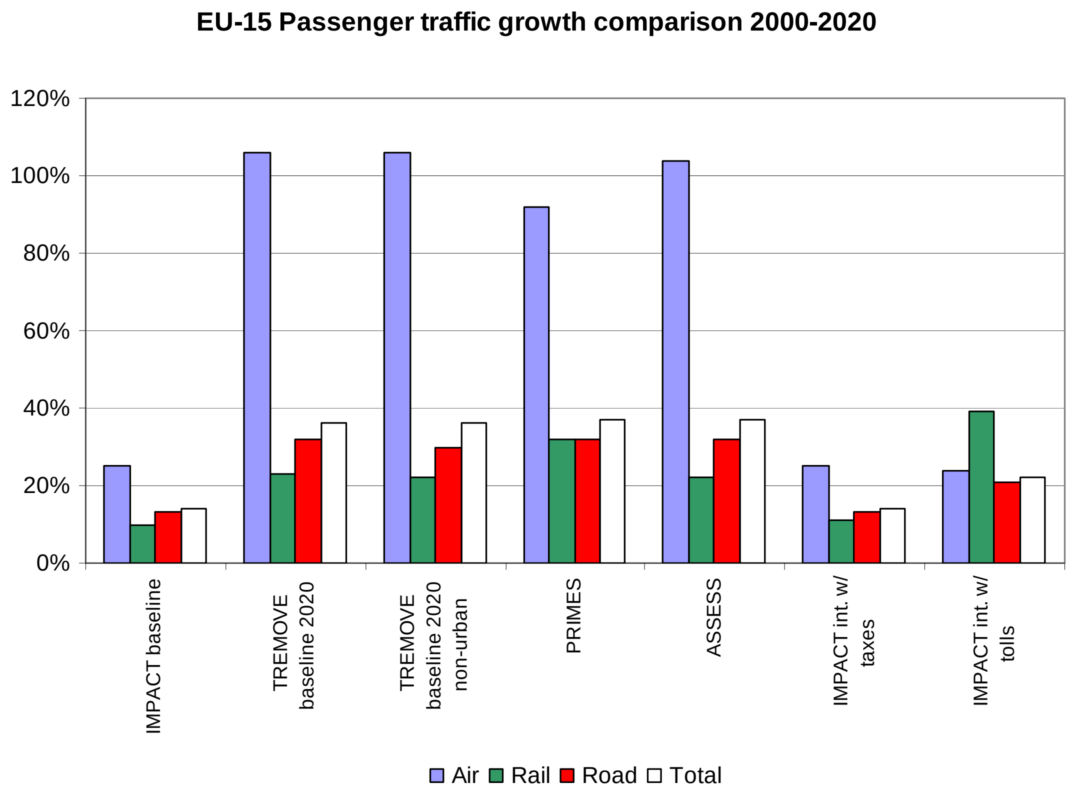



Figure 36: Passenger traffic growth comparison, 2000-2020

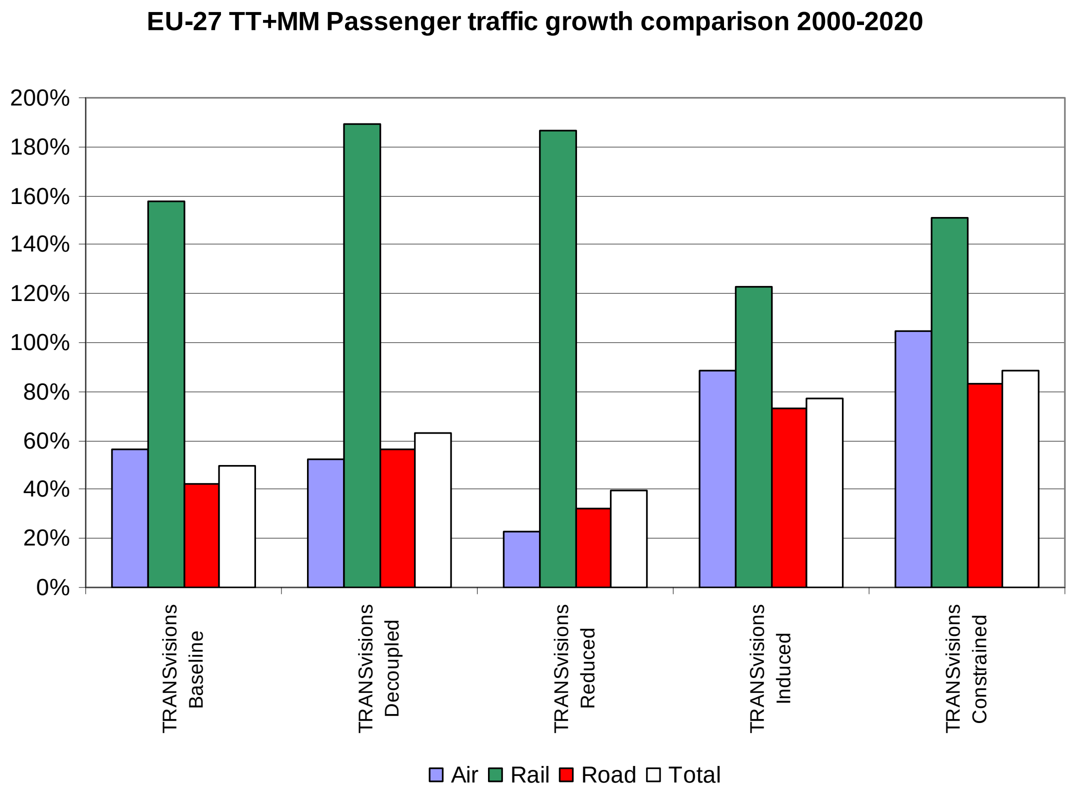



Figure 37: Passenger traffic growth TRANS-TOOLS with Meta-models 2000-2020

The growth of passenger rail shown in figure 29, which is higher than the growth produced by most of the other recent studies, is caused by a relatively small growth in trips (2.4%) from very long distance origins and destinations of 2000km on average. These trips account for 86% of the increase in pax-km. If these 2.4% of new trips with very distant origins and destinations are removed from the matrix, then the rail growth would be 33% in the Baseline scenario (instead of 158%). This increase in long-distance rail produces a reduction on long-distance air trips.

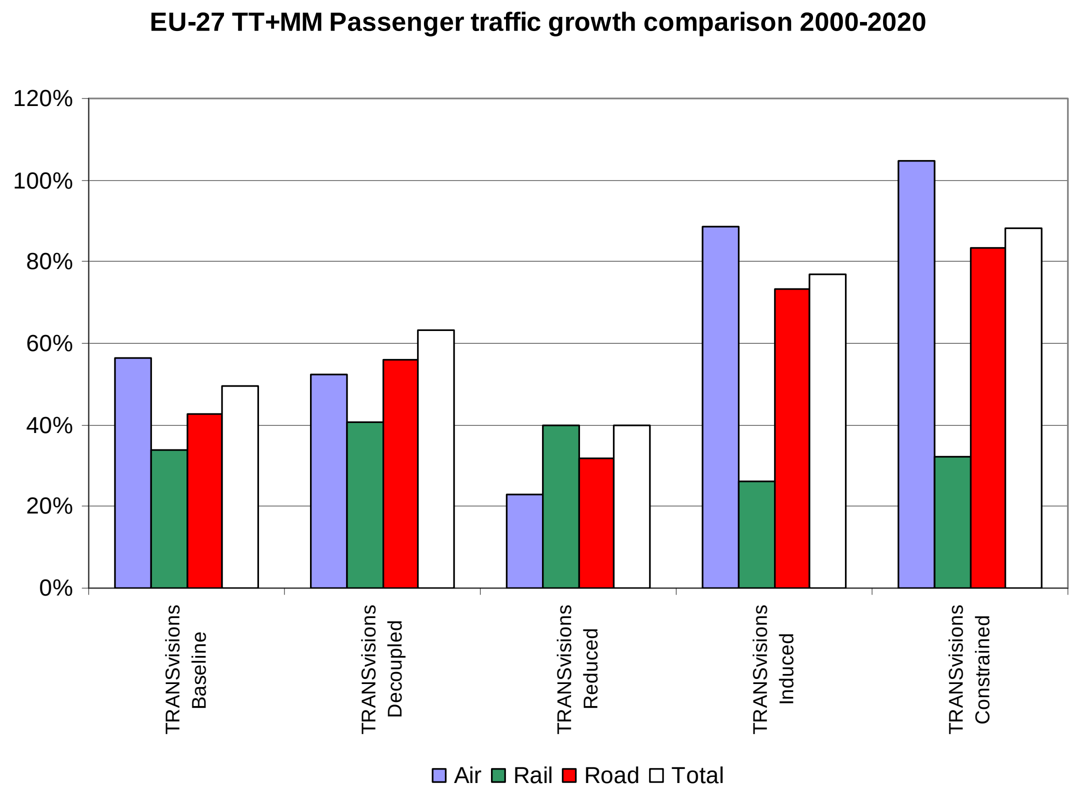



**Figure 38: Passenger traffic growth TRANS-TOOLS+Meta-models 2000-2020 (removing 2.4% new very long-distance pax-km in rail mode)**

With the 158% increase, the modal share of rail grows from 7% to 11% in passenger-km, while the modal share in number of trips remains the same. Applying a 33% growth of rail, resulting from the taking of new long-distance trips, the modal share would remain the same at 7% in pax-km.

The TRANSvisions Baseline scenario is coherent with TRIAS study outputs, considering the 2000-2050 period. Main economic outputs are shared for the two scenarios, but the TRANSvisions baseline assumes a higher demographic growth, mainly due to immigration flows. TRIAS assumes a slightly regressive population evolution.

The volumes of freight by sea grow in the same pattern for both studies. However, rail grows more intensively in TRANSvisions while road use is significantly lower.

Passenger traffic growth is quite similar in both studies. However, there is a shift between the air and train modes of transport, favouring train more in TRANSvisions and air more in TRIAS.

| | Base 100=2000 | TRIAS Study Baseline scenario | TRANSvisions Baseline scenario |
|---|---|---|---|
| Population | 100 | 98 | 100.6 |
| Labour force | 100 | 90 | 107 |
| GDP | 100 | 280 | 302 |
| Exports | 100 | 410 | 532 |
| Gross capital stock | 100 | 290 | 341 |
| Total factor productivity | 100 | 240 | 282 |
| Employment | 100 | 100 | 107 |
| Freight traffic, road (+tkm) | 100 | 380 | 250 |
| Freight traffic, rail (+tkm) | 100 | 320 | 366 |
| Freight traffic, sea (+tkm) | 100 | 230 | 230 |
| Passenger traffic, road (+pkm) | 100 | 160 | 171 |
| Passenger traffic, air (+pkm) | 100 | 200 | 132 |
| Passenger traffic, train (+pkm) | 100 | 125 | 435 |
| Transport emissions $CO_2$ | 100 | 150 | 73 |

**Table 13: Values for main indicators in 2050 baselines compared in theTRIAS study and TRANSvisions.**

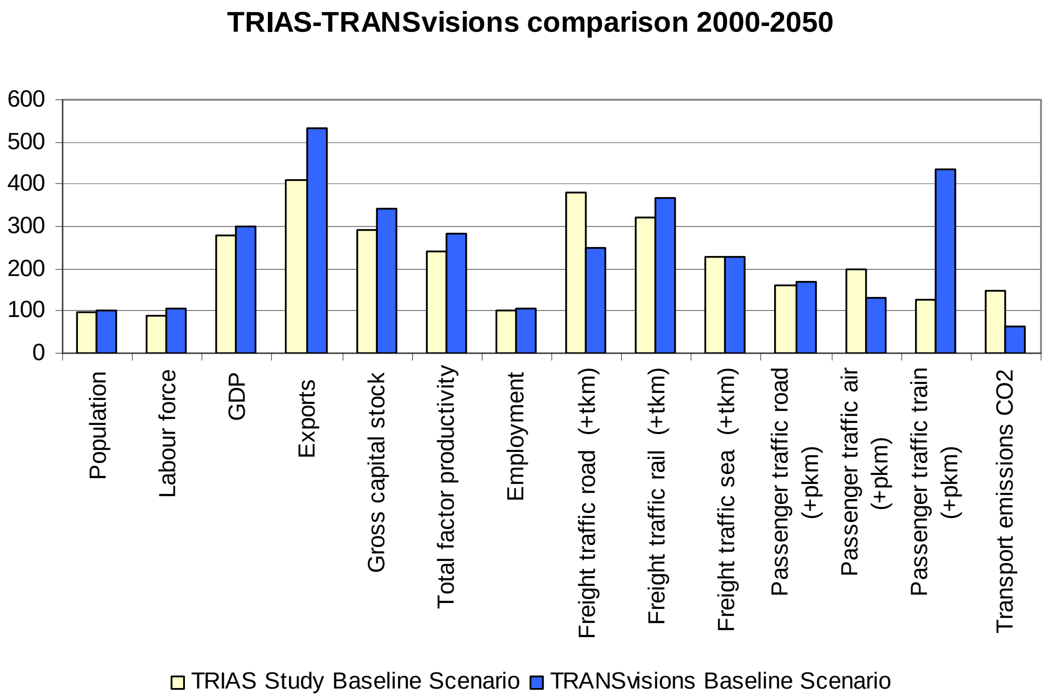



**Figure 39: TRIAS-TRANSvisions comparison, 2005-2050**

# 4. Analysis of results

Now that the calibration between TRANS-TOOLS (2005-2030) and TRANS-TOOLS meta-models (2005-2050) has been discussed, the main results for the exploratory scenarios will be presented. The TRANS-TOOLS results are displayed as points in 2030, while TT meta-models provide the pathways. The figures for key indicators, for all scenarios and time horizons, are included in appendix. The graphics are briefly discussed in broad terms.

## 4.1. *Evolution of main socioeconomic indicators*

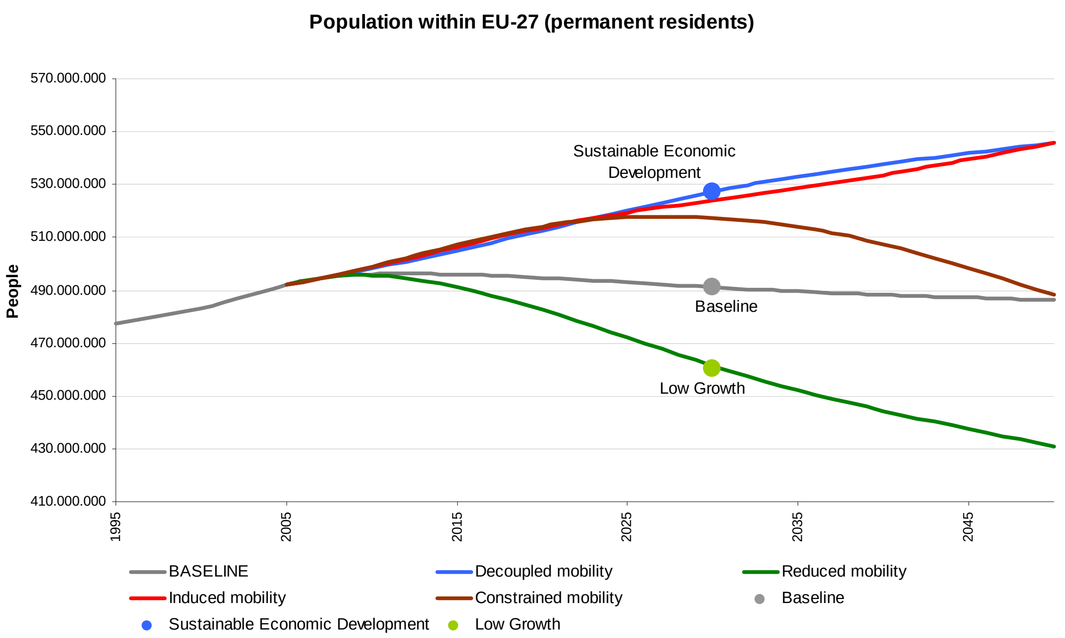



**Figure 40: Population within EU-27 (permanent residents). Evolution 2005-2050 of EU-27 residents in the exploratory scenarios, and values of population for 2030 according to reference scenarios. The graphic does not include the population increase due to EU enlargements.**

The Decoupled Mobility scenario corresponds to a continuous growth of population due to a small increase in fertility rates and to a moderate immigration rate. The Reduced Mobility scenario is almost the opposite, with a steady decline of population due to the decrease in fertility rates and especially to a decline in immigration. The Induced scenario follows the trends of the Decoupled scenario with a higher increase in immigration, while the Constrained scenario responds to a growing trend in the first half and a decrease in the second half, following the global tendency of decline in the frame of the scenario.

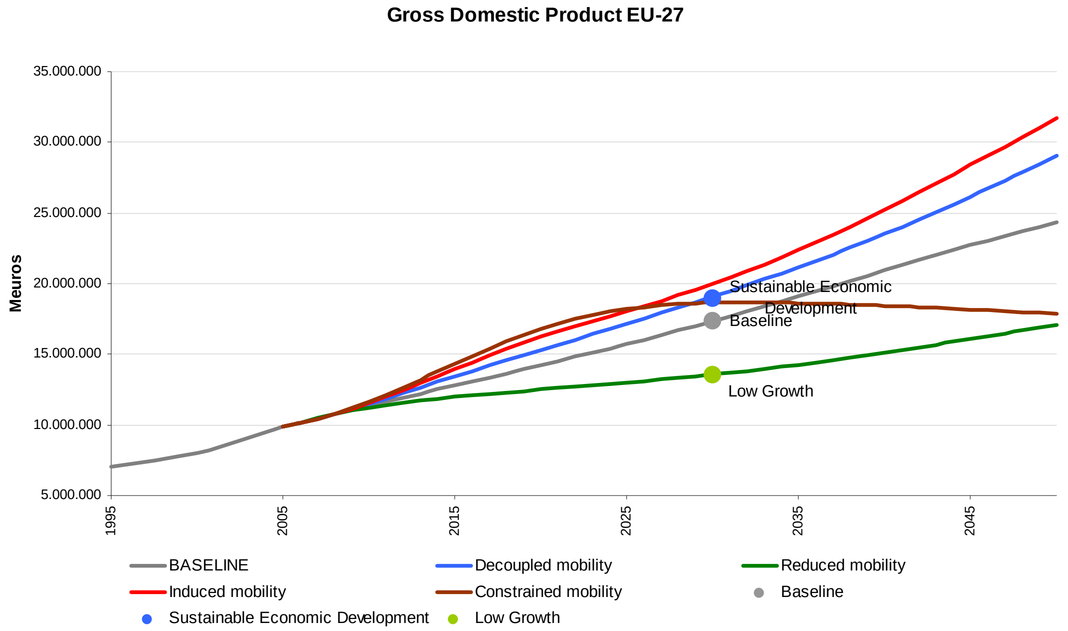



**Figure 41: Gross Domestic Product EU27 Evolution 2005-2050 of the EU-27 Gross Domestic Product in the exploratory scenarios and values of GDP for 2030 according to reference scenarios. The GDP trends show a continuous increase in all scenarios except the Constrained, which grows the most in the first period, failing to maintain this trend and declining from 2030 onwards.**

## 4.2. *Evolution of main transport indicators*

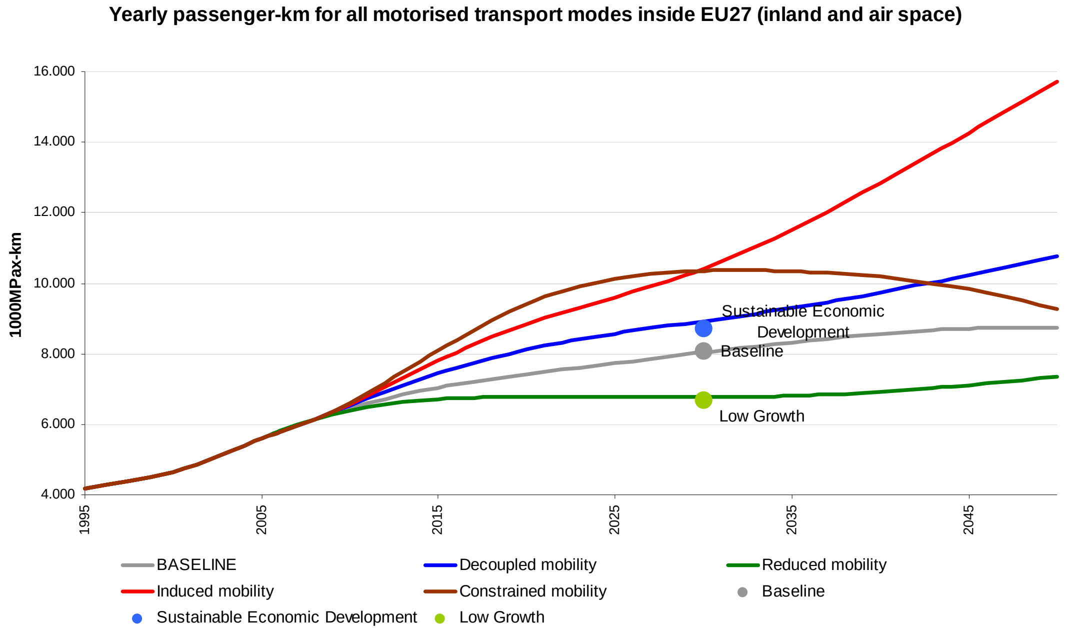



**Figure 42: Annual Passenger-km for all motorised transport modes inside the EU-27 (inland and airspace). 2005-2050 evolution of passenger-km in the exploratory scenarios and values for 2030 according to reference scenarios. The figure refers to the pax-km inside the EU-27 (inland and airspace) for all trips with origin and/or destination in the EU-27.**

These paths show a general rising trend of traffic, except for the Constrained Mobility scenario. To some extent, these paths follow GDP development, but changes in traffic elasticity to GDP makes them deviate. This leads to a Decoupled Mobility scenario with less passenger traffic than one would expect with present elasticity, and so the Induced scenario ends with a very high volume of pax-km. The elasticity for the Reduced scenario is also lower and thus the passenger traffic stagnates for a long time. The Constrained scenario has the highest increase of pax-km in the first period due to the high economic development, similar to the Induced scenario, but traffic levels decrease in the future when this scenario enters the crisis period.

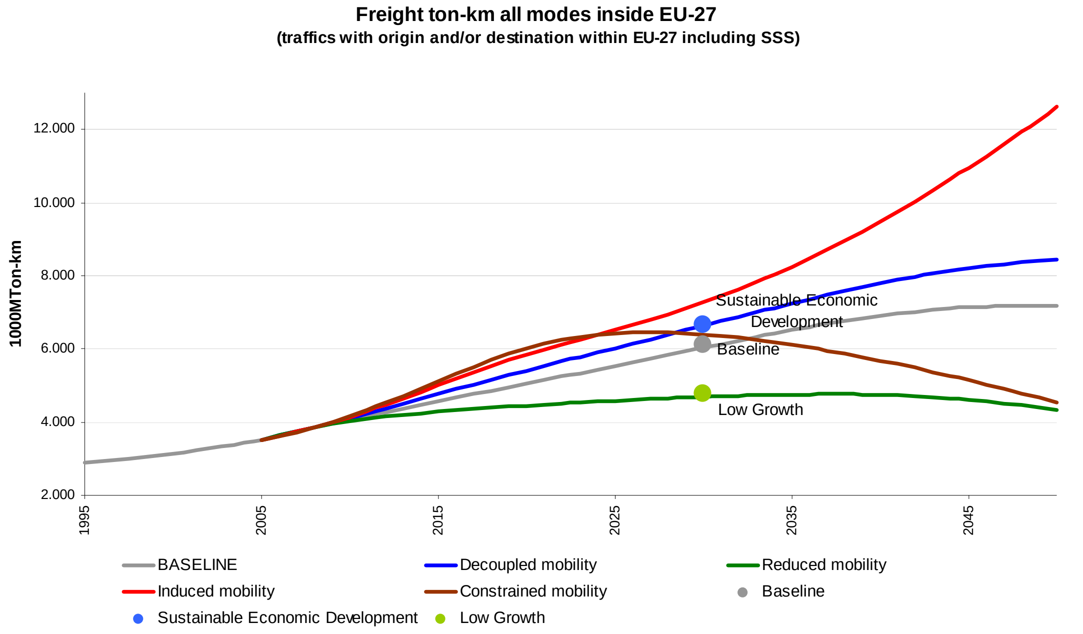



**Figure 43: Freight ton-km all modes inside the EU-27. Evolution 2005-2050 of ton-km in the exploratory scenarios and values for 2030 according to reference scenarios. The figure includes the ton-km inside the EU-27 (inland and short sea shipping (SSS)) for all trips with origin and/or destination in the EU-27.**

Freight is more closely linked to economic activity, meaning it has higher cost elasticity. This is in contrast to passenger mobility, which is not driven purely by economic factors. Similar to passenger traffic, the general trend is a continuous increase in freight traffic, with highest levels for the Induced scenario. In this case, the Reduced scenario has a net decrease of ton-km in the last decade, which reflects the effective decoupling of trade and economy due to long-term behavioural changes experienced in this scenario.

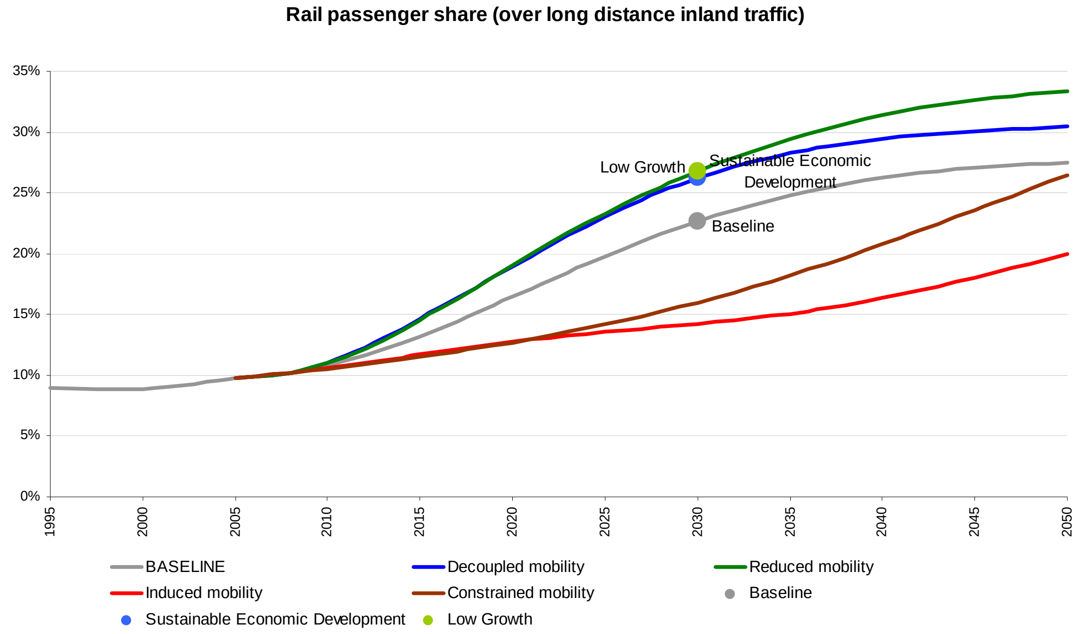



**Figure 44: Rail passenger share (over long-distance inland traffic) (pax-km). Evolution 2005-2050 of Rail passenger share (in relation to rail and road long-distance traffic) in the exploratory scenarios and values for 2030 according to reference scenarios. "Long distance" is here considered as inter-NUTS3 traffic (therefore, it covers a shortest distance in Germany, where NUTS3 are small, than in other countries with larger NUTS3). It should also be noted that passenger rail stabilises towards a level much higher than now, after a period of intensive investments in railways.**

The Baseline scenario follows the present trend of developing of high-speed train networks that will substitute a significant share of long-distance road and short/mid-distance air trips. Both Decoupled and Reduced scenarios have even higher rail shares. The Induced and Constrained scenarios start at a slower growing rate, but still slightly higher than the trend in past years. Even with a decrease in mobility in the period 2030-2050, in the Constrained scenario there is an increase of rail share because road trips as well as air trips are the most affected by the carbon constraints in the scenario. The Induced scenario supposes that development of new technologies in road and air transport will make the shift towards rail unnecessary to reduce $CO_2$ levels, and therefore the share of rail does not increase as much as in the other scenarios.

Next graphic shows the evolution 2005-2050 of rail freight share (in relation to rail and road long distance traffic) in the exploratory scenarios and values for 2030 according to Reference scenarios.

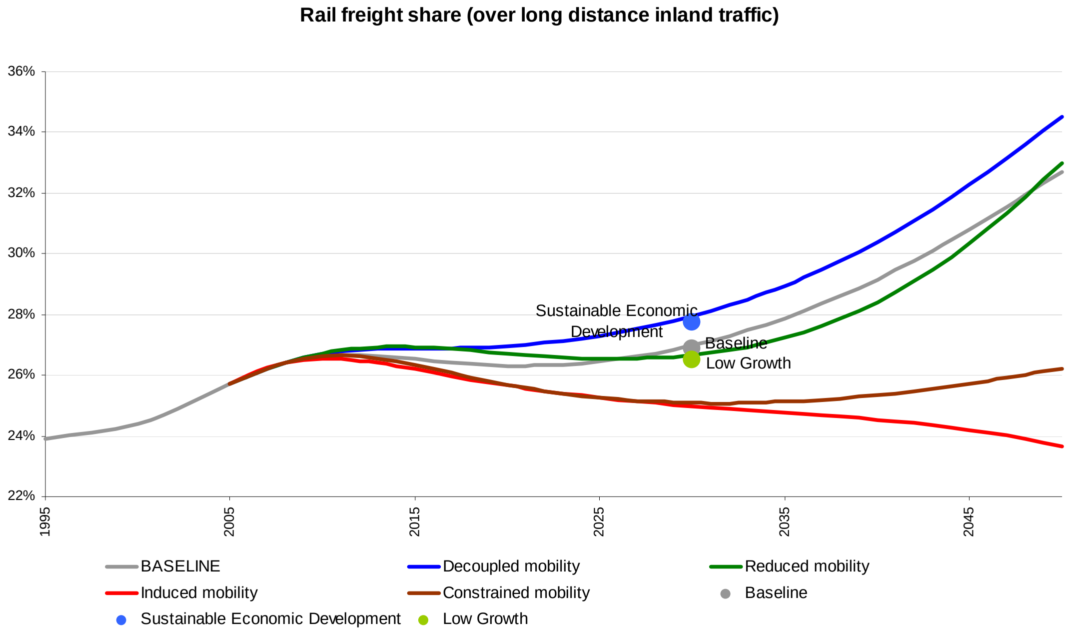



**Figure 45: Rail freight share (over long-distance inland traffic) (tn-km)**

The rail share for freight has a growing tendency in the Baseline, Decoupled and Reduced scenarios. In the Baseline and Decoupled scenarios this trend results from the development of dedicated rail infrastructure, as well as major improvements in management, whereas in the Reduced scenario rail share increases are mainly the result of a modal shift from road freight traffic to rail. The Induced scenario favours roads combined with SSS strategies, and therefore the rail share remains very low. The Constrained scenario follows the path of the Induced scenario, but when the traffic levels decrease once constrained, roads experiment the highest decline, thus making the rail traffic share more important in relative terms.

While passenger rail grows from 10% to almost 35%, the amount of freight growth is lower in all cases: from 27% to 33%, although most of the curves do not stabilise in the end, showing some upside potential. Passenger traffic grows first, putting pressure on freight. From 2030 on, the opposite seems to happen. As already mentioned, in the short-term passenger rail increases in relative terms due to high-speed train (HST) investments and the increase of long-distance trips (in pass-km). In the long-term, freight transported by rail may grow because of the high growth of goods imported from and exported overseas. This is largely because rail is expected to be competitive for this overseas traffic moving to and from large ports and main consumption centres. It must be noted that small increases in the number of tonnes and passengers transported by rail may produce significant increases in rail share, since in most cases they correspond to long trips, and rail shares nowadays are relatively low.

## 4.3. *Elasticity of transport to GDP (EU-27 traffic) 2005-2050*

This next section analyses the elasticity of transport (in pax-km, tn-km) in relation to the GDP for traffic within the EU-27, even if the origin and/or destination may be outside of the EU-27, in the different scenarios. The graphics show that decoupling between freight and passenger traffic within the EU-27 and GDP will happen except for the Induced scenario. It is worth mentioning that decoupling between traffic within the EU-27 and GDP is still consistent with the maintenance of historical mobility patterns, namely of freight transport growth following GDP growth, and passenger transport growth subject to a fixed budget constrain, with no decoupling, if European transport outside the EU-27 grows enough to compensate for the internal decoupling.

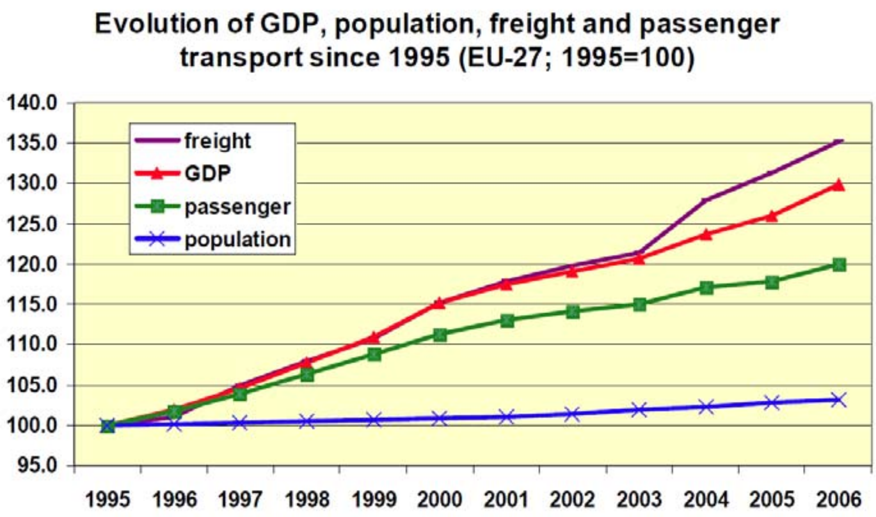



**Figure 46: Evolution of GDP, passenger and freight transport. Source: Transport Pocketbook DGTREN**

The next figures show GDP as well as passenger and freight traffic growth within the EU-27 from 1995 up to 2050, but use 2005 as reference.

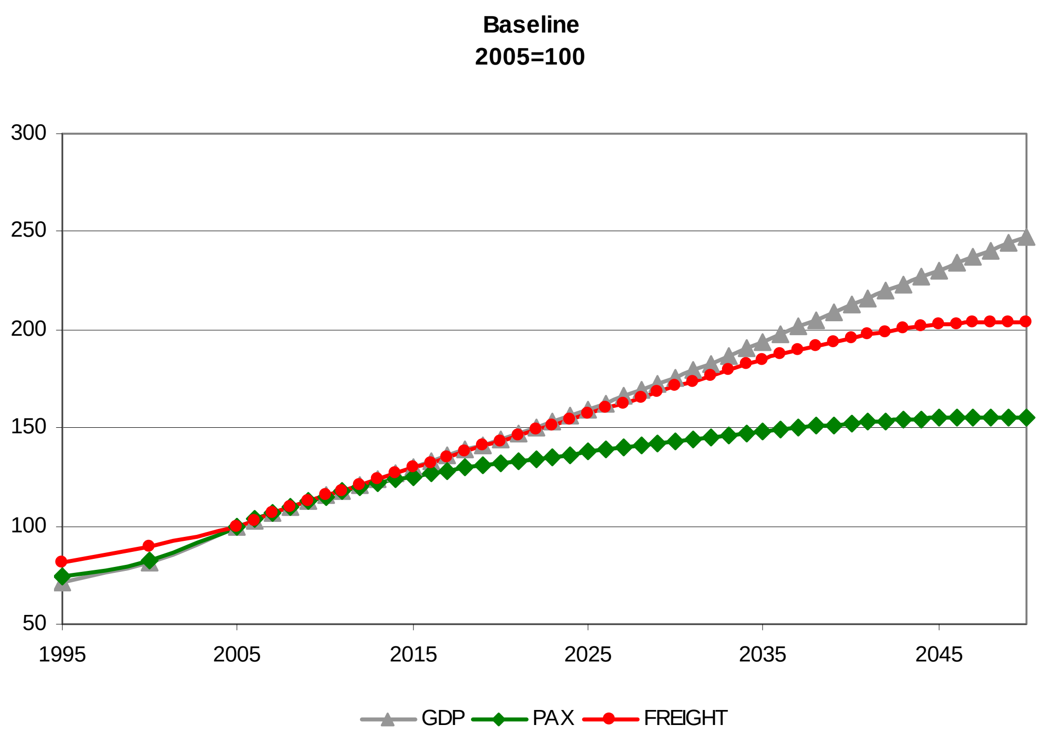



**Figure 47: Baseline scenario elasticity of transport to GDP for EU-27 traffic. Evolution of GDP, Pax-km and Ton-km inside the EU-27 (including air traffic and SSS) for the Baseline. Important decoupling occurs in passenger traffic and to lesser extent in freight.**

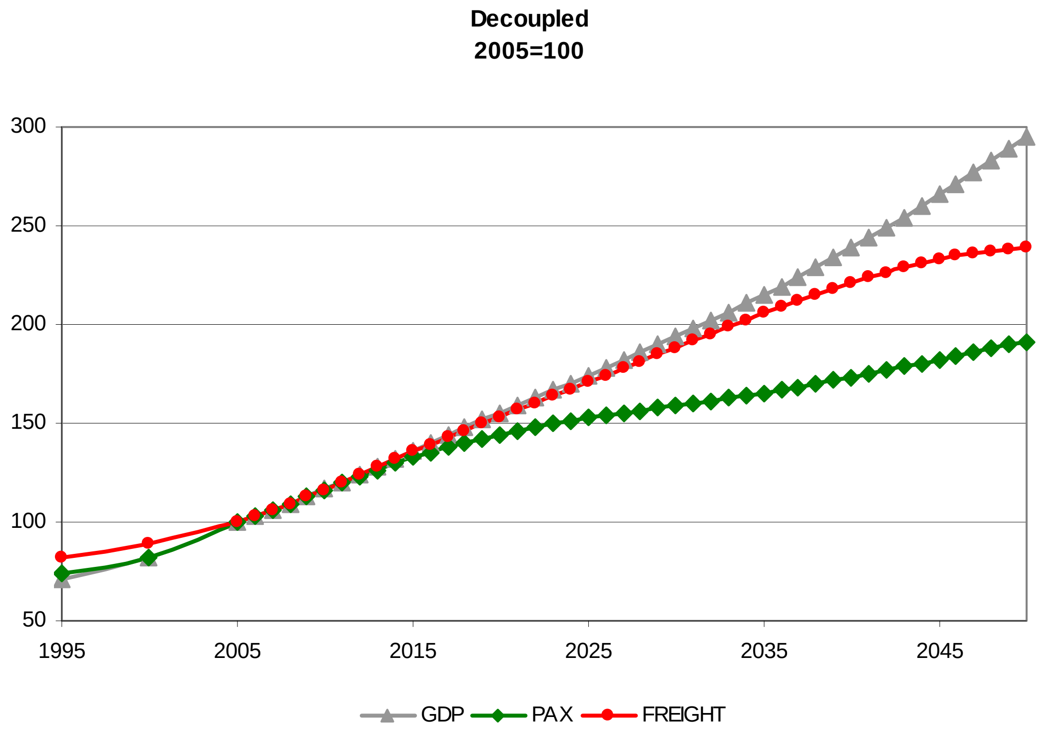



**Figure 48: Decoupled scenario elasticity of transport to GDP for EU-27 traffic. Evolution of GDP, Pax-km and Ton-km inside the EU-27 (including air traffic and SSS) for the Decoupled Mobility scenario. As the name of the scenario suggests there is a strong decoupling of freight and passenger traffic in respect to GDP growth.**

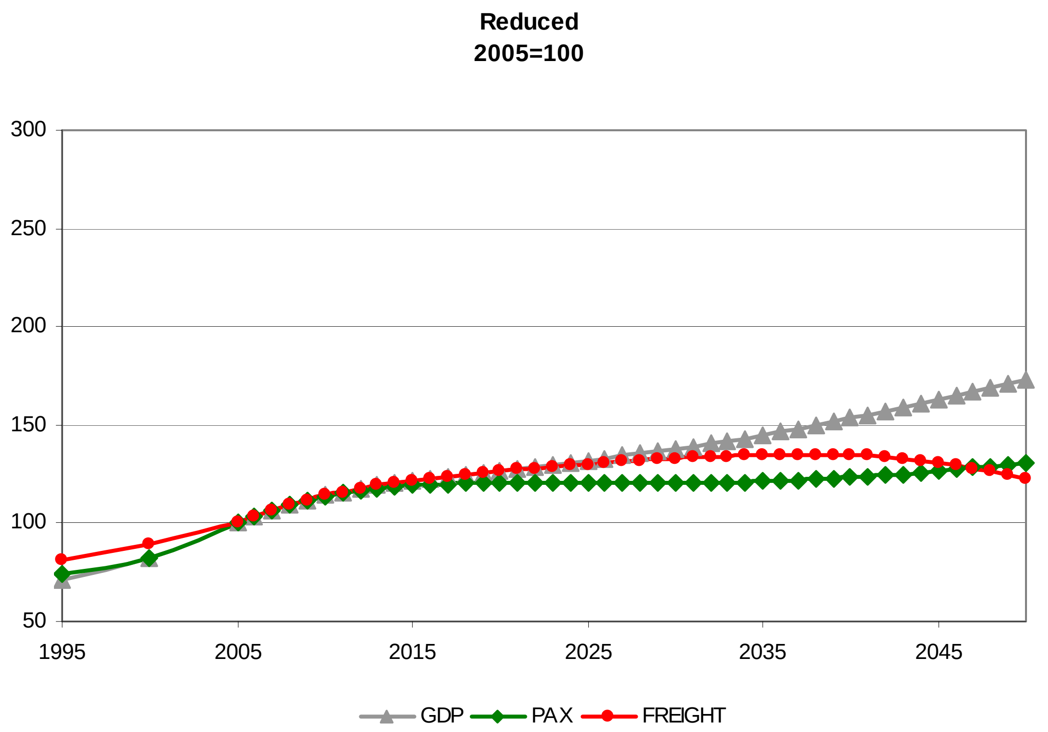



**Figure 49: Reduced scenario elasticity of transport to GDP for EU-27 traffic. Evolution of GDP, Pax-km and Ton-km inside the EU-27 (including air traffic and SSS) for the Reduced Mobility**

**scenario. Passenger traffic decouples from economic development and almost stagnates. Freight traffic follows the present coupling trends but in the mid term declines when behavioural changes in society start to have an impact.**

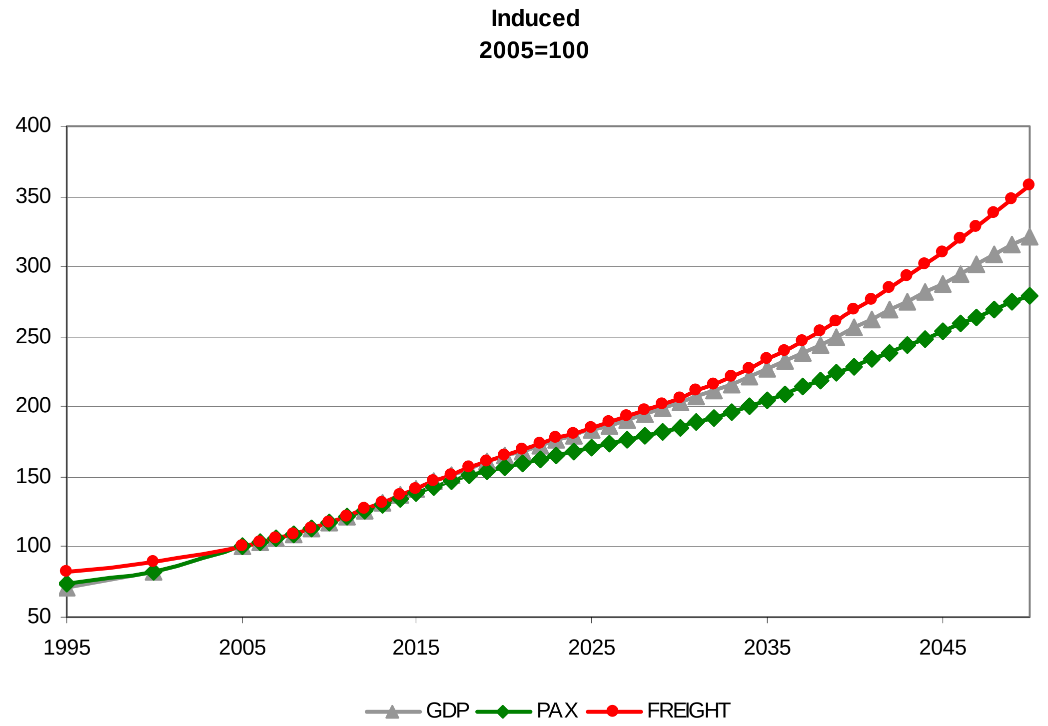



**Figure 50: Induced scenario elasticity of transport to GDP for EU-27 traffic. Evolution of GDP, Pax-km and Ton-km inside the EU-27 (including air traffic and SSS) for the Induced Mobility scenario. Freight traffic increases faster than GDP and passenger decouples but to a lesser extent than in the other scenarios.**

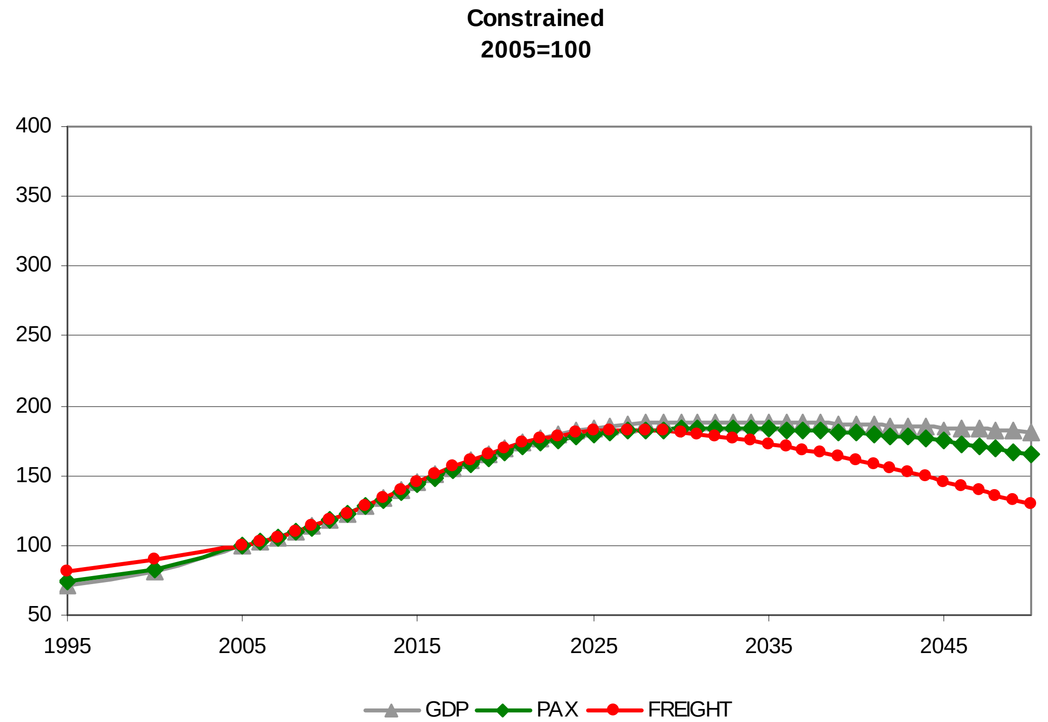


**Figure 51: Constrained scenario elasticity of transport to GDP for EU-27 traffic. Evolution of GDP, Pax-km and Ton-km inside the EU-27 (including air traffic and SSS) for the Constrained Mobility scenario. During the economic growth period, both passenger and freight have a strong coupling with GDP as in the Induced scenario. When economy declines, there is an important decoupling in freight due to reduction in the effects of globalisation trends within Europe.**

### 4.3.1. Long-term tendencies in freight transport

The previous section presented freight transport growth measured in weight. While external trade measured in weight tends to increase slightly faster than GDP, as it has been shown for most scenarios, if measured in value the external European trade is growing much faster than GDP. This is due to the evolution of European economies that are increasingly specialised in added-value products and services.

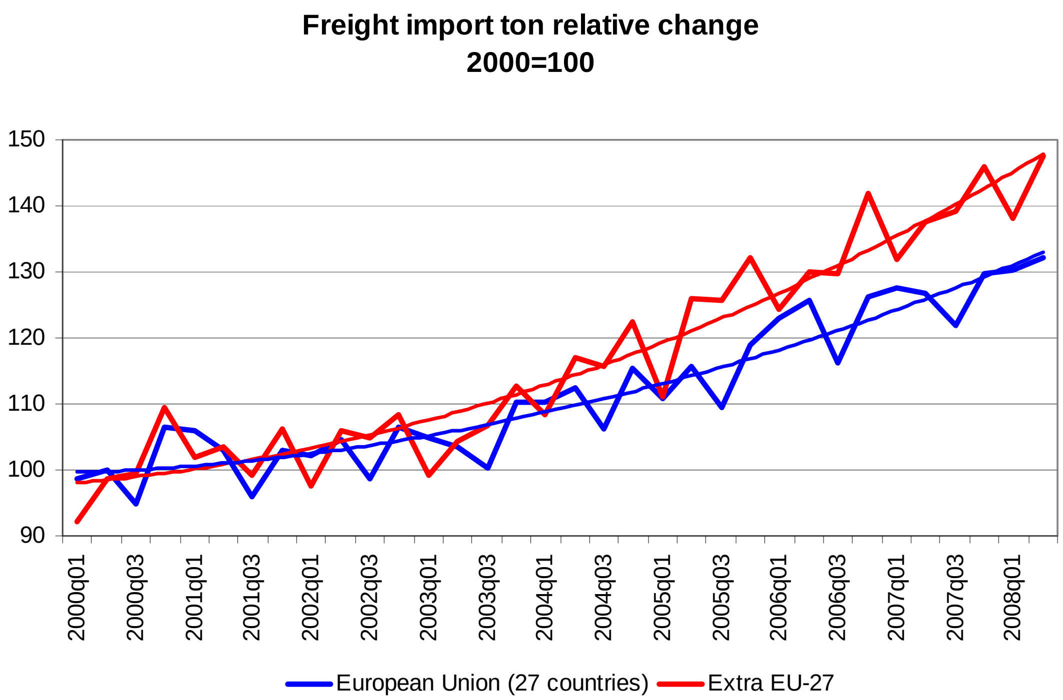



**Figure 52: Quarterly evolution of freight imports intra and extra-EU-27**

This figure shows the higher increase of EU-27 imports in relation to internal traffic. The globalisation trends are then clearly visible as the external traffic grows faster than internal commerce.

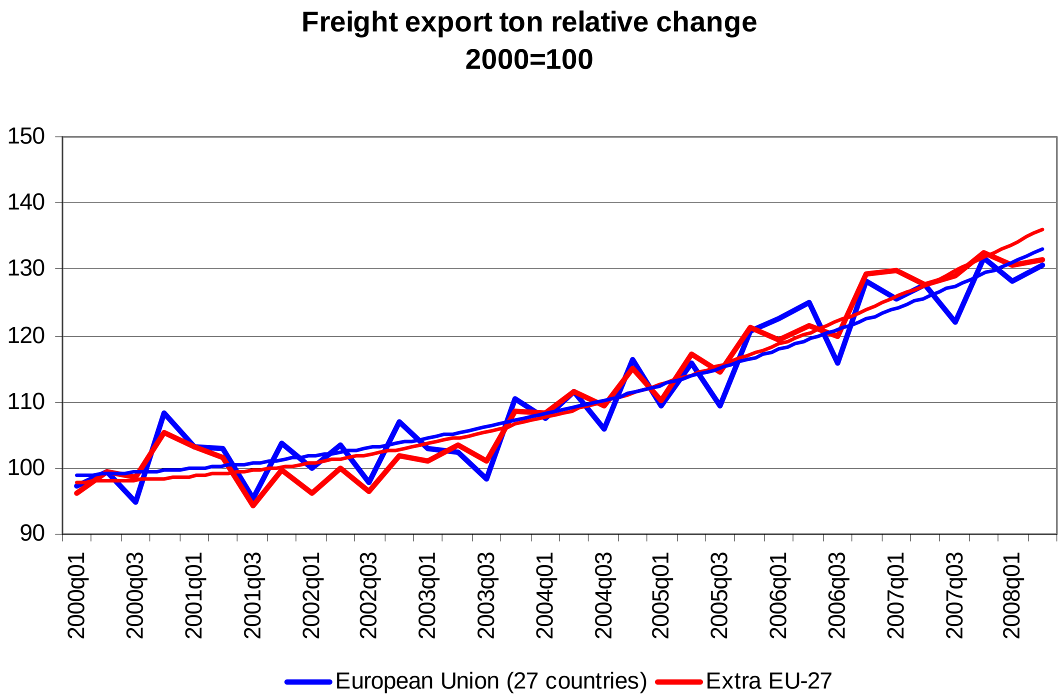



**Figure 53 Quarterly evolution of freight exports for intra and extra-EU-27**

EU-27 exports do not deviate as much as imports from internal traffic growth, but still extra-import/export trade increases much faster than internal commerce and the GDP.

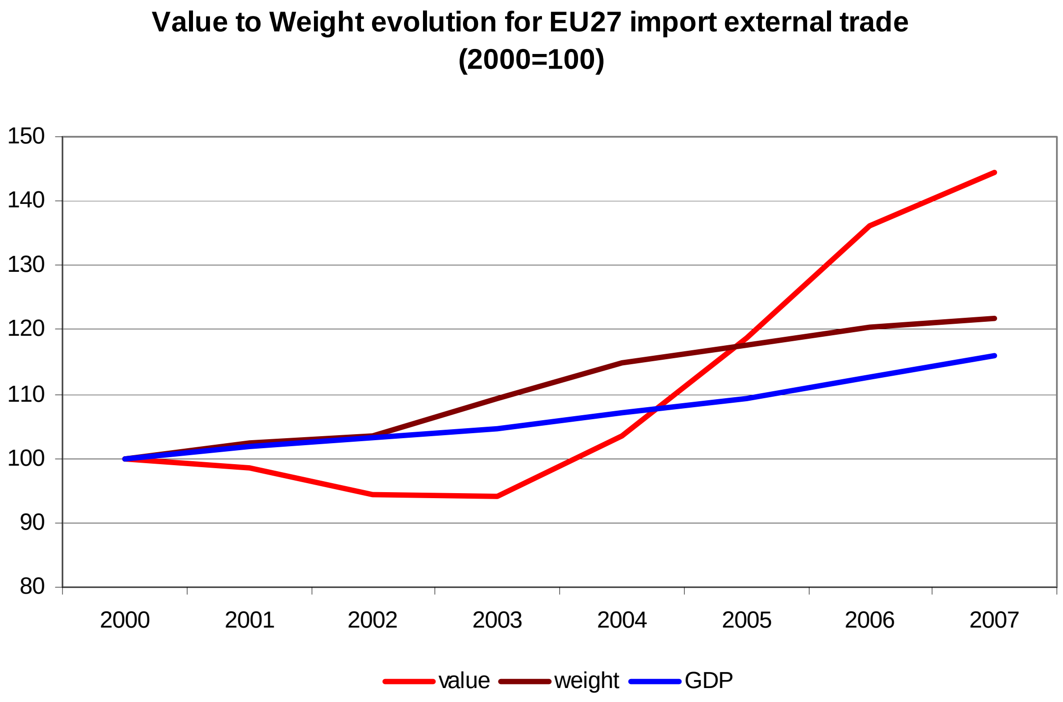



**Figure 54: Evolution of Value and Weight external import trade compared to GDP for the period 2000-2007**

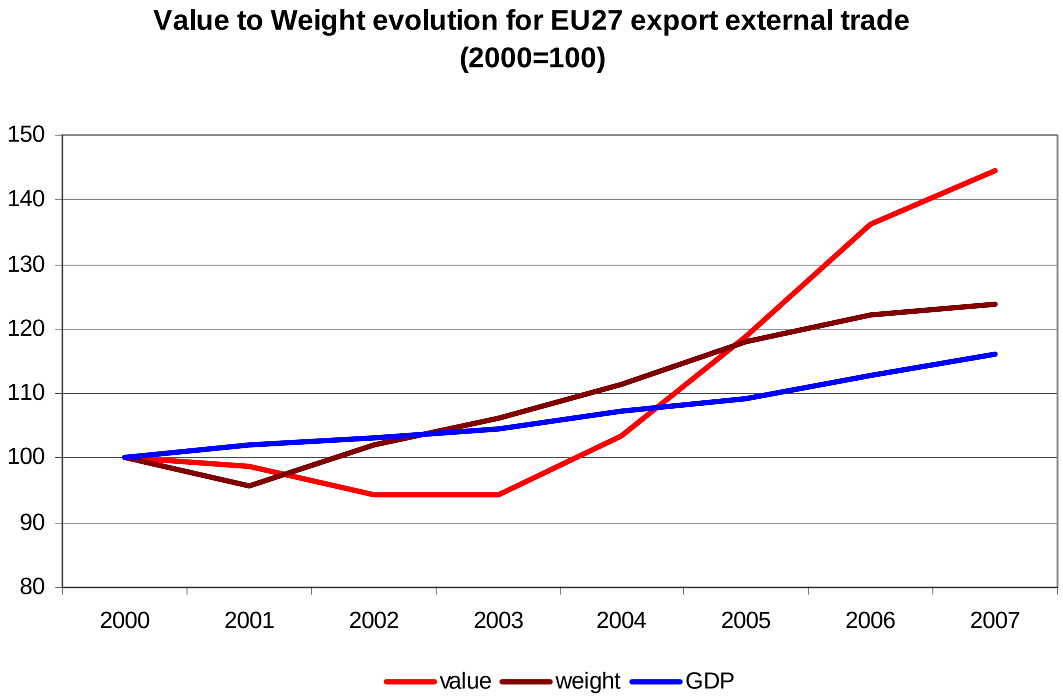



**Figure 55: Evolution of Value and Weight external trade export compared to GDP for the period 2000-2007**

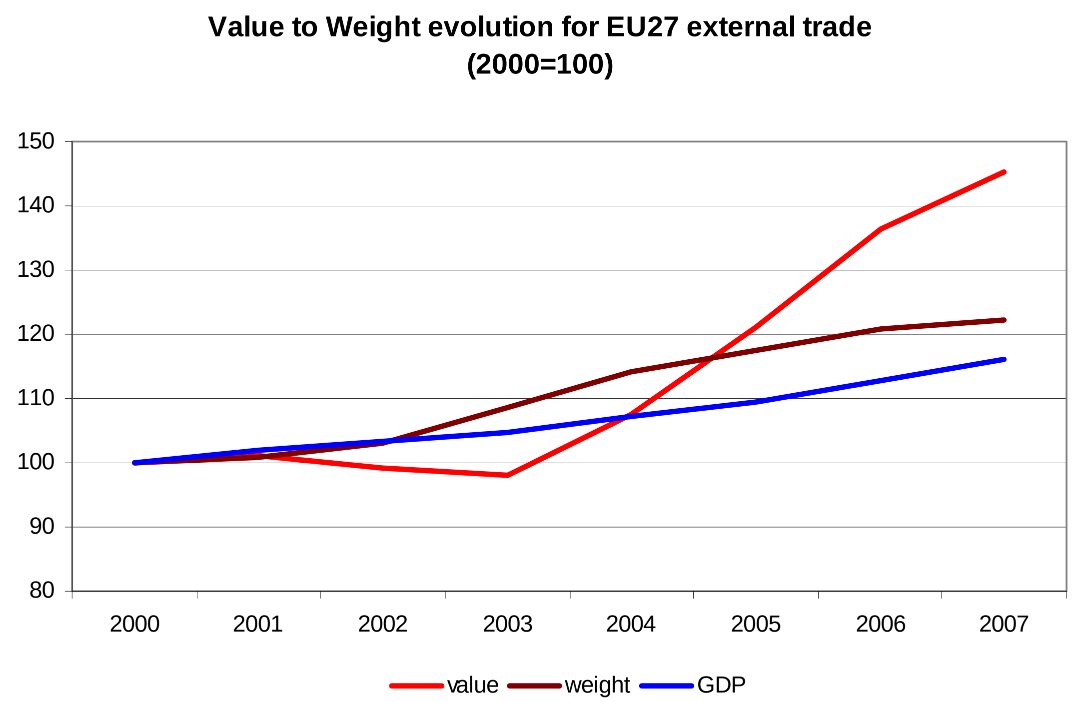



**Figure 56: Evolution of Value and Weight external trade compared to GDP for the period 2000-2007**

### 4.3.2. Long-term tendencies in passenger transport

There is no evidence of a constant elasticity between passenger traffic growth and economic growth. Instead, it is assumed that a fixed personal income ratio (about 15%) is allocated to transport as well as a maximum number of hours per day. Depending on the average cost of travel, people will travel more or less often and to more or less distant places.

| | Baseline | Decoupled mobility | Reduced mobility | Induced mobility | Constrained mobility |
|---|---|---|---|---|---|
| Annual GDP/Capita growth 2030 | 2,29% | 2,40% | 1,55% | 2,61% | 2,38% |
| Annual cost of transport variation 2005-2030 | 0,74% | 0,72% | 0,35% | 0,31% | 0,15% |
| Annual EU-27 passenger traffic variation 2005-2030 | 1,18% | 1,52% | 0,56% | 2,50% | 2,48% |
| Annual total passenger traffic variation 2005-2030 | 1,32% | 1,66% | 0,56% | 2,56% | 2,42% |

| | Baseline | Decoupled mobility | Reduced mobility | Induced mobility | Constrained mobility |
|---|---|---|---|---|---|
| Annual GDP/Capita growth 2050 | 2,06% | 2,20% | 1,53% | 2,40% | 1,35% |
| Annual cost of transport variation 2005-2050 | 1,64% | 1,59% | 1,00% | 0,49% | 0,54% |
| Annual EU-27 passenger traffic variation 2005-2050 | 0,82% | 1,23% | 0,47% | 2,32% | 1,12% |
| Annual total passenger traffic variation 2005-2050 | 1,82% | 2,48% | 0,75% | 4,30% | 1,82% |

### 4.4. *Elasticity of transport to GDP by type of trips*

The elasticity of transport to GDP depends very much on the type of trips.

When considering trips made by EU-27 residents inside the EU-27 territory the growth rate is relatively low (less than 1.3% per year, from 2005 to 2030 in the Baseline scenario). The addition of trips made in EU-27 territory by non-residents, especially trips with origin or destination outside the EU-27, slightly increases the growth rate up to 1.45% per year. This figure is similar to the one provided by EET (European Energy and Transport Baseline). The main difference arises when including the trips made by EU-27 residents outside EU territory, which increases the annual growth to 2.1%.

The next chart compares the elasticity by types of trips between TRANS-TOOLS model (complemented by TRANS-TOOLS meta-models), the DG TREN statistical pocketbook and the EET.

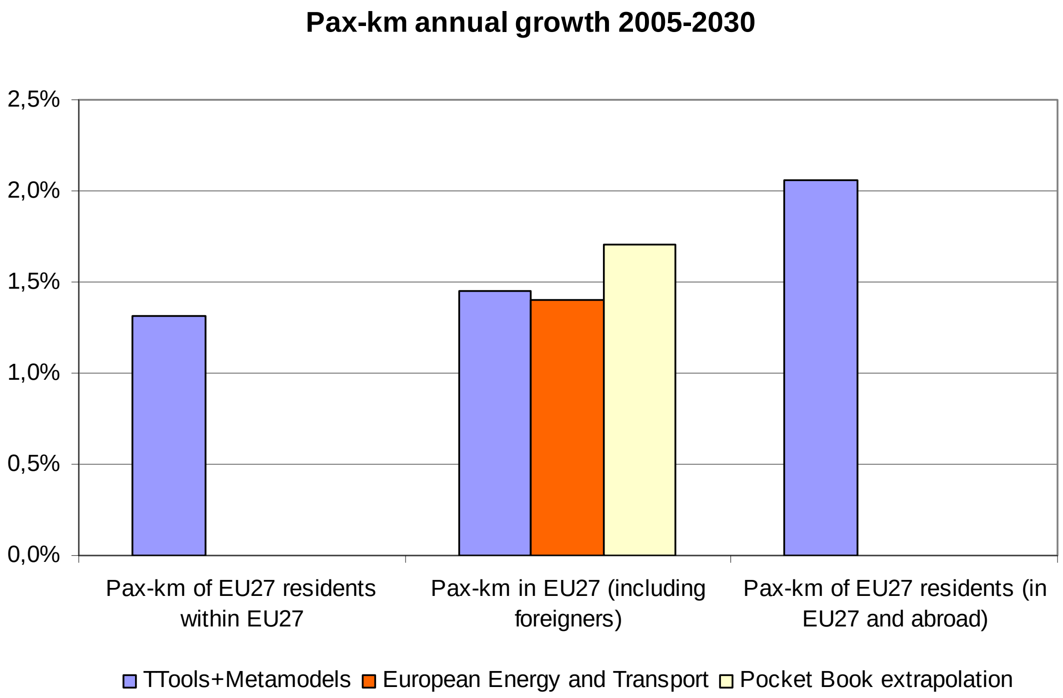



**Figure 57: Comparison pax-km annual growth 2005-2030**

The following chart displays ton-km growth rates by different trip segments, comparing TRANS-TOOLS and meta-models results, also to the European Energy and Transport 2030 baseline and the 2006 Transport DG TREN statistical pocketbook extrapolation.

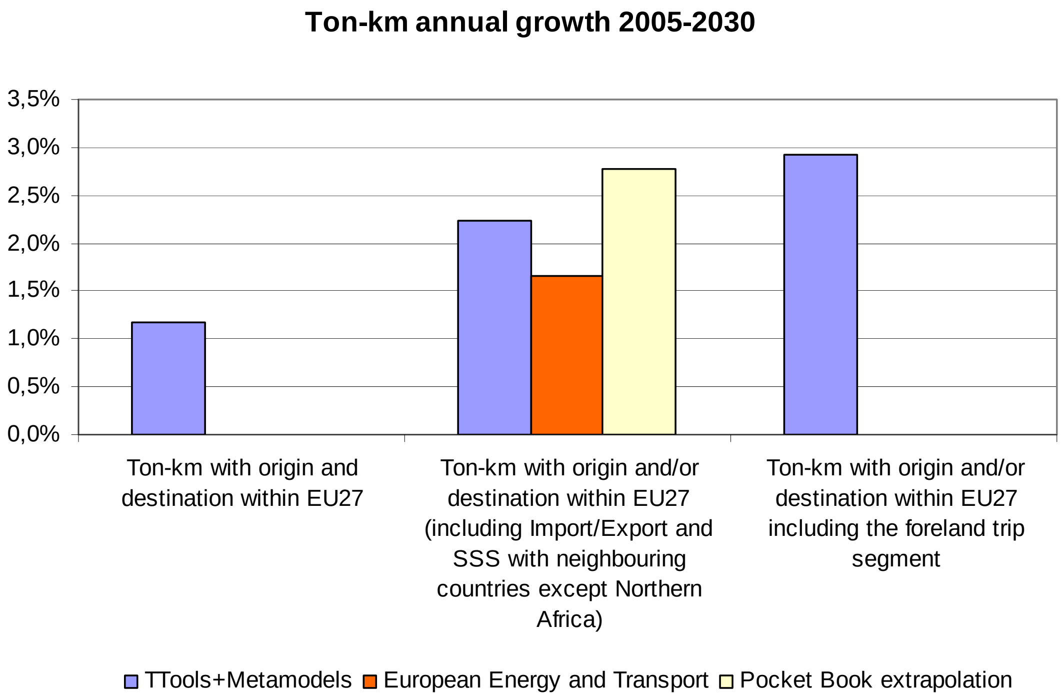



**Figure 58: Ton-km annual growth 2005-2030 comparison**

When only considering freight with an origin and destination within EU-27 territory the growth rate is low, less than 1.2% per year. The addition of freight with origin or destination in EU-27 neighbouring countries (except northern Africa) increases the growth rate to 2.25% per year, mainly due to the great amount of oil, coal and other fuels moved by sea coming from Norway and Russia. This figure is between the EET and PB values. Including the trip segment of freight outside EU-27 territory and surrounding waters, namely long-distance land traffic with Asia, America and Africa, increases the annual growth to 2.8%

## 4.5. *Transport growth measured in trips, trips-km, veh-km*

A comparative summary of traffic measured in trips, trips-km (pax and tonnes) and veh-km is presented for the four exploratory scenarios.

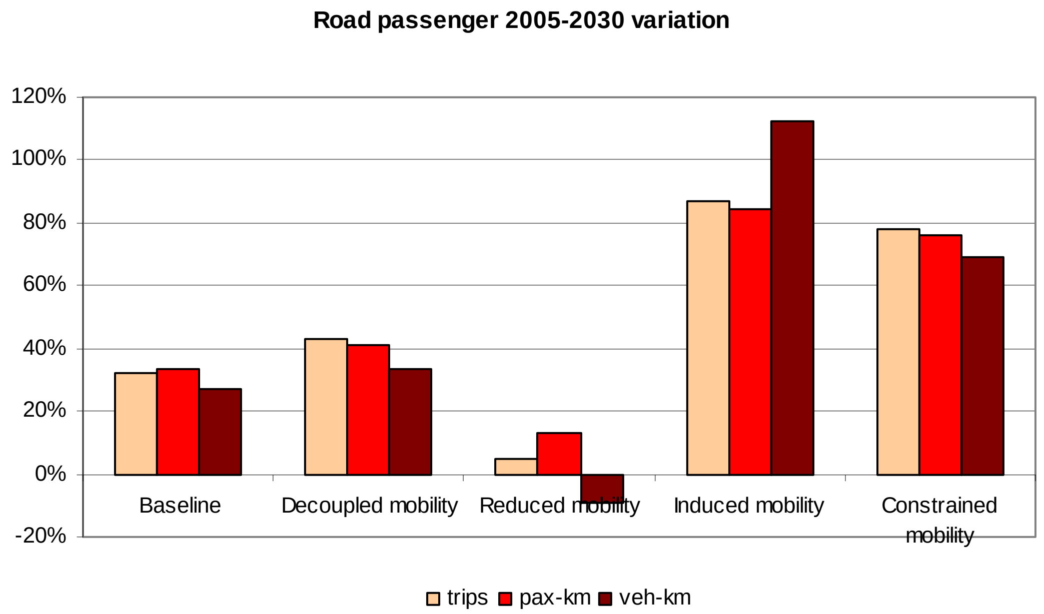



**Figure 59: Changes in trips, pax-km and veh-km for road passenger traffic 2005-2030**

For road passengers, there are no major differences between trips and trip-km, meaning that trips do not become longer or shorter. In almost every scenario, there is a relative reduction of vehicle-km, due to the improvement in occupancy rates. This is not the case of the Induced scenario where the increase in vehicles with low occupancy is important (just the opposite happens in the Reduced scenario, where there is a reduction in veh-km, even with an increase in pax-km).

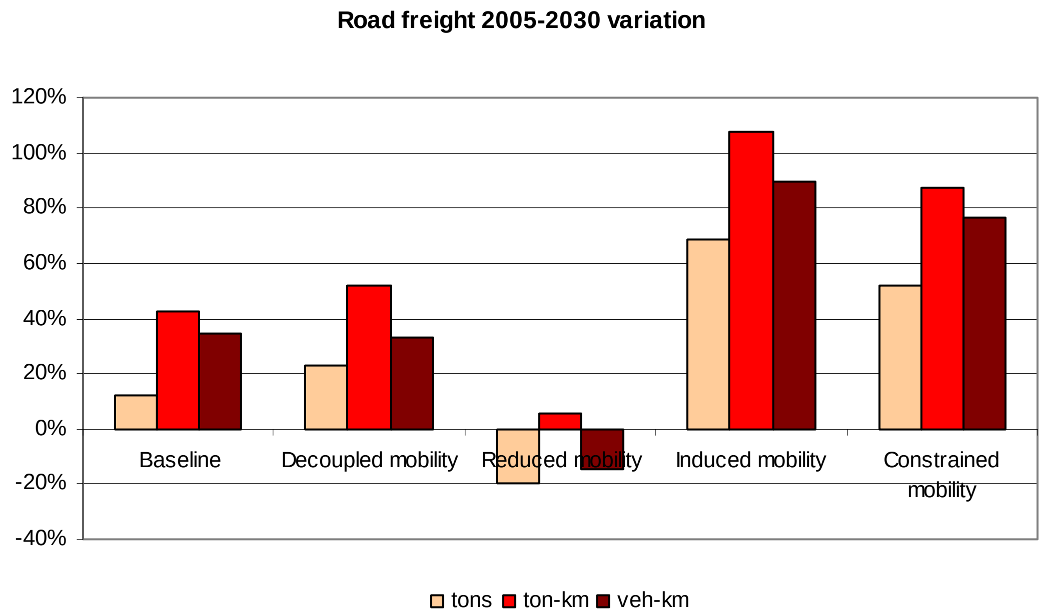



**Figure 60: Changes in trips, ton-km and veh-km for road freight traffic, 2005-2030**

Regarding road freight, a major change happens regarding trips and ton-km. Trips become longer due to the increase of international traffic and the relative stabilisation of short and mid-distance freight exchanges. The figures in veh-km tend to decrease due to likely improvements in logistics that will allow increasing the load factors of trucks and reduce the avoidable trips.

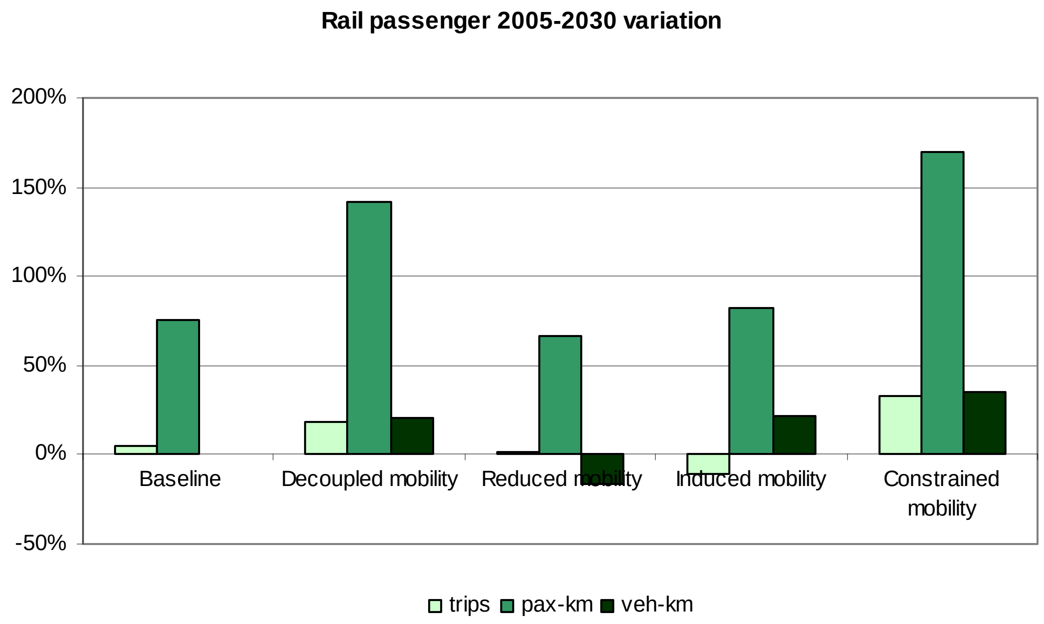



**Figure 61: Changes in trips, pax-km and veh-km for rail passenger traffic 2005-2030**

Passenger rail traffic sees a major increase in pax-km, while trips barely increase. This means that a number of trips become much longer, mainly to the development of HST which takes share from air transport. However, in terms of the number of trains, there cannot be much change as many of these new long trips can be accommodated on already running services.

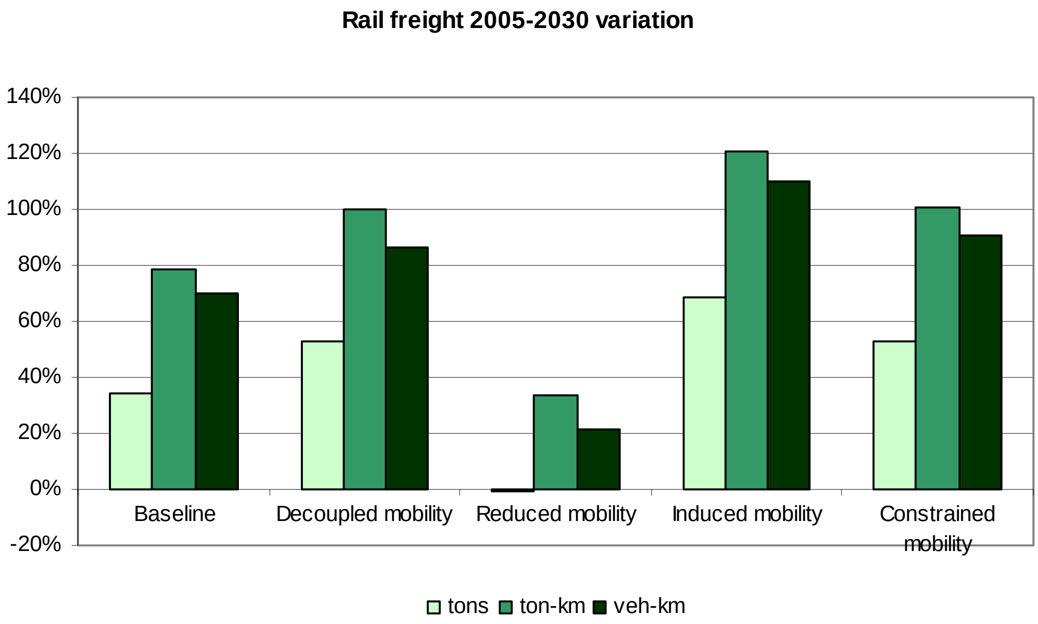



**Figure 62: Changes in trips, ton-km and veh-km for rail freight traffic, 2005-2030**

Rail freight traffic increases in the number of tonnes moved, as there is a modal shift towards rail, mainly in the international traffic moving from ports to logistic centres. The development of HST and the integration of networks of member states allows for the use of conventional lines for freight transport, making it easier to travel longer distances, thus increasing ton-km even more than lifted tonnes.

The number of veh-km increases almost proportionally to the ton-km, as no major gains in occupancy are expected.

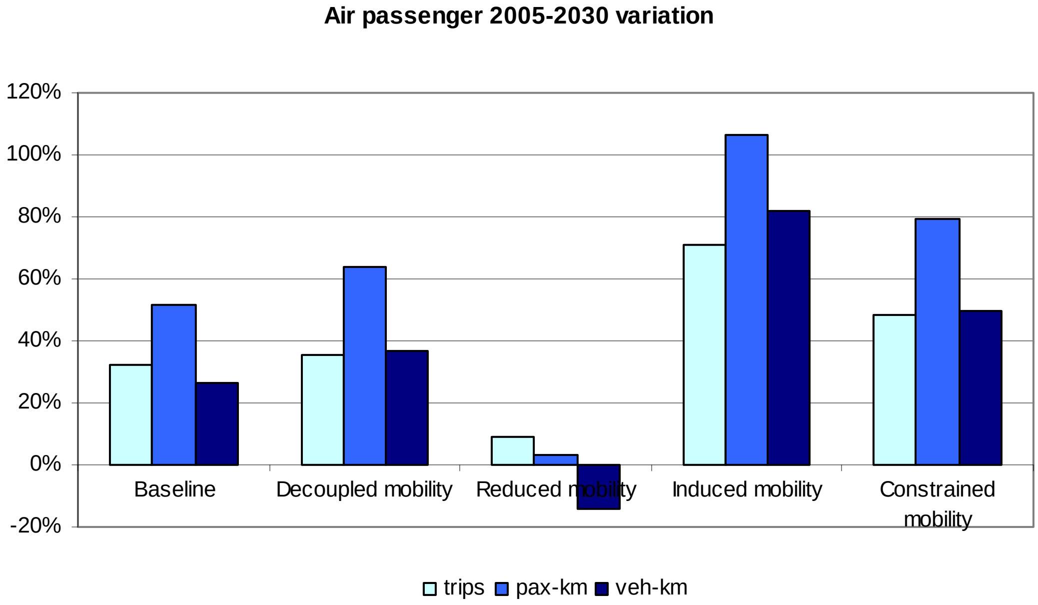



**Figure 63: Changes in trips, pax-km and veh-km for air passenger traffic, 2005-2030 (including trips to overseas)**

The air passenger traffic is expected to grow more in the scenarios with less development of HST. In terms of pax-km, traffic tends to grow more in number of trips, given that the shorter distance trips will be covered by rail. The number of plane-km is expected to grow relatively less as bigger planes enter the market.

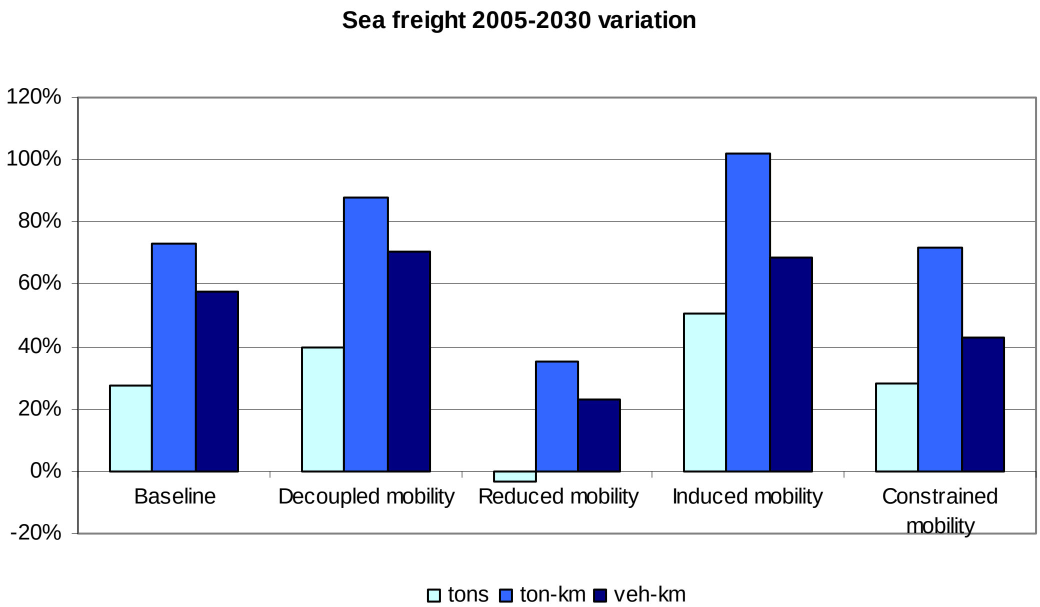



**Figure 64: Changes in trips, ton-km and veh-km for maritime freight traffic 2005-2030**

Maritime freight traffic will increase both in lifted tonnes and ton-km, but the trips will become longer as the SSS routes gain relevance and more traffic comes from overseas.

## 4.6. *Paths for key indicators from 2005 to 2050*

The following graphics show the evolution of passenger trips-km within the EU-27 by geographic distribution, including road, rail and air modes, all for the Baseline scenario. 2005 and 2030 values have been calculated using TRANS-TOOLS. Overall, regional and domestic transport slowly lose share in favour of long-distance trips, mainly cross-EU border trips with neighbouring countries.

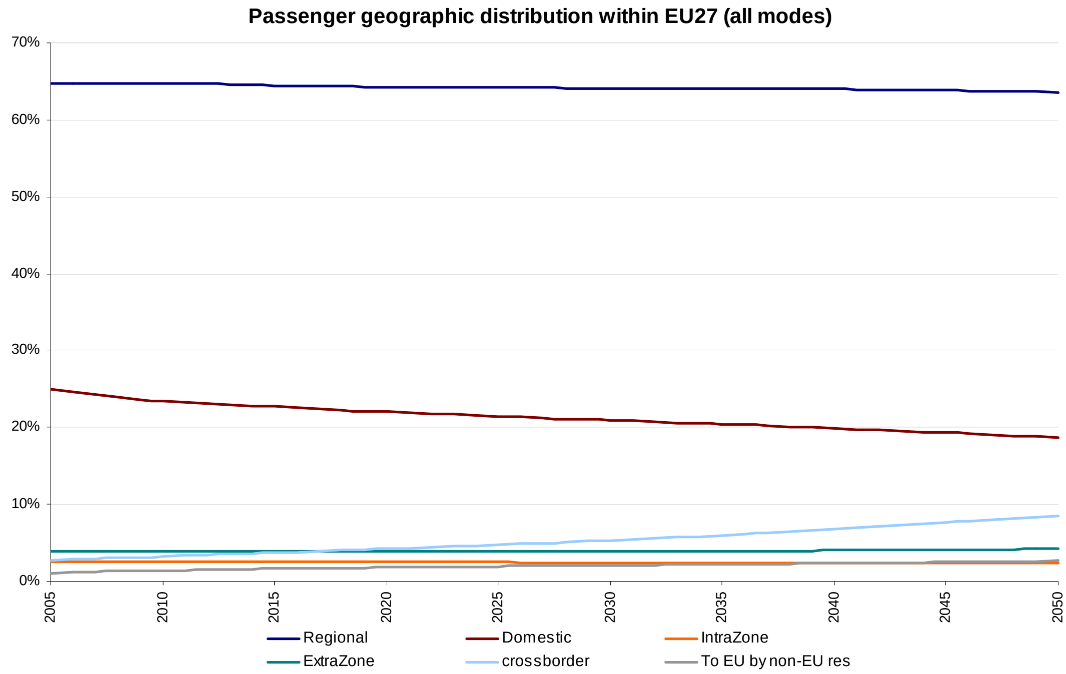



**Figure 65: Passenger geographic distribution within EU-27 (all modes)**

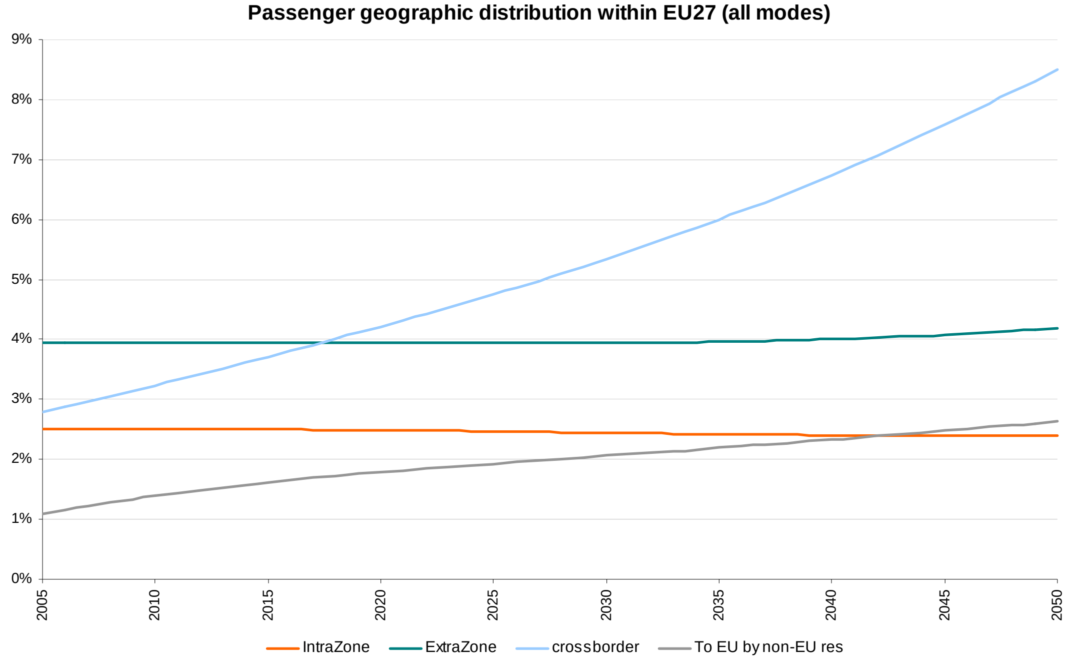



**Figure 66: Passenger geographic distribution within the EU-27 (all modes). Zooming for less than 10% share Evolution of geographic distribution of passenger trips-km within the EU-27 including road, rail and air modes in Baseline scenario. The detail shows the important growth of extra-EU cross-border trips, as well as the increase of trips by foreign visitors and tourists coming from abroad. In addition, the long-term increase of Extra-Zone traffic is significant, meaning that long-distance intra-European trips gain more relevance.**

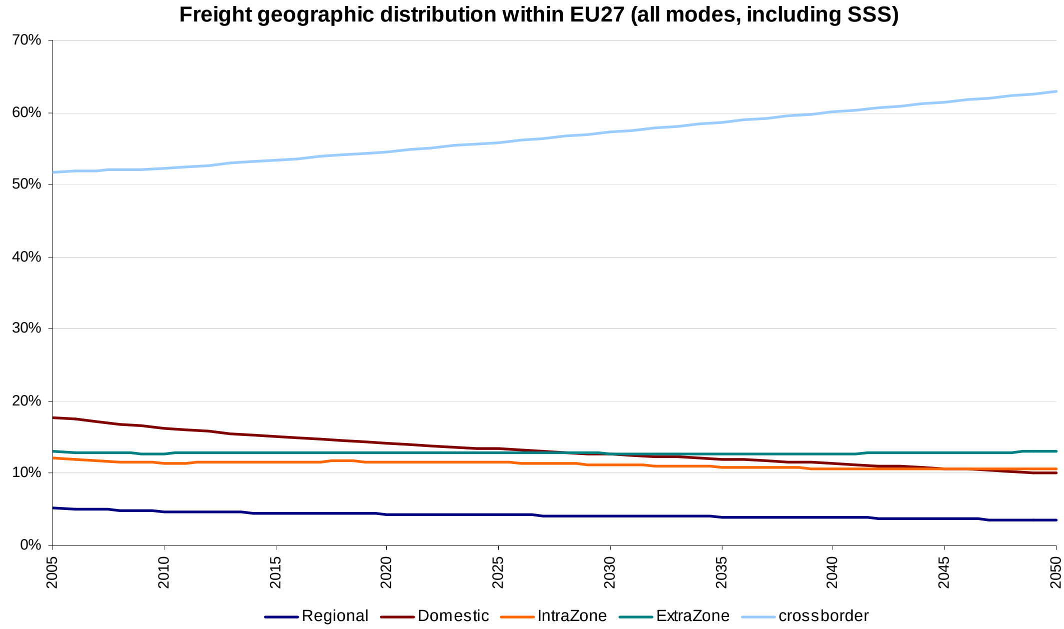



**Figure 67: Geographic distribution of freight within the EU-27 (all modes, including SSS). Evolution of geographic distribution of freight ton-km within the EU-27, including road, rail, IWW and short sea shipping as well as maritime traffic with neighbouring countries in Baseline scenario.**

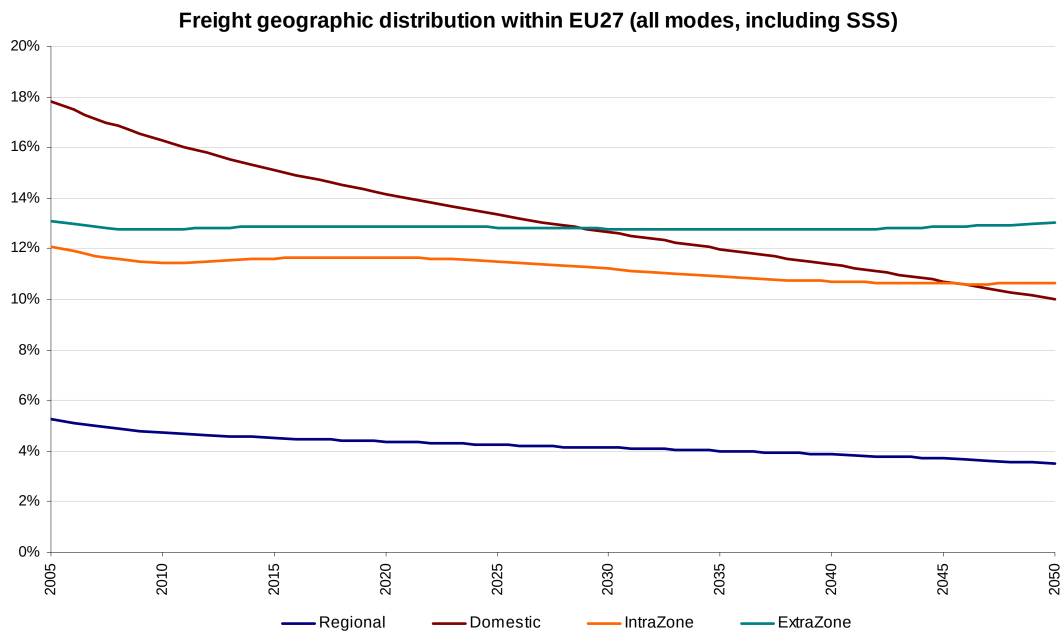



**Figure 68: Geographic distribution of freight within the EU-27 (all modes, including SSS). Detail for low-share trips. Evolution of geographic distribution of freight ton-km within the EU-27, including road, rail, IWW and short sea shipping as well as maritime traffic with neighbouring countries in Baseline scenario (detail for low-share trips). The detail shows the evident decrease in domestic freight but also a small decline in both regional and intra-zone traffic.**

## 4.7. *$CO_2$ emissions from 2005 to 2050*

The main results for direct and indirect $CO_2$ emissions are presented in this section.

The hypotheses adopted for the Baseline scenario were the following:

- The 2005 values refer to EURO 3 technology.
- The 2030 values refer to EURO 5 technology, diesel and petrol, medium size car for passenger and HGV diesel for freight. For HGV travelling on motorways, we have considered a representative vehicle to be >18 ton, for HGV travelling across urban areas, <18 ton HGVs have been considered.
- Emissions coefficients and fuel consumption factors have been taken from the TREMOVE database v. 2.7.

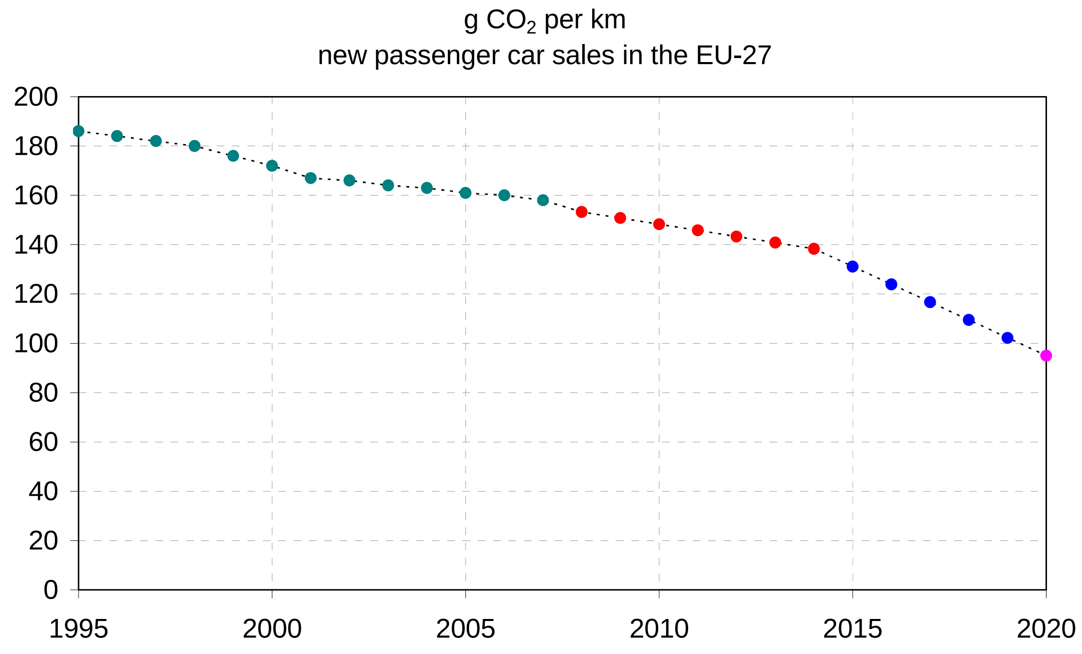



**Figure 69: Evolution of $CO_2$ emission rates for new passenger cars, 1995-2020. The recommendation on the evolution of $CO_2$ emission ratios for new passenger cars is displayed, with a limit of 95g$CO_2$/km in 2020. However, the presence of older vehicles makes the average emission ratio much higher.**

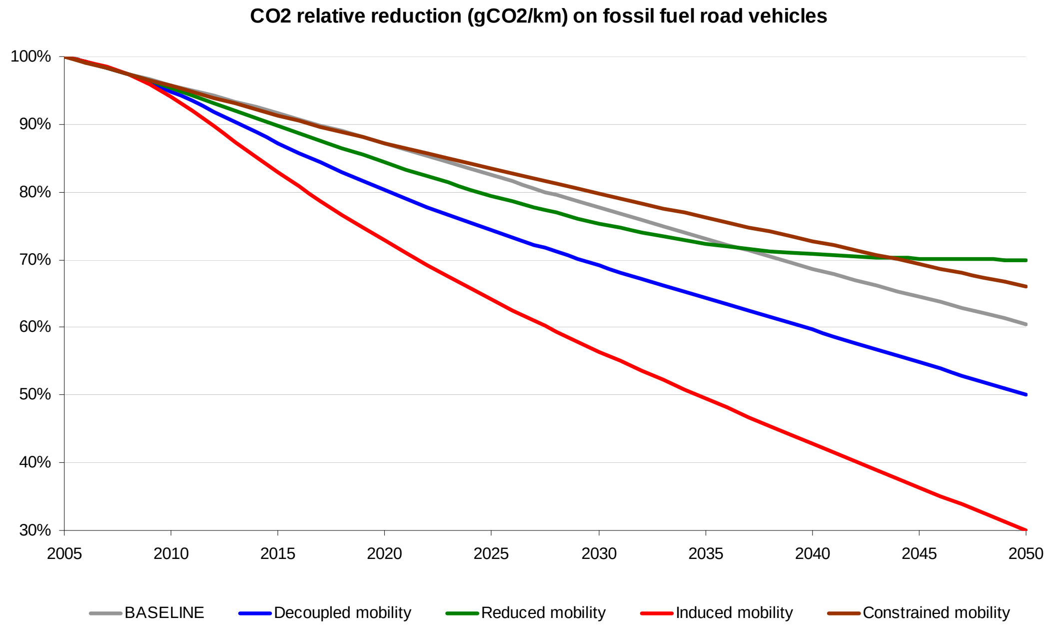



**Figure 70: $CO_2$ relative reduction (g$CO_2$/km) on fossil fuel road vehicles. Evolution 2005-2050 of $CO_2$ emission ratios reduction for fossil fuel vehicles in the exploratory scenarios. Again, the Induced scenario relies mainly in technology and so it has the highest cut in $CO_2$ emission ratios.**

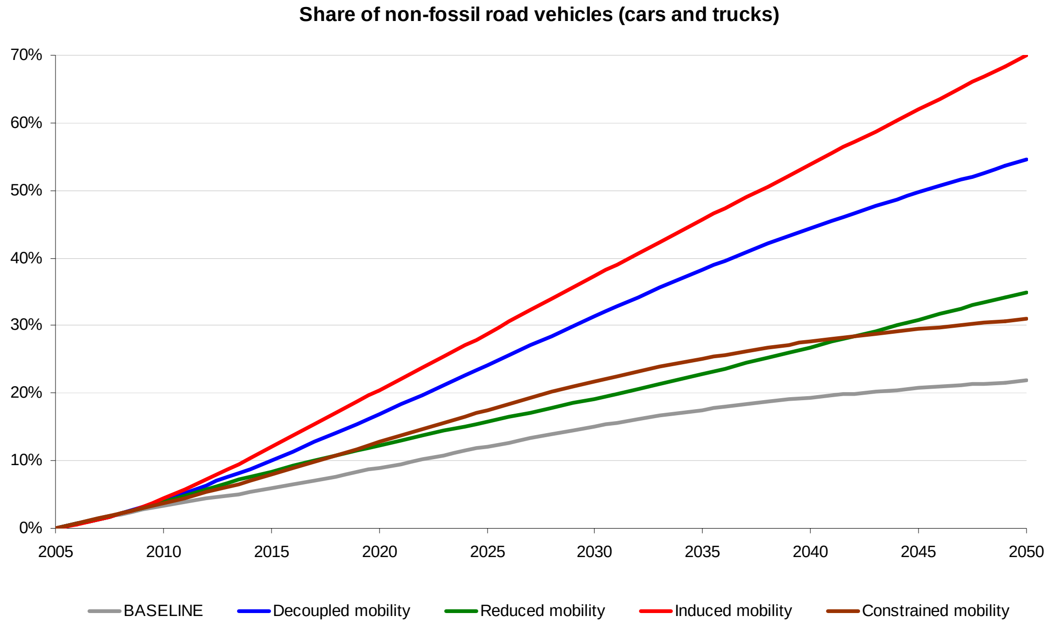



**Figure 71: Share of non-fossil fuel vehicles (cars and trucks). Evolution 2005-2050 of the share of non-fossil fuel vehicles (electric, fuel cell), in the exploratory scenarios. This figure shows how the development of clean technologies is the fastest and most dramatic in the Induced scenario. The Constrained scenario does not rely much on technology and the crisis period from 2030 onwards stops the development of these clean vehicles. In all scenarios, the share is bigger than the Baseline, which suggests that it is a conservative estimate in this respect.**

A consequence of the substitution of fossil fuel-vehicles is the reduction of taxes on oil, as next table expresses:

| 2050 values | 2005 | Baseline | Decoupled mobility | Reduced mobility | Induced mobility | Constrained mobility |
|---|---|---|---|---|---|---|
| Energy consumed by road oil-based transport in MToe | 362 | 291 | 130 | 182 | 99 | 246 |
| Average taxes on oil in €/litre | 0,61 | 1,40 | 1,60 | 1,80 | 1,20 | 2,00 |
| Taxes on oil by transport in M€ | 184.216 | 338.933 | 173.406 | 273.525 | 98.612 | 409.789 |
| % of oil taxes over total GDP | 1,9% | 1,4% | 0,6% | 1,6% | 0,3% | 2,3% |

**Table 14: Taxation from oil used in road transport for 2005 and 2050**

Based on these hypotheses, the direct $CO_2$ emissions due to transport were as follows:

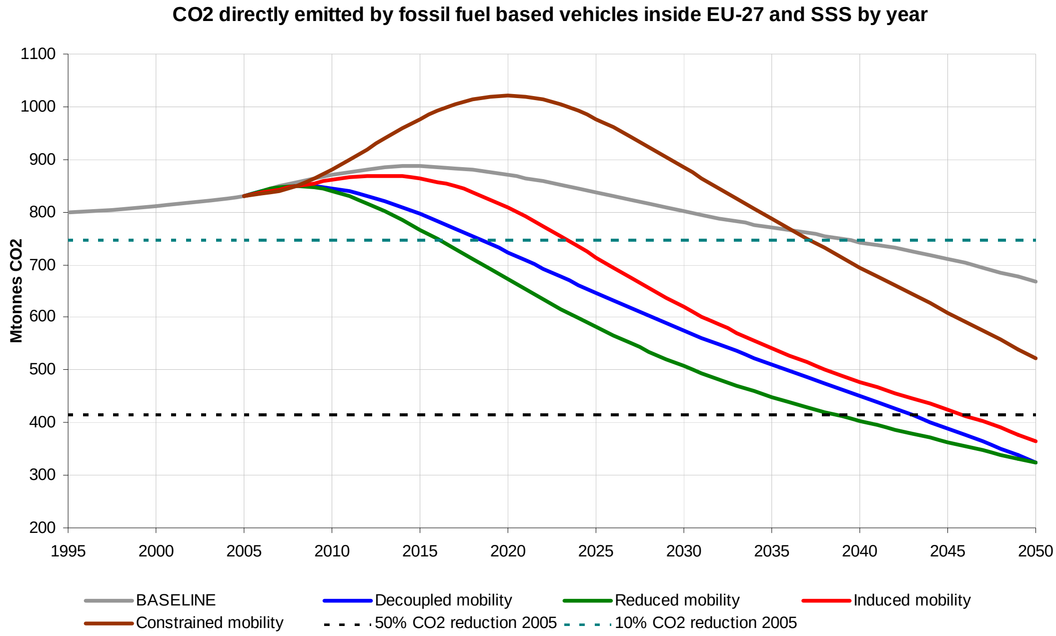



**Figure 72: $CO_2$ directly emitted by fossil fuel-based vehicles inside the EU-27 and SSS by year**

The Reduced and Decoupled scenarios comply with the reduction of $CO_2$ emission levels by 10% in 2020 in respect to 2005. The Induced, Reduced and Decoupled scenarios comply with the reduction of $CO_2$ emission levels by 50% in 2050 in respect to 2005. The slow market penetration of clean technologies in the Constrained scenario, coupled with the high growth of traffic makes $CO_2$ emission rise far more than in the other scenarios during the first half of the period.

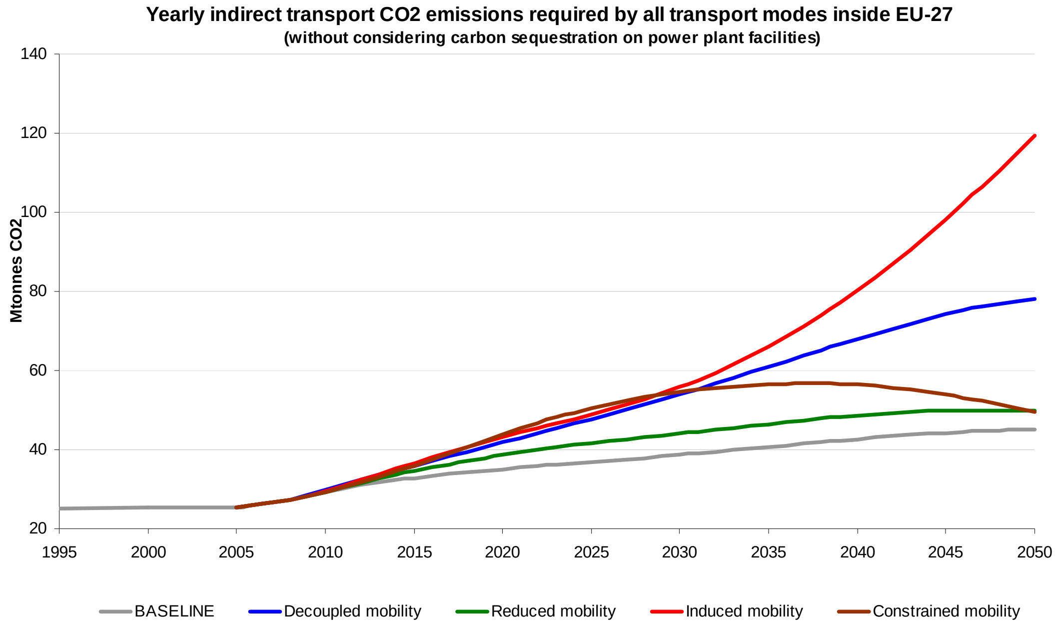



**Figure 73: Annual indirect transport $CO_2$ emissions required by all transport modes inside the EU-27**

Indirect emissions are due to the presence of fossil fuels in the primary generation of electricity and alternative fuels like hydrogen, and take into account the different source mix for each scenario (fossil, nuclear and renewable). Changes in primary generation, coupled with the variation of modal shares cause the paths to fluctuate. It must be noted that the absolute value of these indirect emissions is less than 5% of the total $CO_2$ emissions.

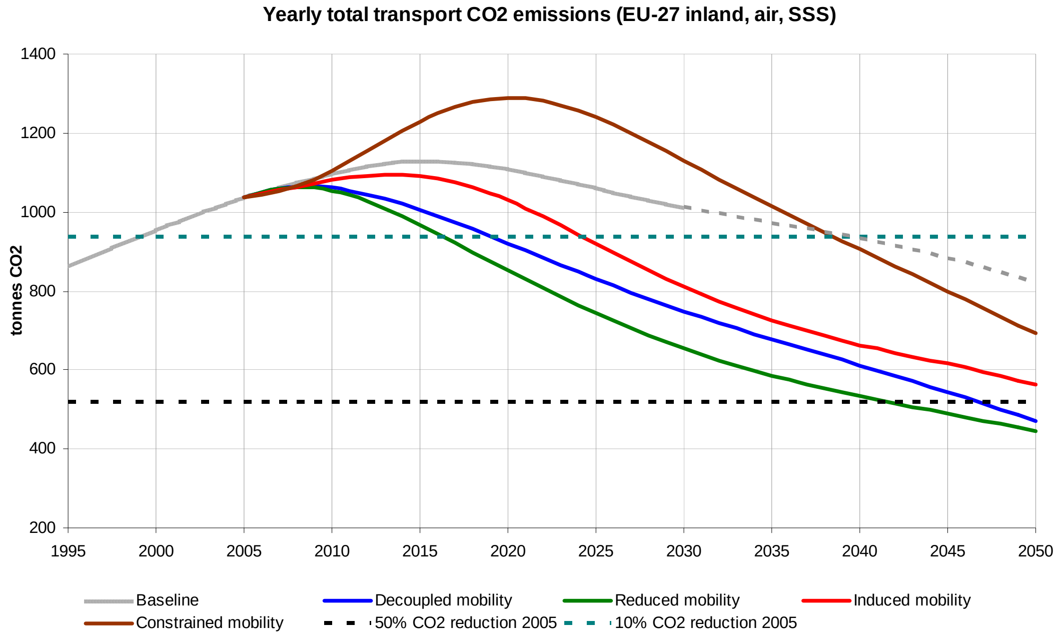



**Figure 74: Annual total transport $CO_2$ emissions (EU-27 inland, air and SSS)**

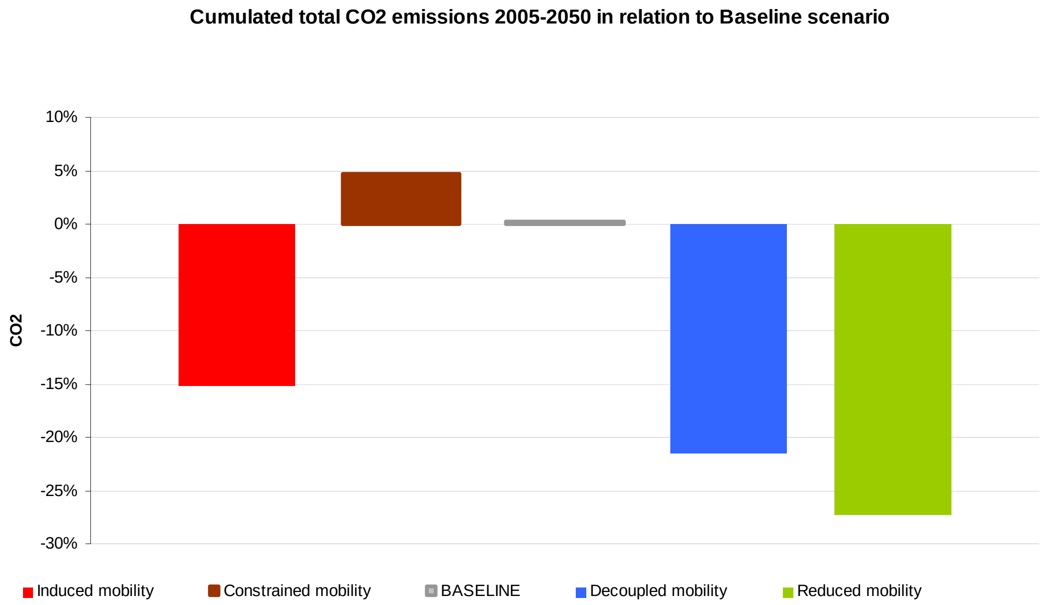



**Figure 75: Cumulative $CO_2$ emissions 2005-2050 in relation to Baseline scenario**

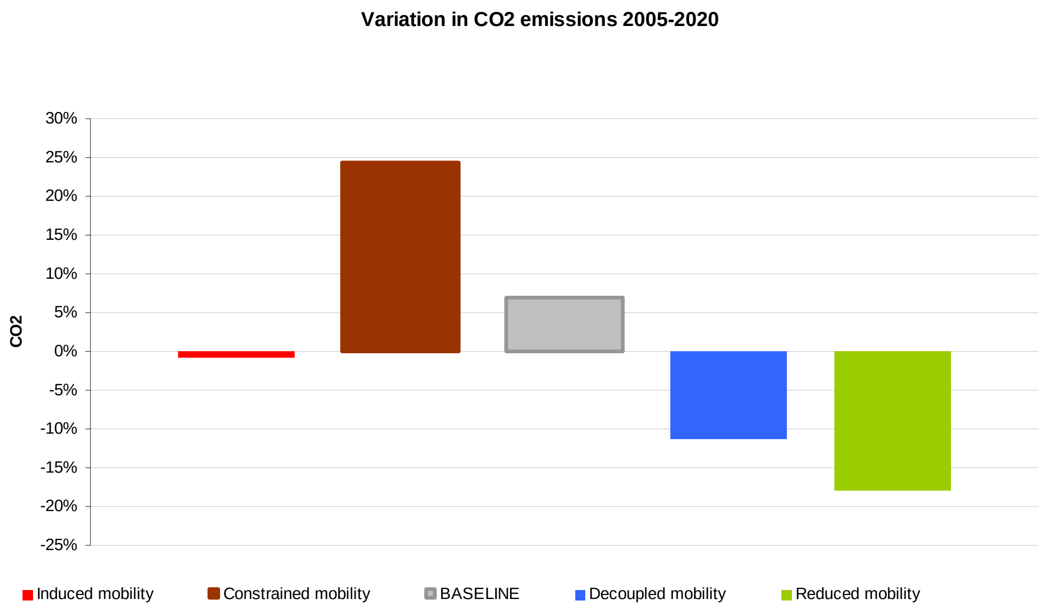



**Figure 76: Variation in total $CO_2$ emissions, 2005-2020**

Only the Decoupled and Reduced scenarios comply with a 10% reduction, Induced maintains about the same levels of 2005, Constrained has a much higher emission level of +23% and the Baseline grows by more than 6%

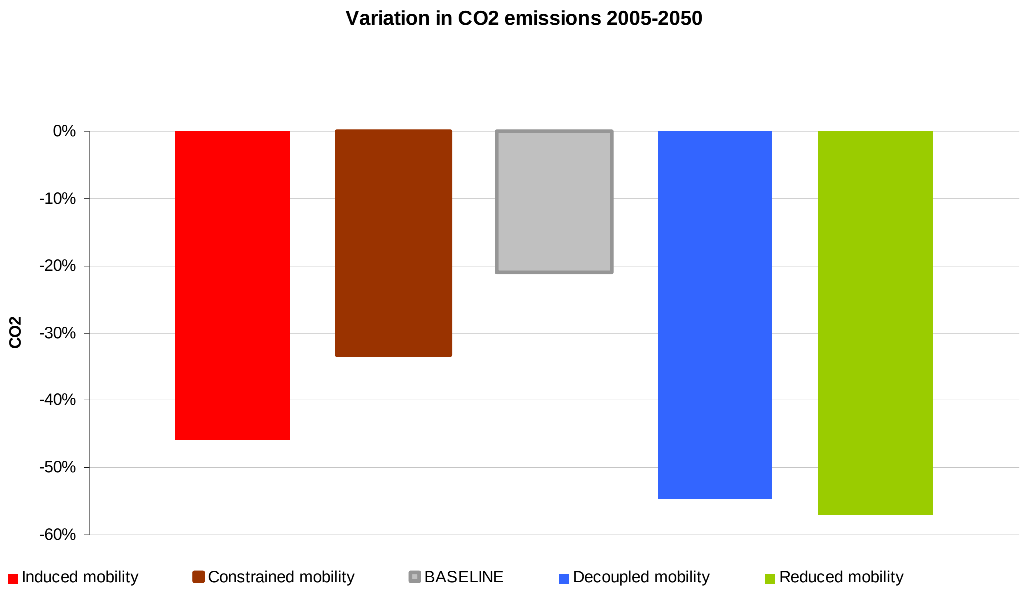



**Figure 77: Variation in total $CO_2$ emissions, 2005-2050**

Here we see that the Decoupled and Reduced scenarios comply with a reduction of 50%.

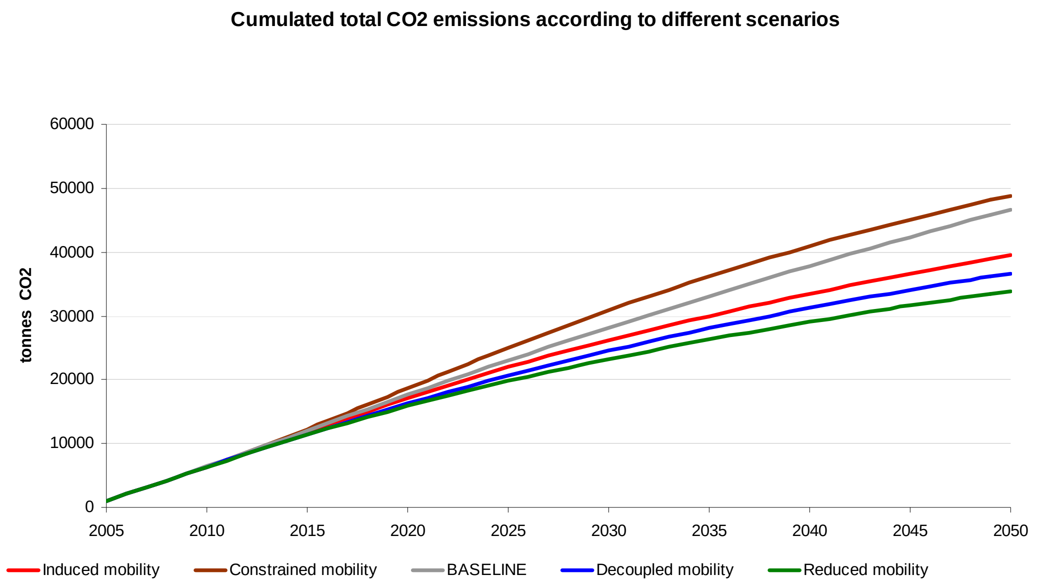



**Figure 78: Cumulative total $CO_2$ emissions according to the different scenarios**

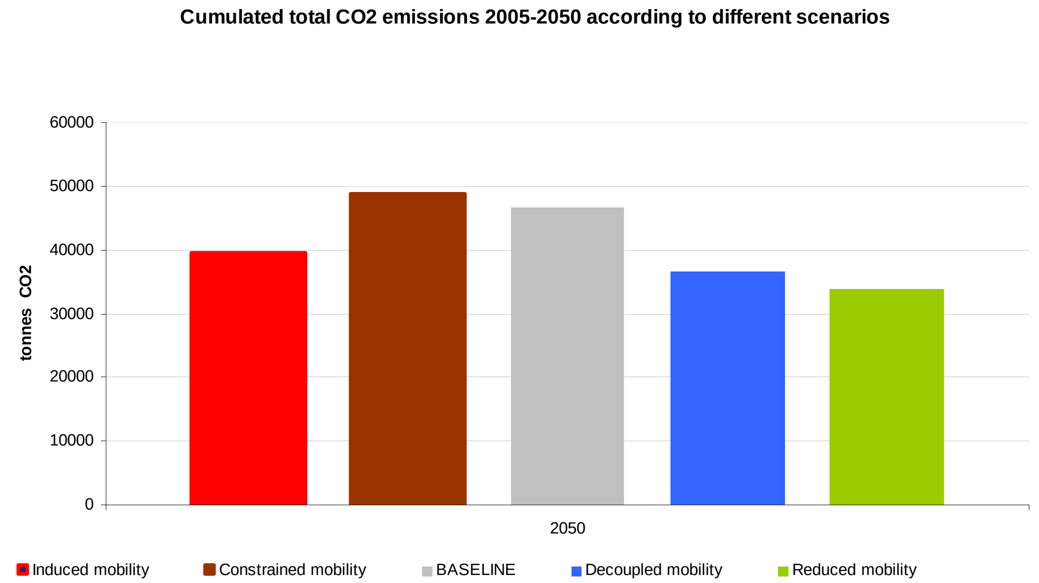



**Figure 79: Cumulative total $CO_2$ emissions, 2005-2050, according to the different scenarios**

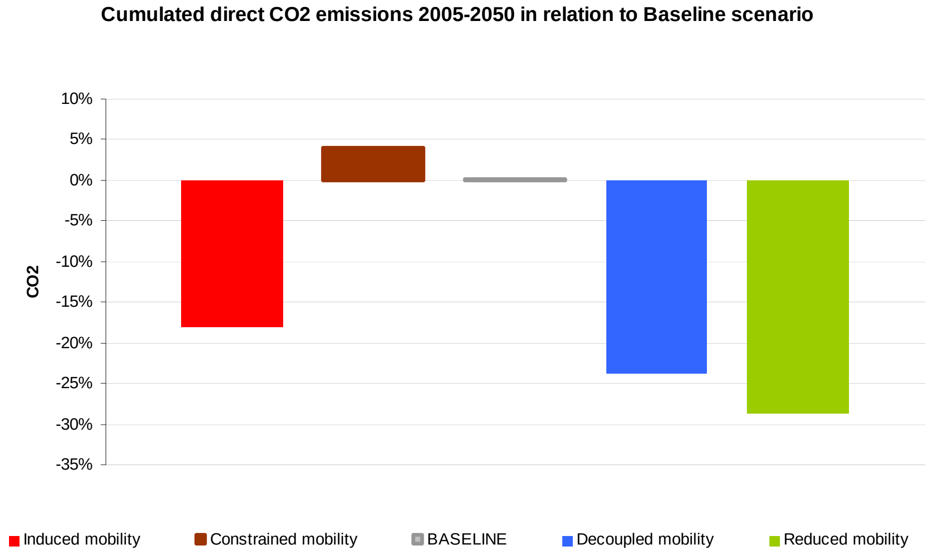



**Figure 80: Cumulative direct $CO_2$ emissions 2005-2050 in relation to Baseline scenario**

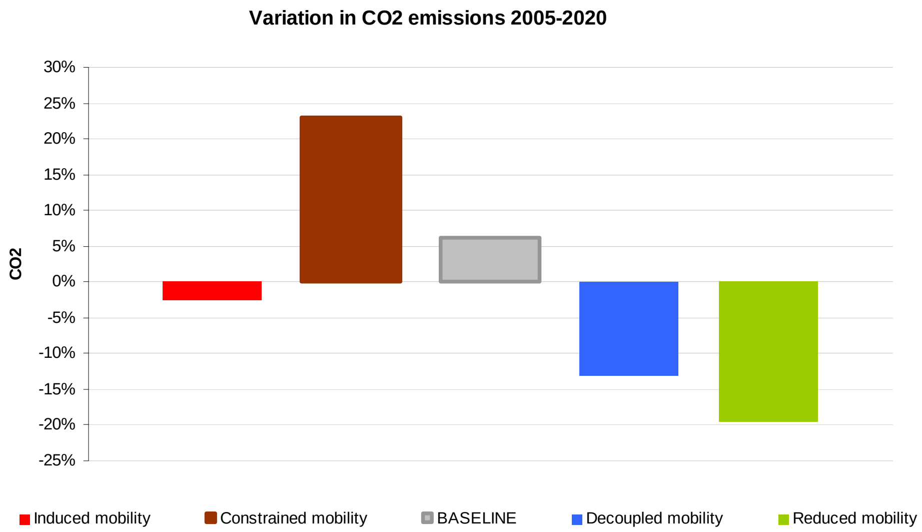



**Figure 81: Variation in direct $CO_2$ emissions, 2005-2020**

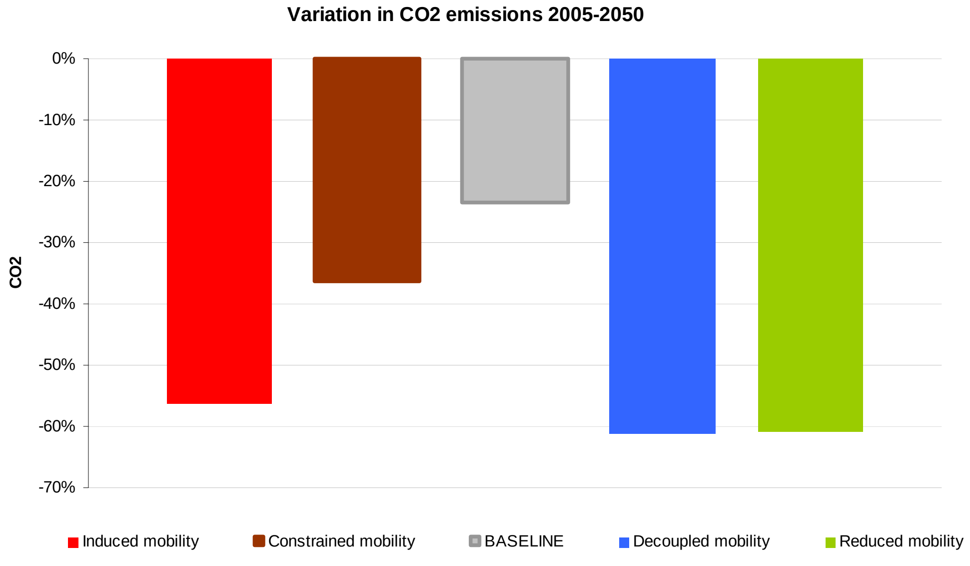



**Figure 82: Variation in $CO_2$ direct emissions, 2005-2050**

The Induced, Decoupled and Reduced scenarios comply with a reduction of 50%.

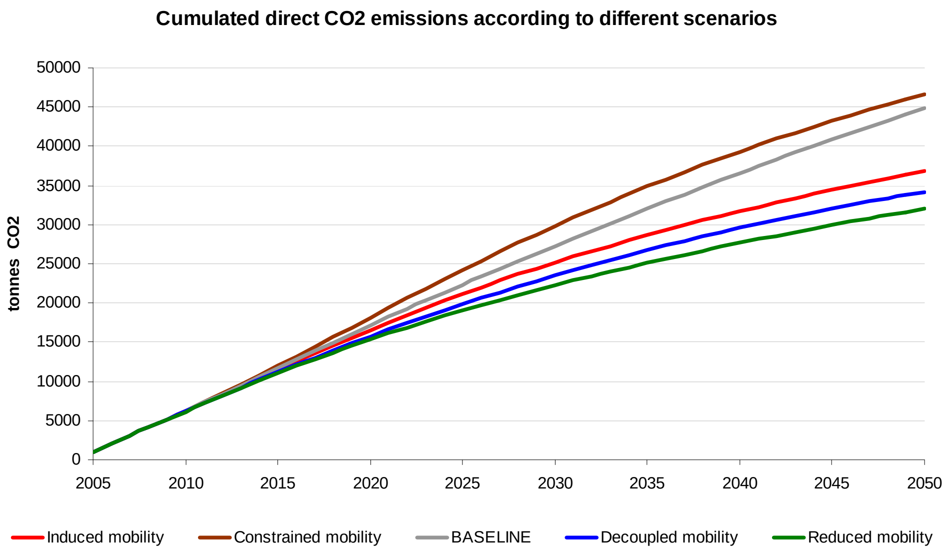



**Figure 83: Cumulative direct $CO_2$ emissions according to different scenarios**

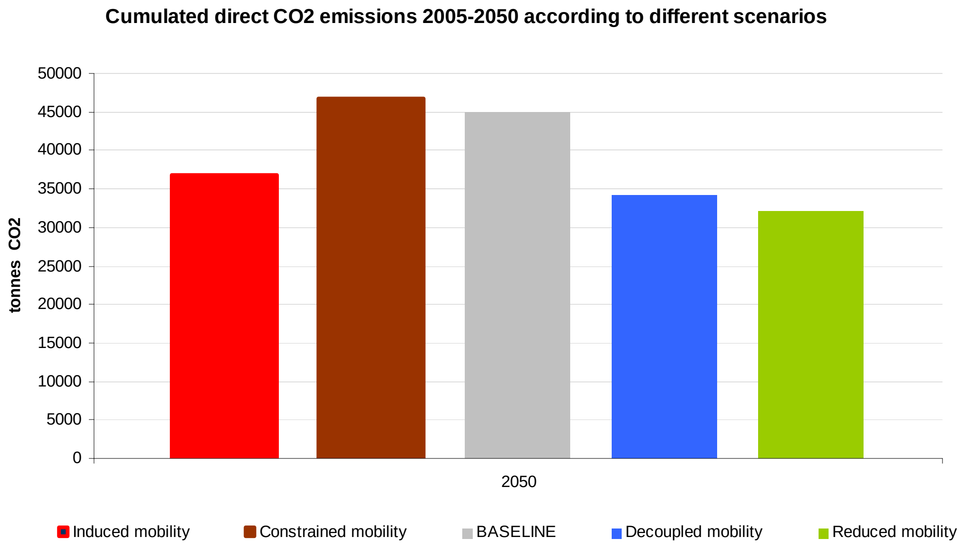



**Figure 84: Cumulative direct $CO_2$ emissions, 2005-2050, according to the different scenarios**

# 5. Policy backcasting, 2050-2005

## 5.1. *Impact of GDP evolution on $CO_2$*

The objective of this analysis is to find the impact that a different GDP progression may have in terms of $CO_2$ for all scenarios, assuming that the hypotheses for the rest of the variables, particularly for technological implementation, remain the same.

In the exercise, for the sake of testing the relation of $CO_2$ emissions to GDP evolution, only the path of economic growth changes, but average annual GDP growth also remains the same, as well as the total growth between 2005 and 2050. This hypothesis allows for an early economic recession that will be later be followed by a growth period that will reach the same average GDP at the end of the period.

The GDP evolution could be as follows (note that the charts start at 2007, two years after the starting point in 2005, when the evolutions start to diverge):

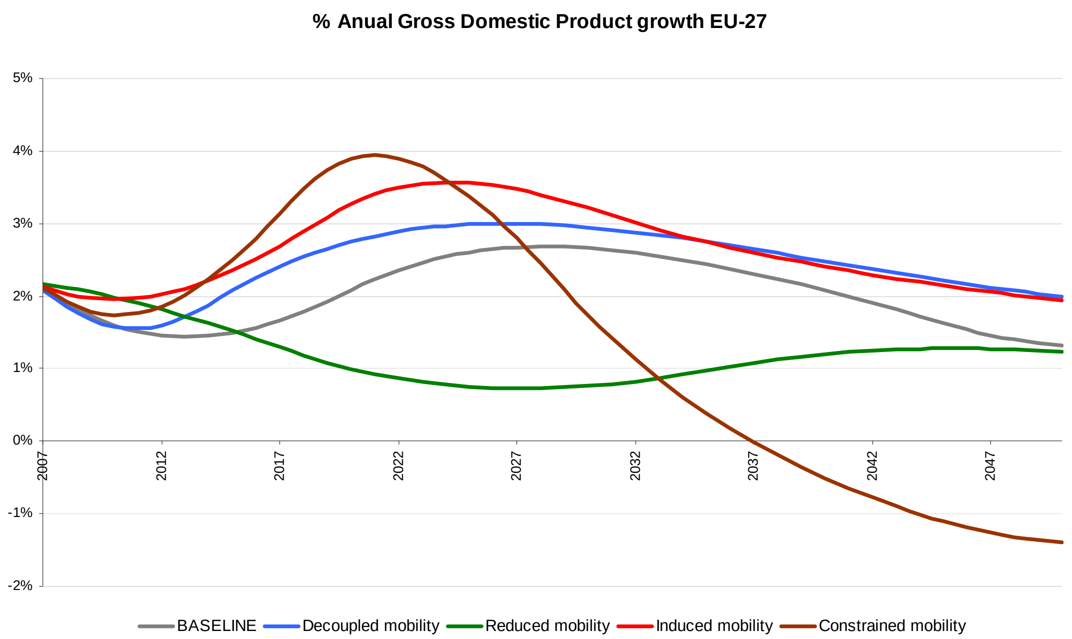


**Figure 85: % Annual Gross Domestic Product growth in the EU-27 Different paths starting with a recession period and having a fast recovery in 2020.**

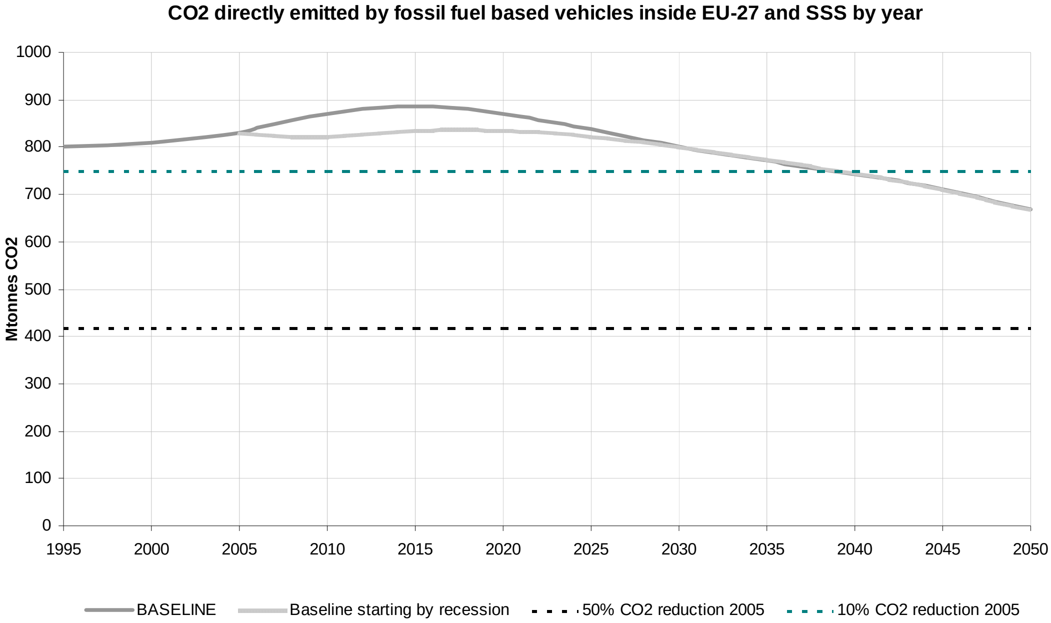



**Figure 86: Comparison between $CO_2$ paths of Baseline scenario, depending on evolution of GDP**

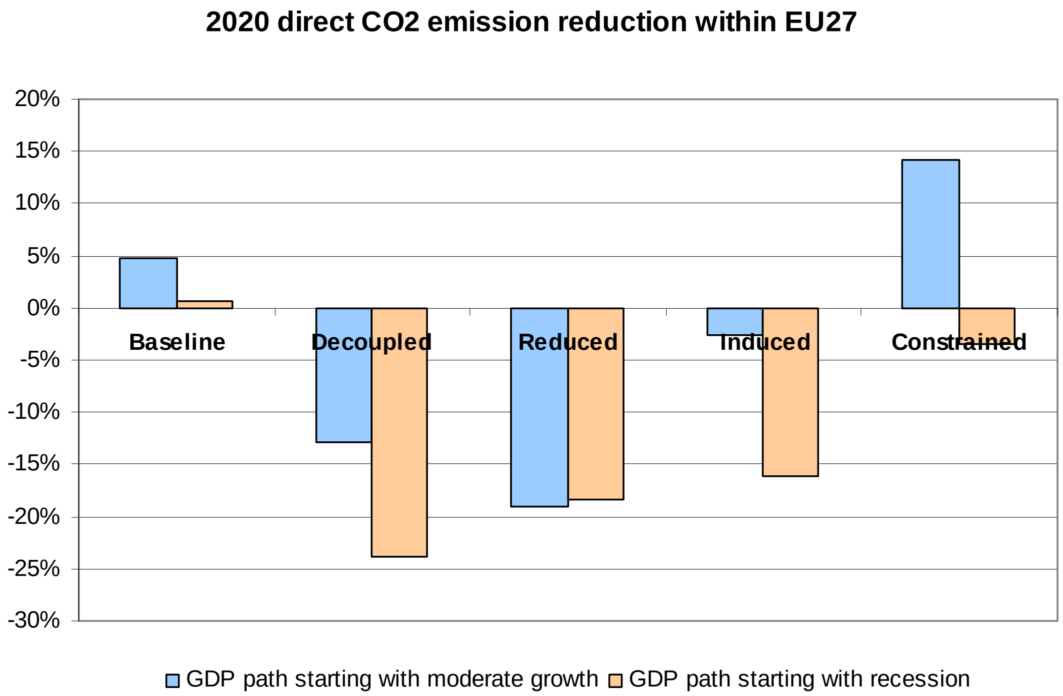



**Figure 87: Direct $CO_2$ emission reduction in 2020 within the EU-27 for two different sets of GDP paths**

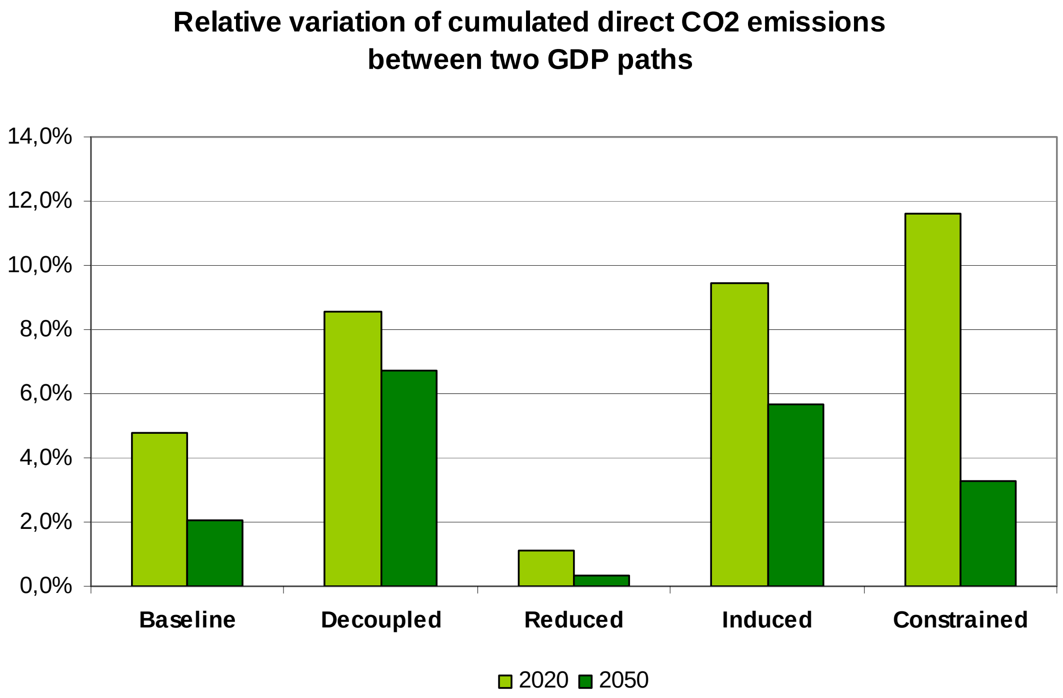



**Figure 88: Relative variation of cumulative direct $CO_2$ emissions on two different sets of GDP paths**

| | | Baseline | Decoupled | Reduced | Induced | Constrained |
|---|---|---|---|---|---|---|
| | **GDP path starting with moderate growth** | | | | | |
| 2020 | Direct $CO_2$ emission variation 2005-2020 | 5% | -13% | -19% | -3% | 14% |
| | Indirect $CO_2$ emission variation 2005-2020 | 15% | 27% | 24% | 25% | 43% |
| | Total $CO_2$ emission variation 2005-2020 | 5% | -11% | -17% | -1% | 15% |
| 2020 | Direct cumulative $CO_2$ emissions 2005-2020 | 13.919 | 12.919 | 12.599 | 13.585 | 14.340 |
| | Indirect cumulative $CO_2$ emissions 2005-2020 | 609 | 650 | 638 | 646 | 676 |
| | Total cumulative $CO_2$ emissions 2005-2020 | 14.528 | 13.570 | 13.237 | 14.232 | 15.016 |
| 2050 | Direct $CO_2$ emission variation 2005-2050 | -20% | -61% | -61% | -56% | -37% |
| | Indirect $CO_2$ emission variation 2005-2050 | 27% | 46% | 22% | 45% | 22% |
| | Total $CO_2$ emission variation 2005-2050 | -18% | -57% | -58% | -52% | -35% |
| 2050 | Direct cumulative $CO_2$ emissions 2005-2050 | 36.983 | 28.196 | 26.413 | 30.171 | 36.438 |
| | Indirect cumulative $CO_2$ emissions 2005-2050 | 1.993 | 2.111 | 1.994 | 1.993 | 2.225 |
| | Total cumulative $CO_2$ emissions 2005-2050 | 38.975 | 30.307 | 28.407 | 32.164 | 38.663 |
| | **GDP path starting with recession** | | | | | |
| 2020 | Direct $CO_2$ emission variation 2005-2020 | 1% | -24% | -18% | -16% | -3% |
| | Indirect $CO_2$ emission variation 2005-2020 | 11% | 11% | 25% | 8% | 21% |

| | | Baseline | Decoupled | Reduced | Induced | Constrained |
|---|---|---|---|---|---|---|
| | Total $CO_2$ emission variation 2005-2020 | 1% | -22% | -17% | -15% | -2% |
| 2020 | Direct cumulative $CO_2$ emissions 2005-2020 | 13.286 | 11.903 | 12.459 | 12.414 | 12.849 |
| | Indirect cumulative $CO_2$ emissions 2005-2020 | 596 | 596 | 632 | 588 | 603 |
| | Total cumulative $CO_2$ emissions 2005-2020 | 13.882 | 12.498 | 13.090 | 13.002 | 13.452 |
| 2050 | Direct $CO_2$ emission variation 2005-2050 | -20% | -61% | -61% | -56% | -37% |
| | Indirect $CO_2$ emission variation 2005-2050 | 46% | 46% | 22% | 45% | 22% |
| | Total $CO_2$ emission variation 2005-2050 | -17% | -57% | -58% | -52% | -35% |
| 2050 | Direct cumulative $CO_2$ emissions 2005-2050 | 36.246 | 26.415 | 26.329 | 28.551 | 35.274 |
| | Indirect cumulative $CO_2$ emissions 2005-2050 | 2.000 | 2.000 | 1.992 | 1.912 | 2.186 |
| | Total cumulative $CO_2$ emissions 2005-2050 | 38.246 | 28.415 | 28.321 | 30.463 | 37.460 |
| | Relative variation of cumulative 2005-2020 direct $CO_2$ emissions between two GDP paths | 4,8% | 8,5% | 1,1% | 9,4% | 11,6% |
| | Relative variation of cumulative 2005-2050 direct $CO_2$ emissions between two GDP paths | 2,0% | 6,7% | 0,3% | 5,7% | 3,3% |

**Table 15: Comparison of $CO_2$ emissions for Baseline and prospective scenarios with two different sets of GDP paths**

The results obtained show a net reduction of $CO_2$ emissions if the GDP starts with a recession, even if the GDP remains the same for the whole period, in average, and reaches the same absolute value in 2050, because technological innovation is assumed to be implemented gradually in the marketplace.

The conclusion is that if technological development is not slowed down due to the recession, lower economic growth will also result in lower traffic growth, providing a net reduction in $CO_2$ emissions. If technology implementation slows down because of the recession, then when the recession is over and traffic grows again, $CO_2$ emissions will increase much faster. In the recession, two things are very likely to happen; first, that firms and states will cut down on their R&D investments, and second the renewal of fleets will be slowed down significantly.

## 5.2. *The impact of technology on $CO_2$ emissions*

The objective of this analysis is to investigate the impact that a slower process of technology implementation might have on $CO_2$ emissions, assuming a 5-year recession period as a starting point for the economy, but maintaining the rest of variables.

It is assumed that technology in year 2050 is the same for both alternatives, so only the implementation path varies.

As expected, the results show a high sensitivity of $CO_2$ emissions to the market implementation of technological innovation in relation to:

- The evolution of the market share of non-fossil fuel vehicles (car and trucks).
- The evolution of the emission rates of fossil fuel vehicles.

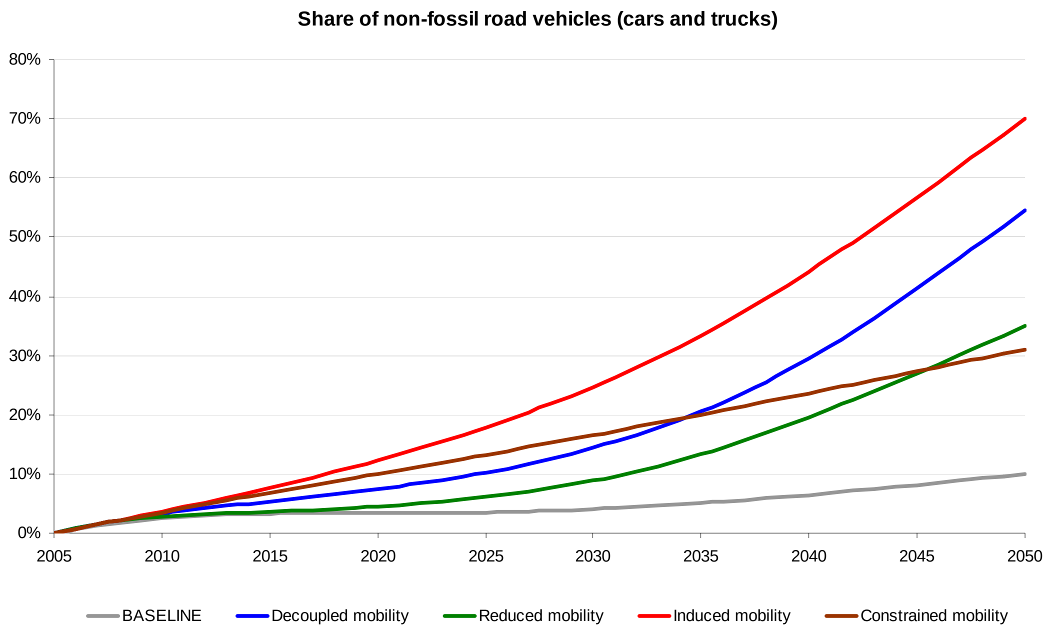



**Figure 89: Share of non-fossil fuel road vehicles (cars and trucks) for slow technology implementation path. See Figure 71 for comparison with fast implementation path**

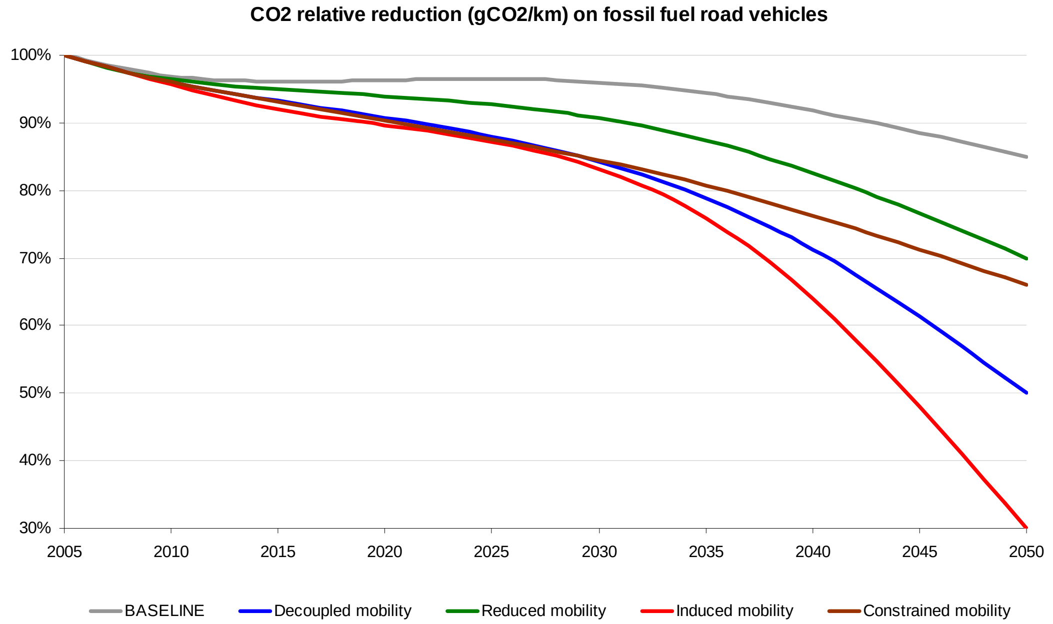



**Figure 90: $CO_2$ relative reduction ($gCO_2/km$) on fossil fuel road vehicles for slow technology implementation path. See Figure 70 for comparison with fast implementation path**

| | | Baseline | Decoupled | Reduced | Induced | Constrained |
|---|---|---|---|---|---|---|
| | **Fast technology implementation path** | | | | | |
| 2020 | Car $CO_2$ emission ratio in $gCO_2/km$ | 171 | 157 | 165 | 143 | 161 |
| | Truck $CO_2$ emission ratio in $gCO_2/km$ | 937 | 776 | 815 | 704 | 795 |
| | % non-fossil fuel vehicles | 4,4% | 16,9% | 12,3% | 20,4% | 14,9% |
| 2030 | Car $CO_2$ emission ratio in $gCO_2/km$ | 188 | 135 | 148 | 111 | 147 |
| | Truck $CO_2$ emission ratio in $gCO_2/km$ | 927 | 668 | 728 | 545 | 725 |
| | % non-fossil fuel vehicles | 4,0% | 31,4% | 19,2% | 37,3% | 24,6% |
| | **Slow technology implementation path** | | | | | |
| 2020 | Car $CO_2$ emission ratio in $gCO_2/km$ | 171 | 178 | 184 | 176 | 177 |
| | Truck $CO_2$ emission ratio in $gCO_2/km$ | 937 | 877 | 908 | 866 | 873 |
| | % non-fossil fuel vehicles | 4,4% | 7,5% | 4,5% | 12,3% | 9,9% |
| 2030 | Car $CO_2$ emission ratio in $gCO_2/km$ | 188 | 165 | 178 | 163 | 166 |
| | Truck $CO_2$ emission ratio in $gCO_2/km$ | 927 | 814 | 876 | 804 | 816 |
| | % non-fossil fuel vehicles | 4,0% | 14,3% | 8,9% | 24,7% | 16,6% |

**Table 16: Comparison of alternative technology development paths for the prospective scenarios. Average values for urban and inter-urban traffic**

The next figures show that $CO_2$ reduction targets are not fulfilled in year 2020 in any scenario in the slow technological implementation path. Although the reduction is achieved in some scenarios in the year 2050, the cumulative $CO_2$ emissions are much higher, particularly in the case of Induced scenario, being only 7.5% more in year 2020 but more than 30% in year 2050.

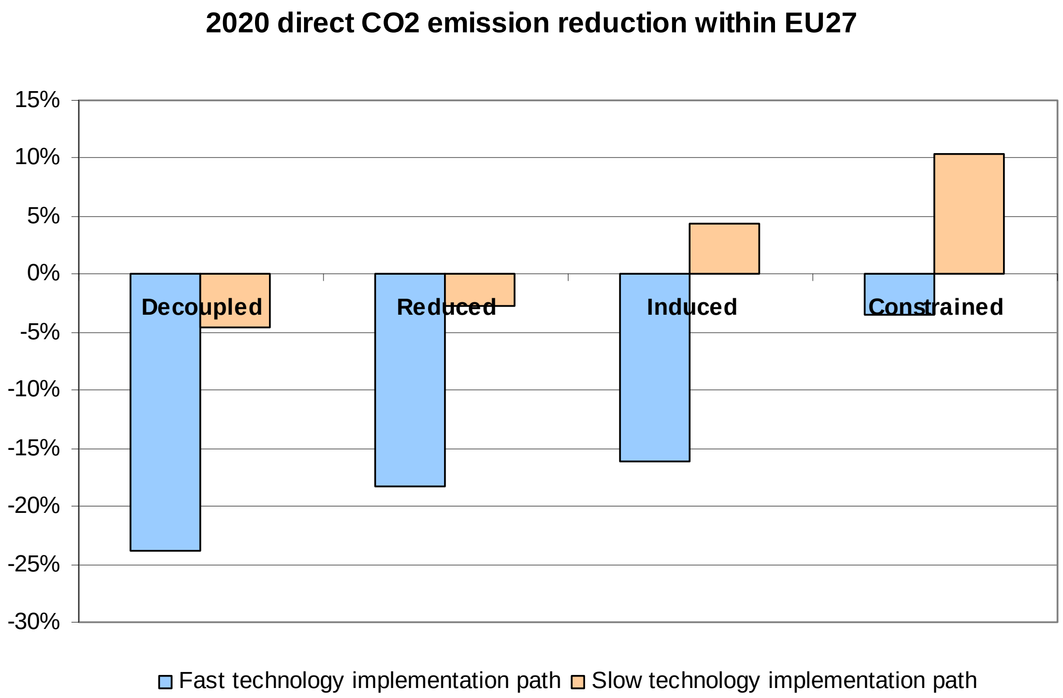



**Figure 91: Direct $CO_2$ emission reduction in 2020 within the EU-27 for two different sets of technology implementation paths**

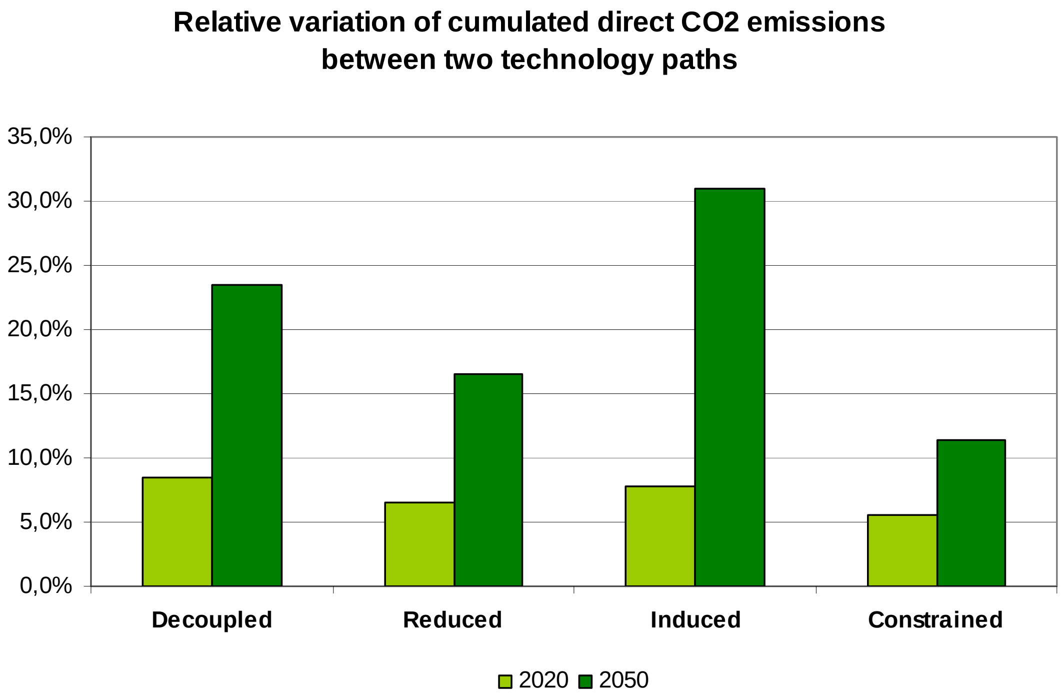



**Figure 92: Relative variation of cumulative direct $CO_2$ emissions between two different sets of technology implementation paths**

**Fast technology implementation path**

| | | Decoupled | Reduced | Induced | Constrained |
|---|---|---|---|---|---|
| 2020 | Direct $CO_2$ emission variation 2005-2020 | -24% | -18% | -16% | -3% |
| | Indirect $CO_2$ emission variation 2005-2020 | 11% | 25% | 8% | 21% |
| | Total $CO_2$ emission variation 2005-2020 | -22% | -17% | -15% | -2% |

| | | | | | |
|---|---|---|---|---|---|
| 2020 | Direct cumulative $CO_2$ emissions 2005-2020 | 11.903 | 12.459 | 12.414 | 12.849 |
| | Indirect cumulative $CO_2$ emissions 2005-2020 | 596 | 632 | 588 | 603 |
| | Total cumulative $CO_2$ emissions 2005-2020 | 12.498 | 13.090 | 13.002 | 13.452 |

| | | | | | |
|---|---|---|---|---|---|
| 2050 | Direct $CO_2$ emission variation 2005-2050 | -61% | -61% | -56% | -37% |
| | Indirect $CO_2$ emission variation 2005-2050 | 46% | 22% | 45% | 22% |
| | Total $CO_2$ emission variation 2005-2050 | -57% | -58% | -52% | -35% |

| | | | | | |
|---|---|---|---|---|---|
| 2050 | Direct cumulative $CO_2$ emissions 2005-2050 | 26.415 | 26.329 | 28.551 | 35.274 |
| | Indirect cumulative $CO_2$ emissions 2005-2050 | 2.000 | 1.992 | 1.912 | 2.186 |
| | Total cumulative $CO_2$ emissions 2005-2050 | 28.415 | 28.321 | 30.463 | 37.460 |

**Slow technology implementation path**

| | | | | | |
|---|---|---|---|---|---|
| 2020 | Direct $CO_2$ emission variation 2005-2020 | -5% | -3% | 4% | 10% |
| | Indirect $CO_2$ emission variation 2005-2020 | 11% | 25% | 8% | 21% |
| | Total $CO_2$ emission variation 2005-2020 | -4% | -2% | 4% | 11% |

| | | | | | |
|---|---|---|---|---|---|
| 2020 | Direct cumulative $CO_2$ emissions 2005-2020 | 12.919 | 13.274 | 13.384 | 13.569 |
| | Indirect cumulative $CO_2$ emissions 2005-2020 | 596 | 632 | 588 | 603 |
| | Total cumulative $CO_2$ emissions 2005-2020 | 13.515 | 13.906 | 13.972 | 14.172 |

| | | Decoupled | Reduced | Induced | Constrained |
|---|---|---|---|---|---|
| 2050 | Direct $CO_2$ emission variation 2005-2050 | -61% | -61% | -56% | -37% |
| | Indirect $CO_2$ emission variation 2005-2050 | 46% | 22% | 45% | 22% |
| | Total $CO_2$ emission variation 2005-2050 | -57% | -58% | -52% | -35% |

| | | | | | |
|---|---|---|---|---|---|
| 2050 | Direct cumulative $CO_2$ emissions 2005-2050 | 32.616 | 30.669 | 37.401 | 39.290 |
| | Indirect cumulative $CO_2$ emissions 2005-2050 | 2.000 | 1.992 | 1.912 | 2.186 |
| | Total cumulative $CO_2$ emissions 2005-2050 | 34.616 | 32.661 | 39.312 | 41.476 |

| | | | | |
|---|---|---|---|---|
| Relative variation of cumulative 2005-2020 direct $CO_2$ emissions between two technological paths | 8,5% | 6,5% | 7,8% | 5,6% |
| Relative variation of cumulative 2005-2050 direct $CO_2$ emissions between two technological paths | 23,5% | 16,5% | 31,0% | 11,4% |

**Table 17: Comparison of $CO_2$ emissions for Baseline and prospective scenarios with two different sets of technology implementation paths**

## 5.3. *Impact of speed limits and car technology (EURO V directive) on $CO_2$ emissions*

Based on vehicle-km and speeds on roads, and using emission curves from TREMOVE, emissions have been calculated under different hypotheses.

TREMOVE allows us to compute, among other variables, fuel consumption and $CO_2$ emissions for different vehicle technologies. Next, synthetic curves are based on the present vehicle fleet and suppose that all existing vehicles will comply with the EURO V directive:

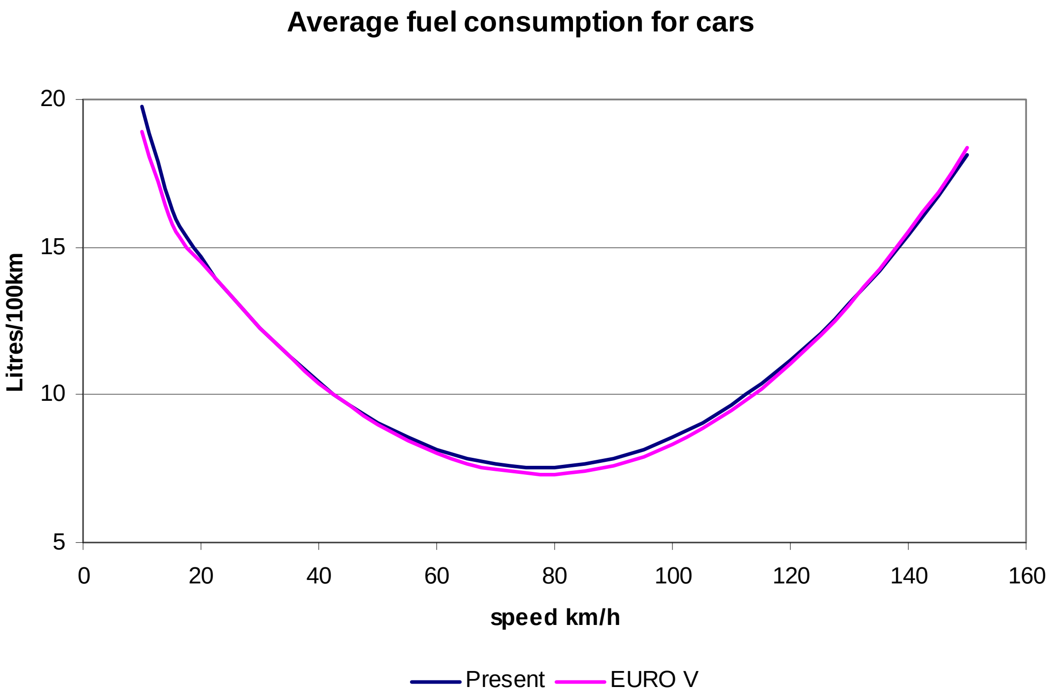



**Figure 93: Average fuel consumption curve for European car fleet in the present and supposing a full implementation of EURO V directive**

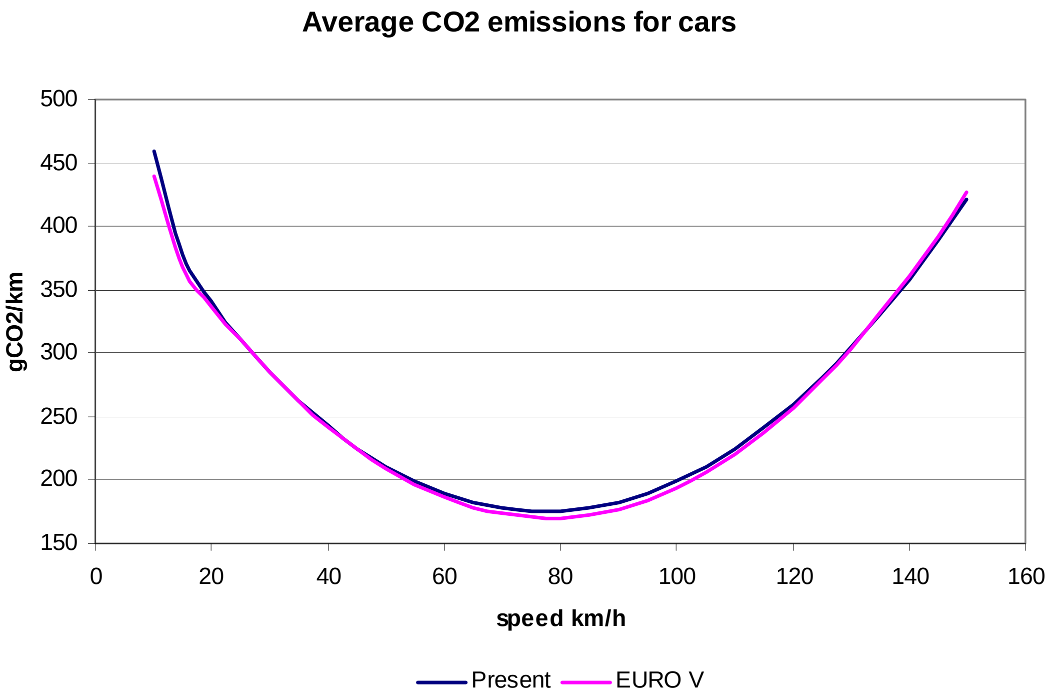



**Figure 94: Average$CO_2$ emissions curve for European car fleet in the present and supposing a full implementation of the EURO V directive**

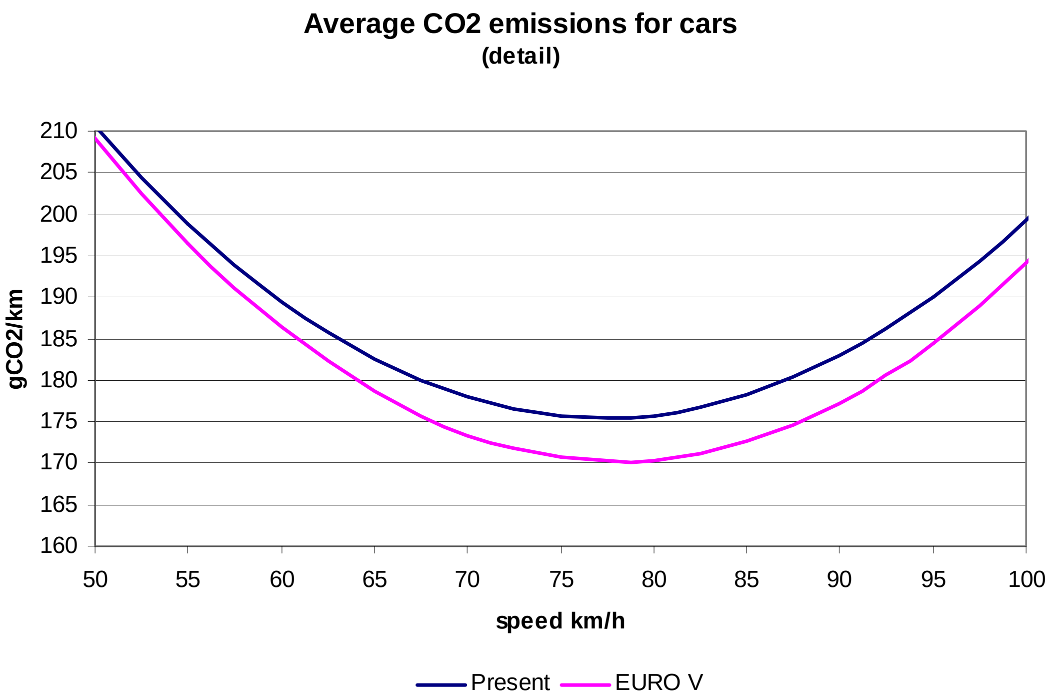



**Figure 95: Average$CO_2$ emission curve for European car fleet in the present and supposing a full implementation of EURO V directive. Detail for central speed range.**

In 2005, there is the following distribution of traffic in vehicle-km according to speed range:

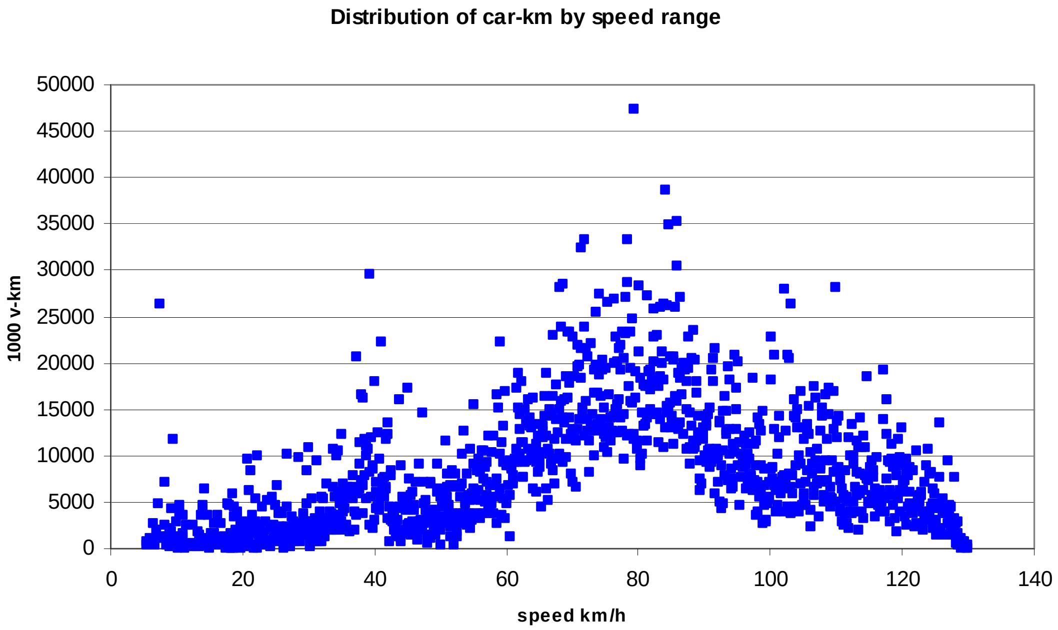



**Figure 96: Distribution of car-km by speed range in 2005 TRANS-TOOLS results**

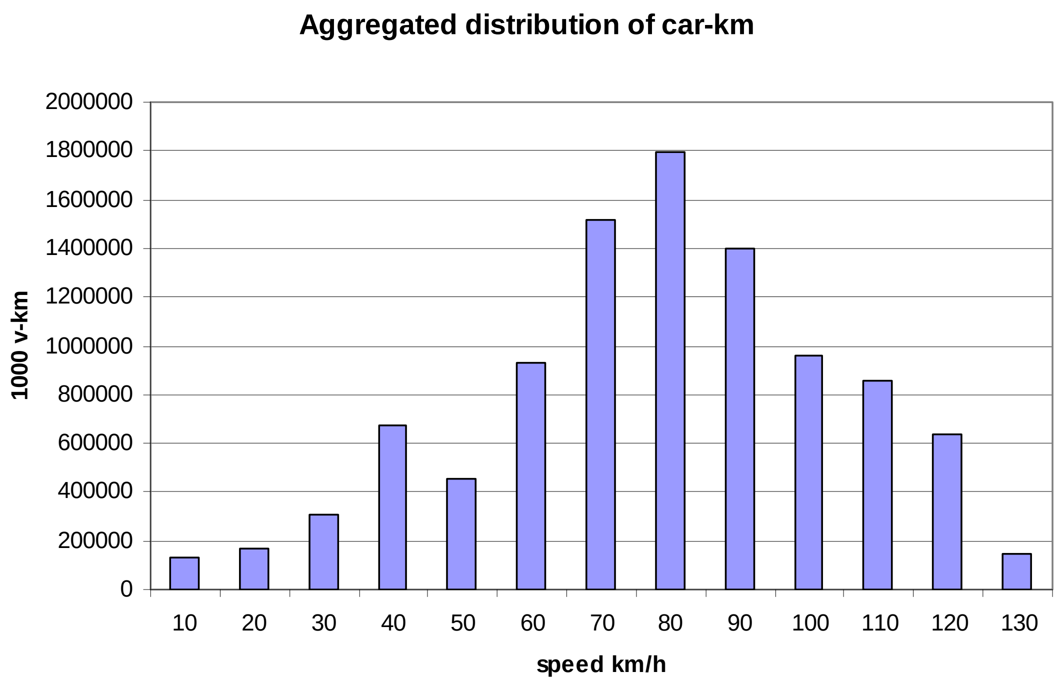



**Figure 97: Aggregated distribution of car-km by speed range in 2005 TRANS-TOOLS results**

A possible way to reduce $CO_2$ emissions would then be to reduce maximum speed limits to 100 km/h for motorways and 80 km/h for trunk roads. However, as seen in the Figure 97 most vehicle-km are grouped in the 70-90 km/h range, which means they are already circulating at an optimal speed in terms of $CO_2$ emissions. However, the implementation of 80/100 speed limits on current traffic would yield a significant 4.6% reduction of $CO_2$ emissions.

An alternative measure would consist of fully implementing the EURO V directive for cars substituting all the older ones. This option reduces $CO_2$ emissions by 1.8%.

| EURO V | 80/100 |
|---|---|
| 1,8% | 4,6% |

**Table 18: $CO_2$ emission reduction for different policies**

## 5.4. *Policy backcasting exercises*

In addition to the four exploratory scenarios, two "backcasting scenarios" have been defined. Essentially, the purpose of backcasting scenarios is to construct images of the future in which certain targets are met through selective policy interventions. Such scenarios are constructed against backgrounds provided by the exploratory scenarios.

Both scenarios have been constructed based on the underlying socioeconomic hypotheses of the Induced and Decoupled scenarios but only having the TRANSvisions Baseline policies. Neither of these two new scenarios comply with the $CO_2$ reductions of 10% in 2020 and 50% in 2050. This is the starting point to define a policy alternative in relation to each of them in order to reduce emissions. Therefore, two new auxiliary scenarios or trends have been created: an Induced-Baseline and a Decoupled-Baseline that give rise to the Induced-Backcast and to the Decoupled-Backcast. The Induced-Baseline and the Decoupled-Baseline are therefore different from the Induced and Decoupled scenarios used in the rest of the study. In the figures, they are shown as Induced-Backcast and Decoupled-Backcast.

The two backcasting scenarios were specified as follows:

- The first backcasting scenario was built with the help of the Decoupled Mobility scenario. The Decoupled scenario is used as reference for socio-economy and transport, with only the policies implemented in the Baseline. Several policies are then applied to fulfil $CO_2$ emission reduction targets—a 10% $CO_2$ reduction in 2020, and a 50% reduction in 2050, both from 2005 levels.

- The second backcasting scenario was built with the help of the Induced scenario. The Induced scenario is used as a reference on socio-economy and transport, with the policies implemented in the Baseline. Several policies are also implemented to fulfil $CO_2$ emission reduction targets—a 10% $CO_2$ reduction in 2020, and a 50% reduction in 2050, both from 2005 levels.

### 5.4.1. How to achieve $CO_2$ emissions targets in the Decoupled scenario?

The results of the exercise are as follows:

| | | Decoupled Baseline | Decoupled Backcast | Decoupled Baseline | Decoupled Backcast |
|---|---|---|---|---|---|
| | 2005 | 2020 | | 2050 | |
| %non-fossil fuel vehicles | 0% | 7.5% | 12.2% | 21,8% | 40,0% |
| average $gCO_2$/km in cars | 196 | 176 | 167 | 119 | 98 |
| average $gCO_2$/km in trucks | 966 | 869 | 821 | 584 | 483 |
| Rail pax share LD | 9.8% | 18.9% | 19.4% | 30.4% | 35.2% |
| Rail pax share SD | 6% | 6.2% | 6.7% | 20,0% | 20,0% |
| Rail freight share | 28.7% | 30% | 32.4% | 37,5% | 44,6% |
| | | | | | |
| **Direct $CO_2$ reduction** | **-** | **-4%** | **-11.7%** | | |

**Table 19: Parameter variation on the Decoupled backcasting scenario**

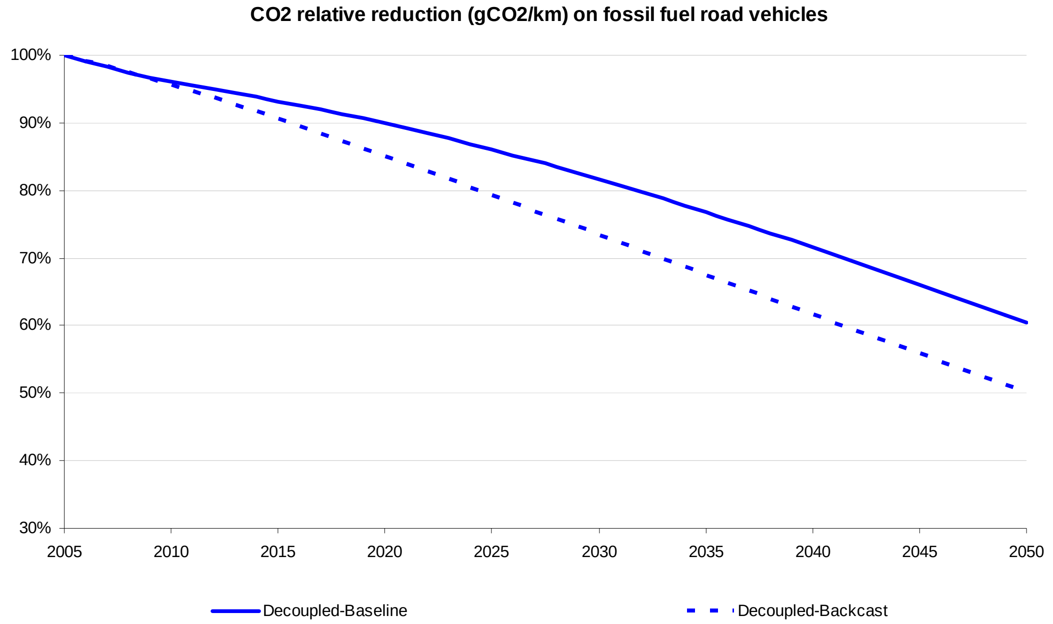



**Figure 98: Reduction of $CO_2$ emission rates on fossil fuel road vehicles for the Backcast Decoupled scenario**

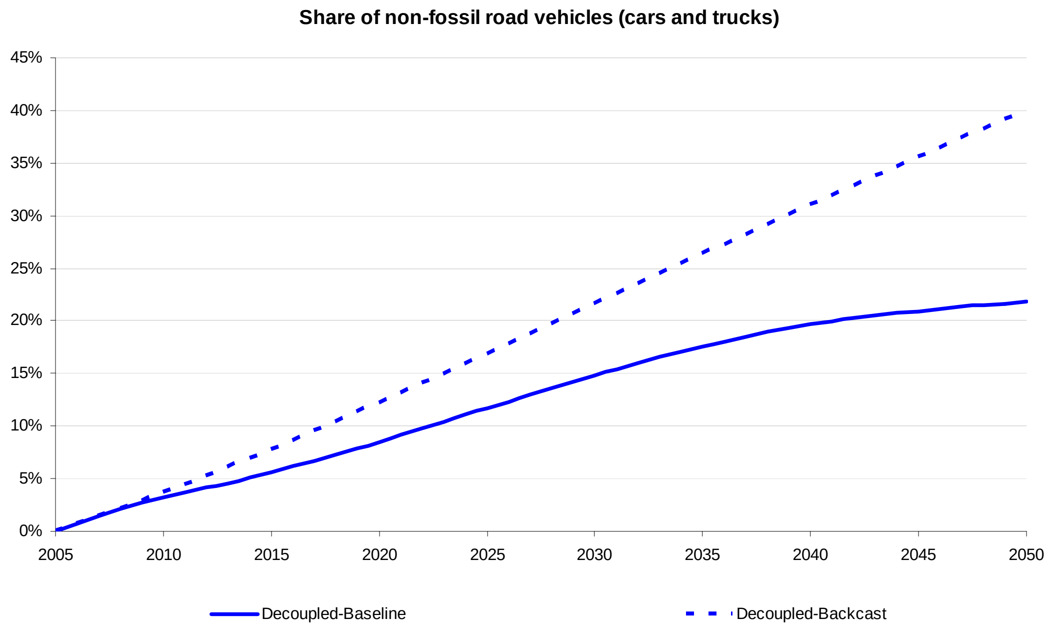



**Figure 99: Share of non-fossil fuel road vehicles for the Backcast Decoupled scenario**

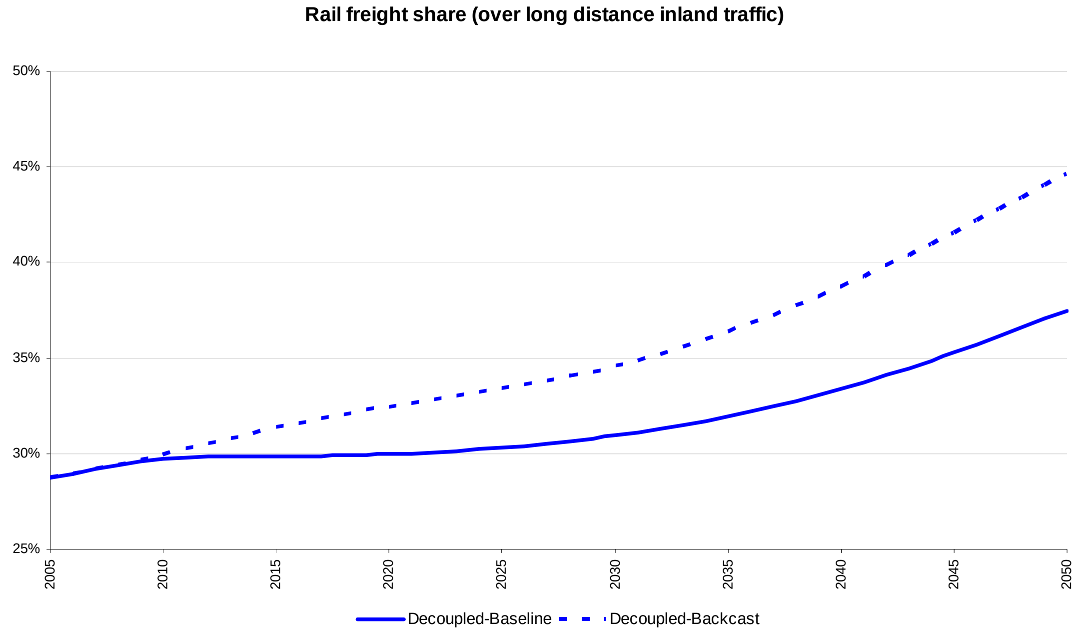



**Figure 100: Rail freight share over long-distance inland traffic for Decoupled Backcast scenario**

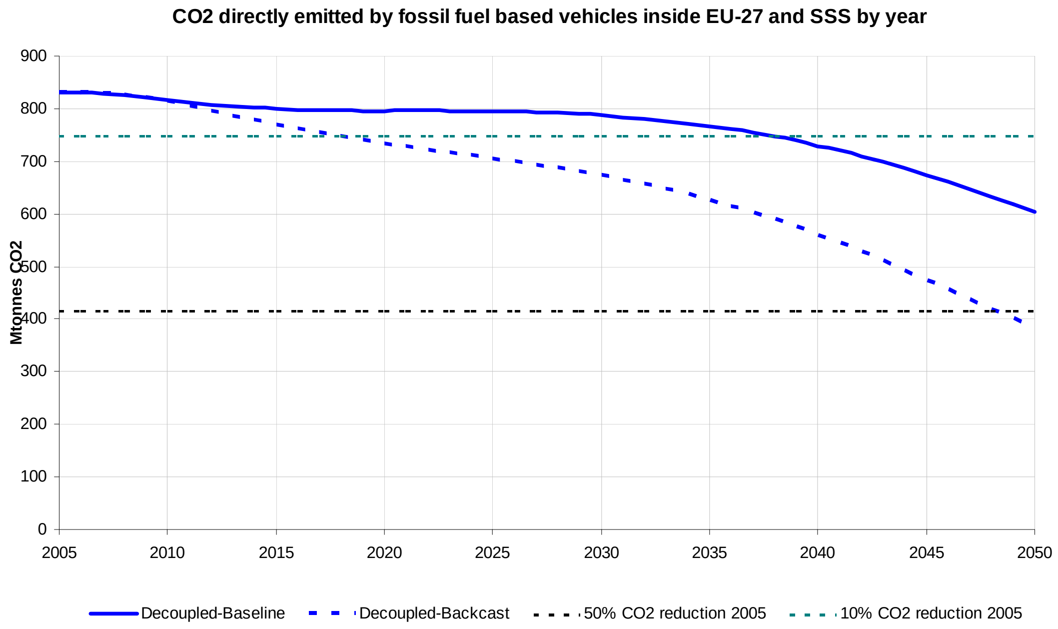



**Figure 101: Direct $CO_2$ emissions for the Decoupled Backcast scenario**

## 5.4.2. How to achieve $CO_2$ emissions targets in the Induced scenario?

According to "Trends in Vehicle and Fuel Technologies" (JRC-IPTS, 2003), a likely evolution of car technologies is:

- Market shares of hybrid cars 27%; fuel cell 10%; electric 5% by 2020.
- 28% reduction of $CO_2$ emissions in fossil fuel-based cars by 2020 due to increases in efficiency.

It is assumed that in the backcasting scenario a faster implementation of technologies is applied thanks to a policy-driven technological development (following the evolution of the study mentioned above), whereas the reference Induced scenario assumes a slower, mainly market-driven implementation.

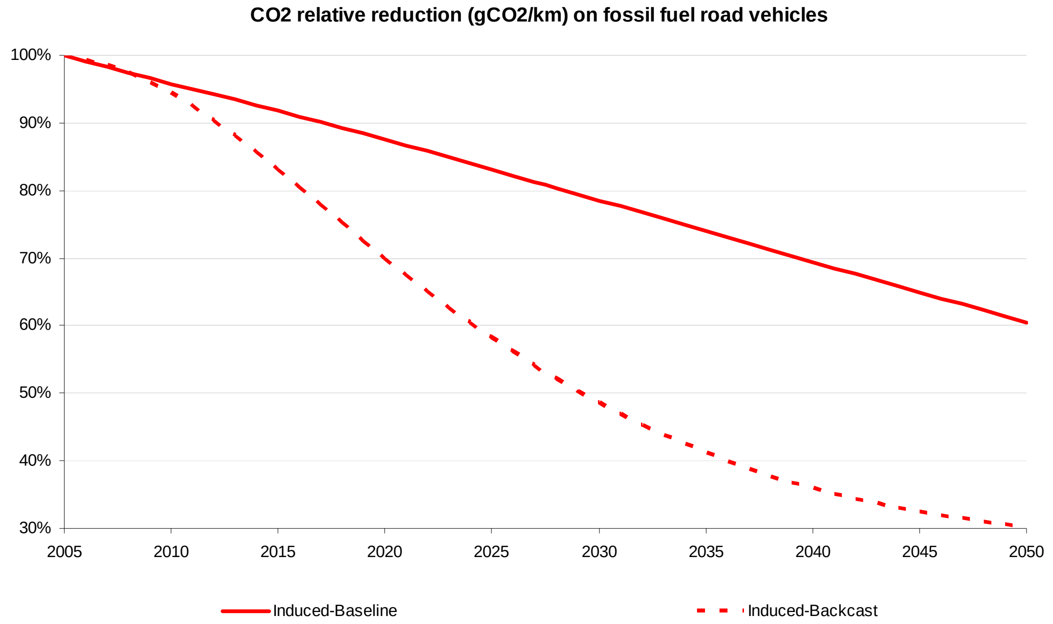



**Figure 102: Reduction of $CO_2$ emission rates in fossil fuel road vehicles for the Backcast Induced scenario**

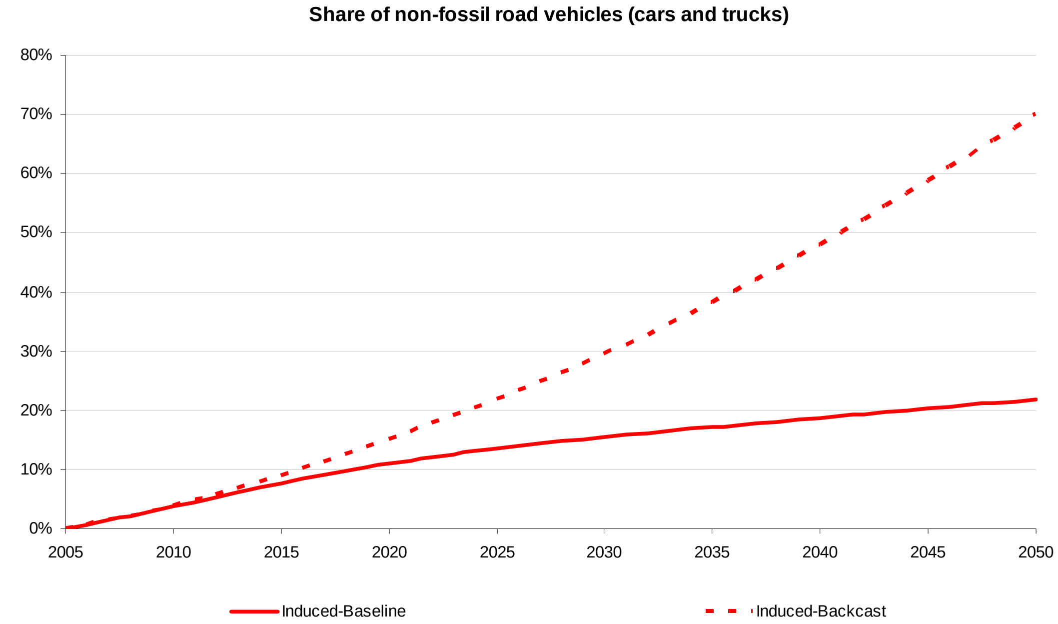



**Figure 103: Share of non-fossil fuel road vehicles for the Backcast Induced scenario**

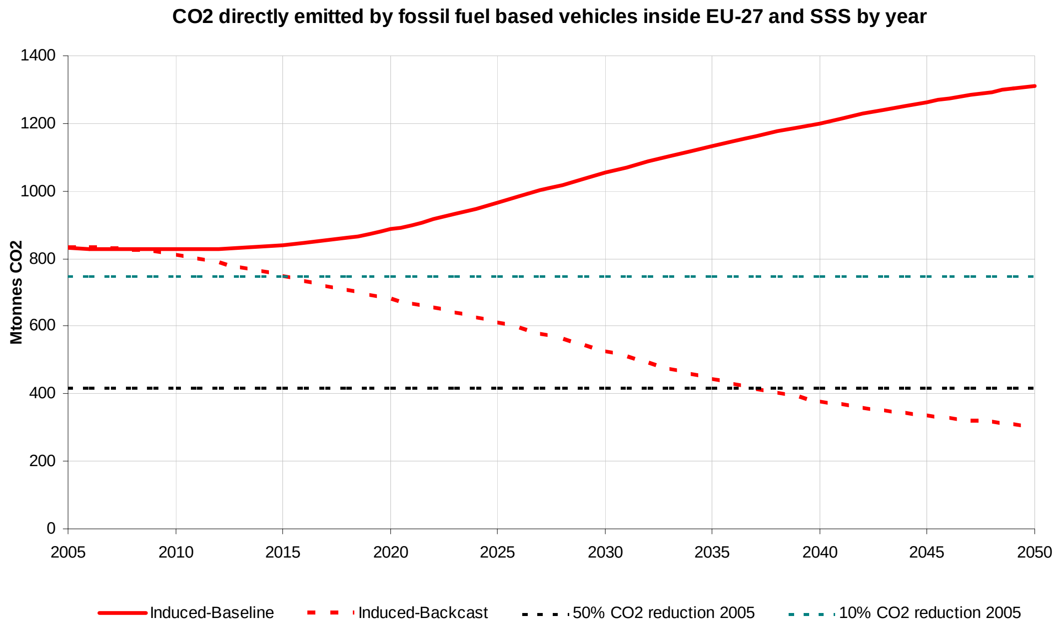



**Figure 104: Direct $CO_2$ emissions for the Induced Backcast scenario**

| | | Induced Baseline | Induced Backcast | Induced Baseline | Induced Backcast |
|---|---|---|---|---|---|
| | 2005 | 2020 | | 2050 | |
| %non-fossil fuel vehicles | 0% | 11,0% | 15,1% | 21,8% | 70,0% |
| average $gCO_2$/km in cars | 196 | 172 | 137 | 119 | 59 |
| average $gCO_2$/km in trucks | 966 | 846 | 676 | 584 | 290 |
| | | | | | |
| **Direct $CO_2$ reduction** | - | 7% | 18% | 58% | 64% |

**Table 20: Parameter variation on the Induced backcasting scenario**

In conclusion, the results obtained are as follows:

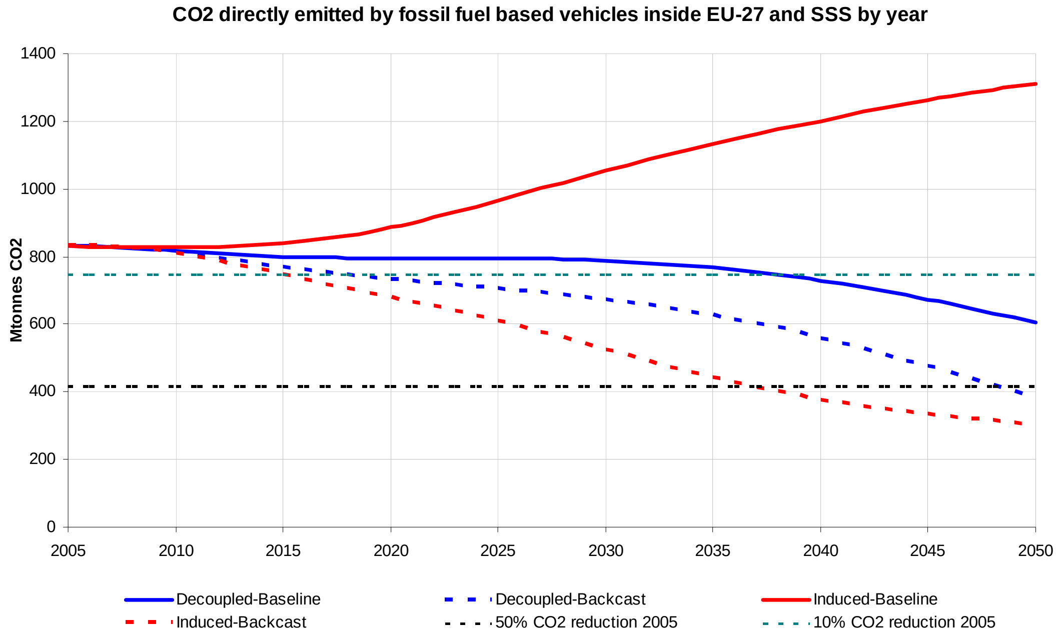



**Figure 105: Direct $CO_2$ emissions in the Backcast scenarios**

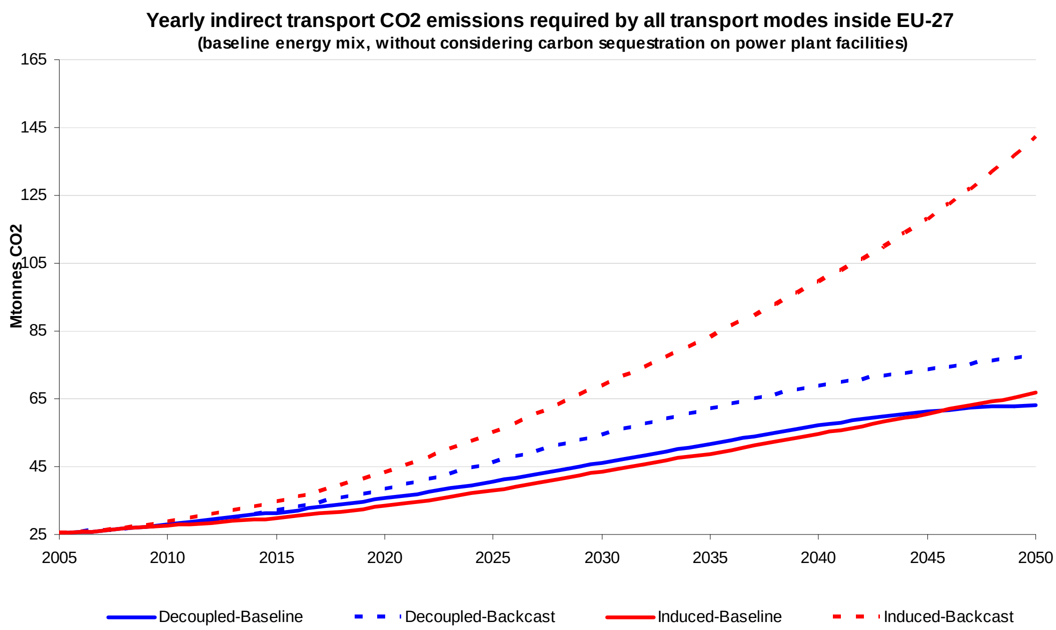



**Figure 106: Indirect $CO_2$ emissions in the Backcast scenarios**

Indirect emissions are related to vehicles that do not use fossil fuels, therefore a higher use of rail or an increase in the share of electric vehicles produces an increase in indirect $CO_2$ emissions.

| | | Total $CO_2$ reduction within the EU-27 with respect to 2005 levels | |
|---|---|---|---|
| Trends | Policies | 2020 | 2050 |
| Decoupled | Decoupled | -11% | -54% |
| Decoupled | Baseline | -4.1% | -27.3% |
| Induced | Induced | -18% | -63% |
| Induced | Baseline | 6.7% | 58% |

**Table 21: $CO_2$ emissions reduction within the EU-27**

From the previous table it can be seen that a major growth in the economy, leading to a major increase in traffic (Induced scenario) can result in an increase in $CO_2$ emissions of more than 50% if current trends regarding transport technologies and modal share are maintained (Induced/Baseline). However, the implementation of policies to control emission ratios can completely change the path (Induced/backcast2) instead leading to a 63% reduction.

A similar description can be made for the Decoupled scenario, having less economic growth as well as a decoupling of transport from GDP. In this case, the Decoupled/Baseline scenario does not comply with the reduction targets, although it has a tendency to reduce emissions. To meet the targets of -10% in 2020 and -50% in 2050 different policies regarding vehicle technologies and modal share are applied (Decoupled/backcast2), leading to a reduction of 54%.

## 5.5. *Which policies will achieve $CO_2$ emissions targets in 2020 and 2030?*

Several policy packages have been tested against the Baseline scenario to measure their effectiveness in reducing $CO_2$ emissions.

| | | | | Policies | | | Baseline | | | Maximum values in exploratory scenarios | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Policy | Indicator | 2005 | 2020 | 2030 | 2050 | 2020 | 2030 | 2050 | 2020 | 2030 | 2050 |
| Vehicle technology | Increase the share of non-fossil fuel based vehicles | % non-$CO_2$ | 0% | 15% | 25% | 40% | 9% | 15% | 22% | 20% | 37% | 70% |
| | Imposing new $CO_2$ emission limits for new vehicles and accelerate the retirement of older cars | % reduction $CO_2$ emissions | 0% | 15% | 25% | 50% | 13% | 23% | 40% | 28% | 44% | 70% |
| Speed limits, Land Use and Local Public Transport | Limit the maximum speeds to 100km/h in motorways and 80km/h in trunk roads | % reduction $CO_2$ emissions | 0% | 18% | 28% | 45% | 13% | 23% | 40% | 28% | 44% | 70% |
| | Reduce urban sprawl changing Land Use, to increase the share of urban rail | Short-distance passenger rail share | 6% | 10% | 15% | 28% | 7% | 7,5% | 8% | 7% | 7,5% | 20% |
| Occupancy, Load Factor and Rail share | Increase the average occupancy rates of cars for urban and interurban traffic | Urban occupancy rate | 1,4 | 1,52 | 1,71 | 2,25 | 1,46 | 1,48 | 1,5 | 1,55 | 1,7 | 2,1 |
| | | Interurban occupancy rate | 2 | 2,21 | 2,5 | 3,25 | 2,12 | 2,21 | 2,5 | 2,13 | 2,23 | 2,5 |
| | Increase in average load on trucks | Average load increase | 0% | 5% | 8,5% | 20% | 3% | 5% | 10% | 5% | 11% | 30% |
| | Increase rail share | Passenger rail share | 8% | 15% | 22% | 28% | 14% | 21% | 25% | 17% | 24% | 30% |
| | | Freight rail share | 15% | 15% | 16% | 21% | 15% | 16% | 20% | 16% | 16% | 21% |
| Road Infrastructure | Increase investment in roads to reduce congestion 20% over the Baseline level (from 4.000M€/yr to 5.000M€/yr) | % reduction $CO_2$ emissions | 0% | 10% | 16% | 23% | 9% | 15% | 22% | 28% | 44% | 70% |

**Table 22: Values of the indicators defined in the policy packages**

**The first policy package** consists of technological measures, the reduction of emission ratios for new vehicles and the introduction of non-fossil fuel vehicles. This implies a renovation of the fleet leading to a reduction of $CO_2$ emissions for cars from 196 down to 159g/km in 2020 (plus about 15% of the fleet not using fossil fuels). Values for 2050 descend to 98g/km (plus about 40% of the fleet not using fossil fuels). Direct $CO_2$ emissions for transport within the EU-27 is reduced by 4% in 2020 and by 23% in 2050.

This is one of the most efficient policy packages to reduce $CO_2$ emissions. However, it implies a major change on the fleet of vehicles, so it is more feasible in the mid and long term, while an early implementation might require strong policy enforcements.

**The second policy package** consists of regulatory measures: a reduction of maximum speeds in the whole road network (100km/h on motorways and 80km/h on trunk roads) and strict land use planning to avoid urban sprawl which encourages urban public transport. This package, assuming that enough urban rail capacity exists or is provided, increases the urban rail share from 6% in 2005 to 10% in 2020, and 28% in 2050, instead of the Baseline values of 7% in 2020 and 8% in 2050. With these measures direct $CO_2$ emissions are reduced 3% in 2020 and 13% in 2050.

Limiting speeds is moderately effective, as it can yield a reduction of almost 5%, depending on existing traffic, but is quite difficult to implement from a political point of view. The limitation of speeds might encourage the modal change towards rail, especially in metropolitan trips, thus complementing the second part of the package.

**The third policy package** includes pricing mechanisms to increase the average occupancy of cars, load factor of trucks and share of the long distance rail mode. This package increases the urban car occupancy up to 50% and the interurban car occupancy up to 30% more than the Baseline. Truck loads increase up to 20% instead of the 10% of the Baseline. Passenger rail share increases 3% in relation to the Baseline while freight rail share increases 2%. In this case the $CO_2$ emissions are reduced 2% by 2020 and 22% by 2050.

This package focuses mainly on mid and long-distance traffic, and while it is the one that takes the longest to show results, it is the most effective. The policies on changing vehicle occupancy do not require new infrastructure, so they might be the most cost-effective solutions to reduce $CO_2$ emissions. On the other hand, the modal shift requires investments in rail infrastructure.

**The fourth policy package** to reduce $CO_2$ emissions consists of selective road investments aiming to reduce actual congestion levels about 20%. This translates in an average reduction of -1% of $CO_2$.

This policy could possibly have the effect of increasing $CO_2$ emissions, as the reduction of congestion might encourage more trips, but specific investments in selected bottlenecks can have an important impact at the local or regional level.

If the four packages are applied together then a reduction of 10.2% in direct $CO_2$ emissions is obtained by 2020, assuming the polices are not overlapping. For the year 2050, the reduction would be 58%

In conclusion, it seems likely to achieve the 2050 reduction target, but relatively difficult to achieve the 2020 target, unless new technologies are implemented faster than expected or there is a deep recession during the coming years. On the other hand, the achievement of 2020 $CO_2$ targets is highly sensitive to the policies to be implemented in the coming years.

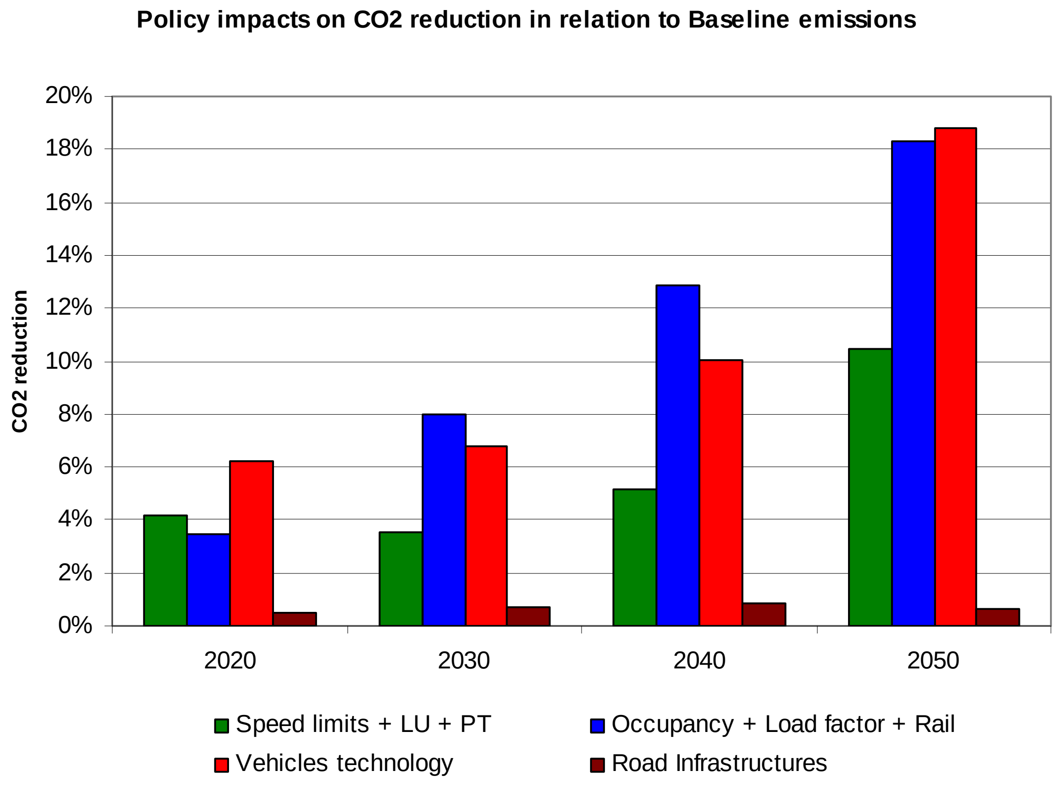



**Figure 107: Policy impacts on $CO_2$ reduction in relation to Baseline emissions**

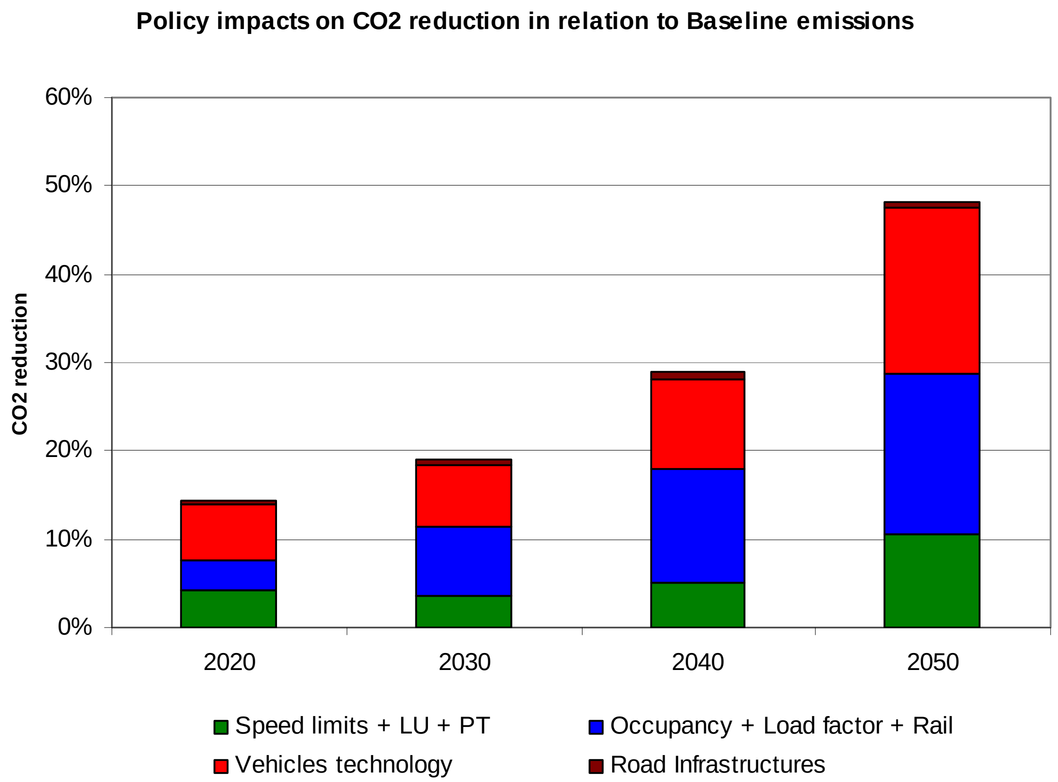



**Figure 108: Accumulated policy impacts on $CO_2$ reduction in relation to Baseline emissions**

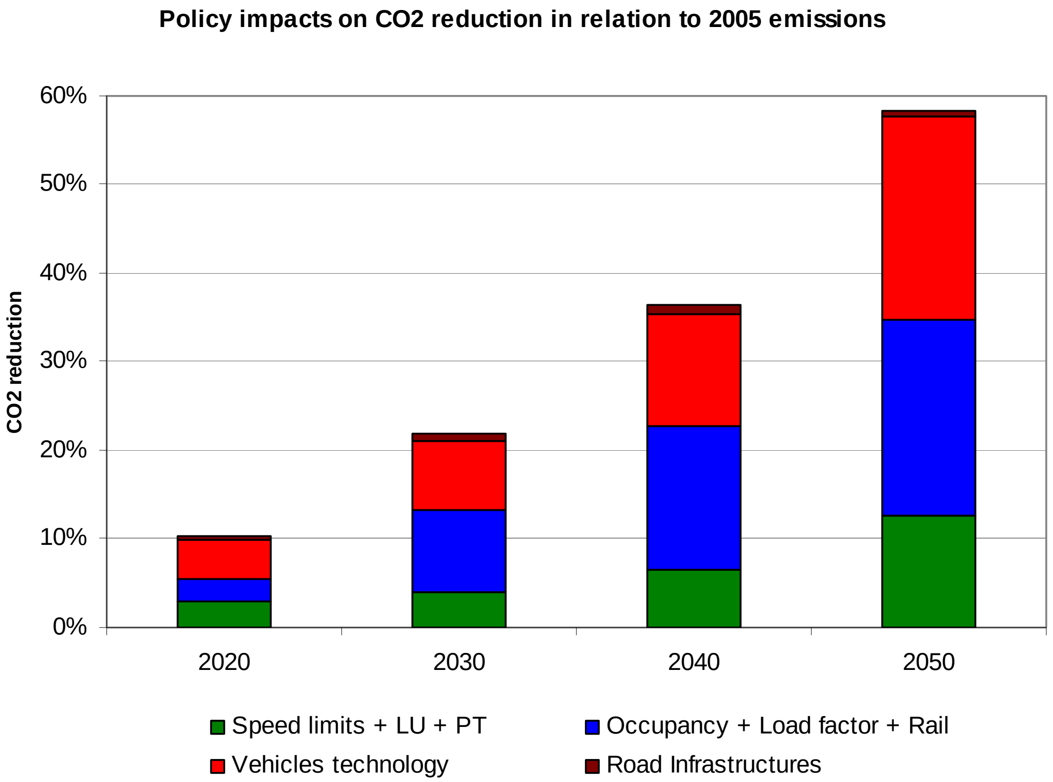



**Figure 109: Accumulated policy impacts on $CO_2$ reduction in relation to 2005 emissions**

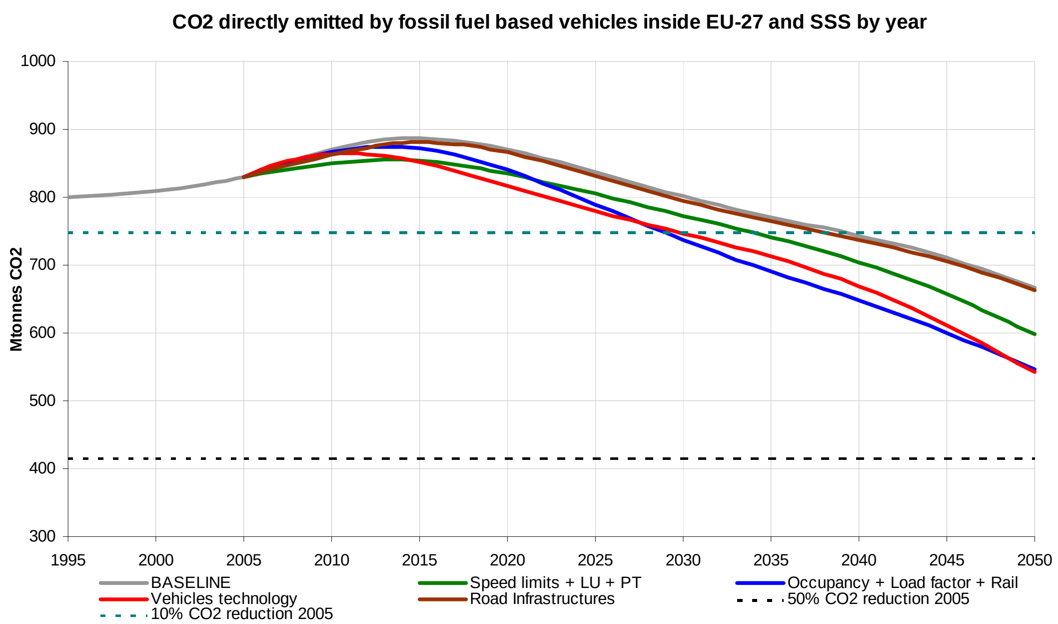



**Figure 110: Evolution of direct $CO_2$ emissions for different policy packages**

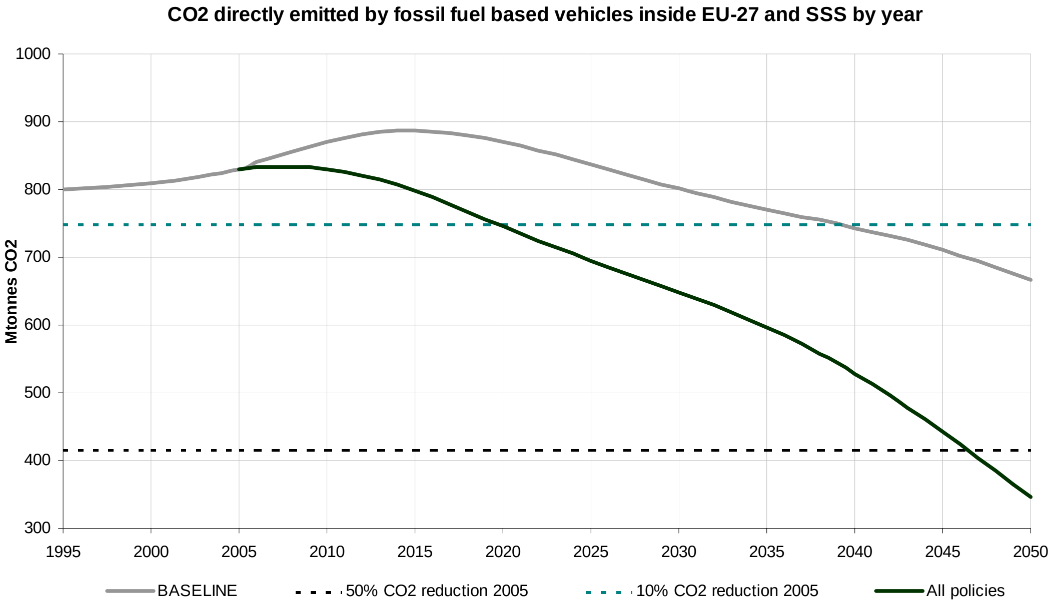



**Figure 111: Evolution of direct $CO_2$ emissions for the Baseline and all policy packages applied**

# 6. Conclusions

The following are the three fundamental uncertainties for the future of European transport:

- Will the strong correlation that has been observed between passenger and freight transport on one side, and GDP development on the other side, continue? (For which segments of the market? In which regions of Europe? Depending on which policies?)
- Will transport growth be decoupled from environmental impacts? (By which modes, or trip purposes? Using which technologies?)
- Which transport policies could be the most effective reducing $CO_2$ emissions generated by transport activities over time, facilitating sustainable and more stable economic development?

First, an integrated storyline with all scenarios will be presented, and later on these questions will be answered more explicitly.

## 6.1. *Visions of the future of European transport*

The following storyline was derived from integrating results from all scenarios. The figures mentioned can be found in the appendices of this report.

*The EU-27 could have 486 million inhabitants in 2050, or 545, depending on the scenario, but the European Union could reach 744 million, with successive enlargements. Eastern economies catching up the economic development levels of the EU-27 will produce more intensive east-west passenger and freight traffic.*

*Internal migration will probably be mostly from north to south, instead of east-west, and the number of temporary residents in southern regions and larger cities may grow significantly, as well as international couples.*

*External immigrations is far more uncertain; the number of immigrants could reach 5.5 million or many times more, 71 million in the Induced mobility scenario, generating most of the population growth, and largely increasing trips to/from outside Europe.*

*Depending on migration, a dramatic increase in the elderly dependence index is expected, from only 45% to 55% of people between 15-65 years, putting the financial* *viability of public pension benefit systems under considerable stress and then reducing the capacity of governments to maintain investments on economic infrastructures or R&D. Total public expenditure on social protection may change according to different scenarios, from around 20% to 35%. Ageing will also reduce the global saving rate in Europe and raise interest rates, especially if family structures become weaker and the number of elderly and people in general living alone grows.*

*Structural reforms in the labour market and public social systems are expected, with the end of facilitating more flexible and customized working schedules and working places, consistent with a more service-oriented and technology-based economy. Productivity increases due to more advanced technology and more effective organizations, smaller and better-networked, could reduce the total number of equivalent full-workers from 95% to 80%. More flexible working environments and telecommunications will not make a net substitution of passenger travel, but will facilitate more flexibility in travel decisions and reduce peak-hour transit.*

*Technology will be a major driver in social and economic changes. It is expected that before 2050 the capacity of a 1,000€ PC will have more capacity to manage information than a human being will. Biotechnology and nanotechnology may result in much longer life spans for human beings, reinforcing the ageing trend and making safety increasingly important. People above 65 will likely be in good health and find more options to work on a more flexible and customized basis, as is needed to overcome the burden on public pension systems.*

*The decoupling of GDP and energy consumption will continue, and oil will be substituted by renewable energy sources such as wind and solar, with the energy produced by renewable sources reaching from 20% to 40% in 2050. Nuclear energy will increase, in some scenarios reaching up to 50% of the total energy. The total energy consumed by road oil-based transport in MToe in the transport sector in 2050 may be very different, from 99 to 292 MToe. A decentralised Transeuropean electric grid will likely be developed, but the time it will require to be fully developed is uncertain. If successful, the number of connected energy producers may grow exponentially as well as the system's overall productivity. The use of hydrogen as an energy repository will make the overall management of the system more efficient.*

*Technology will have a huge impact on transportation vehicles for all modes, as much cleaner, more intelligent and further customized vehicles are already emerging. The uncertainty is related not so much to the availability of a new generation of energy production technologies or transport vehicles in ten or twenty years, but rather how fast they will be commercialised. Public policies establishing the right regulations and incentives may be decisive in accelerating the process, or constraining it. In general, new vehicles and more intelligent, online traffic pricing and management will result in more productive transport infrastructure. This will certainly have important consequences on transport taxation, now largely dependant on oil consumption.*

*The amount of RTD in the GDP may grow between 5% and 10%, but most activities will internalise their own development and innovation investments, so this figure will actually be much higher.*

*As for GDP, small differences in growth rates may represent important differences over time. The European economy may grow between 2.6% and 1.3% over the 2005-2050 period, with increasingly stable evolutions, since it is already a mature economy. At the moment, the Commission's 2007-2060 estimates point to 1.7% in the Baseline, 1.2% in the worst "no migration" case and 1.9% growth per annum in the best "productivity reforms" case*[3]*, which could point in the latter case to even more than a doubling of economic output. The gap between regions is expected to be reduced.*

*The demand for personal travel will change according to the evolution of the economy, which is increasingly dematerialized and more service-oriented, from large industrial firms devoted mass production to a more flexible, productive and service-oriented network of small, medium and large companies. There is no empirical evidence that the long-term pattern of people devoting a given amount of time and available budget to travel will change. Daily commuting trips to work may remain stable, but less concentrated in peak hours, increasing trips for business and non-business activities, especially long-distance within Europe. Decoupling of passenger transport and economic growth measured by GDP will happen for traffic within Europe, but overall, because of traffic outside the EU, the long-term pattern of elasticity will remain.*

*For freight, the increase of imports and exports as well as longer multimodal logistic chains within Europe will compensate for the decrease in domestic freight due to deindustrialisation, and freight will keep growing as it has been. The transport system could have to accommodate between 2 and 4 times more trucks than now, depending on the capacity of railways to improve their efficiency. The number of passenger kilometres that roads and rails may have to accommodate may be twice as much or more, depending on the scenario. Growth in long-distance freight, due to increasing imports from overseas entering by the largest ports, will make railways and combined transport more efficient for this market.*

*In highly-congested corridors and urban areas transport policies may have a critical impact on improving transport productivity in the short term. Better supply and demand management strategies will be applied using ICT innovation.*

*Different sets of policies can be applied to face all of these challenges. From a liberal, market-oriented approach, economic growth in the short term is indispensable (aiming at an overall 2.6% for the 2005-2050 period). If public institutions are capable of implementing a non-constraining and reliable regulatory framework as well as structural reforms, technology will facilitate decoupling traffic growth from environmental impacts when cost-effective. This optimistic scenario may fail, in the mid-term, if neither technology nor institutional reforms see the required evolution, if*

[3] The 2009 Ageing Report. European Economy no. 7/2008. Directorate General Economic and Financial Affairs. European Commission.

*peak-oil occurs or oil becomes much more expensive to extract, resulting in a fast economic decline linked to social conflicts. Between these two scenarios and the scenario favouring an almost zero-growth economy or a very unlikely change in people's behaviour, the moderate growth scenario is a reasonable alternative.*

## 6.2. *Concluding remarks*

Three fundamental uncertainties in the future of European transport were defined as specific goals for this study:

- Will the strong correlation that has been observed between passenger and freight transport on one side and GDP and GDP per capita growth on the other continue? (For which segments of the market? In which zones of Europe? Depending on what policies?)
- Will transport growth be decoupled from environmental impacts, especially direct $CO_2$ emissions? (By which modes, or trip purposes? Using which technologies?)
- Which transport policies are the most effective to reduce $CO_2$ emissions generated by transport activities over time, facilitating a sustainable and more stable economic development?

In order to explore these questions, the TRANSvisions study has defined long-term scenarios concerning the directions in which the European transport system could evolve. These scenarios, once defined qualitatively, were analysed by the TRANS-TOOLS model until the 2030 horizon, and complemented by meta-models that, from 2030 to 2050, also integrated results from other previous forecasts made by the European Commission and other institutions. TRANS-TOOLS is the Commission's new transport model that is based on a state-of-the-practice methodology, and was largely improved and updated in November 2008. It is already operational but not free from problems.

The scenarios were constructed by first studying the driving factors behind transport growth. Needless to say, the factors themselves are full of uncertainty. Such difficult factors include but are not limited to the ageing population, economic growth in the next phases of the globalisation process, new technologies—particularly in the field of energy and transportation, and transport infrastructure. All scenarios are plausible futures, even if they represent extreme or at least very different alternatives towards a post-carbon society.

From now until 2030, we may assume that policies now under discussion and emerging technologies will still be important. However, we do not know what transport will be like in 2050. The majority of policies and technologies that there will be in 2050 do not currently exist. It is possible that vehicles will pollute less and be more intelligent, and that online pricing and traffic management will make the current divide between scheduled, collective transport and individual vehicles much smaller. It therefore makes sense that the categories we use today as “transport modes” may not even be relevant in forty years. In order to somehow explore the many uncertainties involved, TRANSvisions made an intensive investigation into *seeds*, current developments all over the world that, even if embryonic, may show the starting point of a change that may have a huge impact in the future. These can range from online pricing and intelligent traffic management to new vehicles and energy sources or to major port and airport developments.

Some caution is always needed when analysing modelling results. Models, by definition, simplify reality but help us when thinking strategically, if they are systematic and consistent.

Considering current economic conditions, the Baseline scenario adopted in TRANSvisions (based on the official scenarios defined by DGTREN) may seem optimistic as to economic growth (1.9% p.a. in the Baseline up to 2050). However, it refers to the long-term future, and attaining this growth rate is still possible if structural reforms are carried out in the rest of the economy, and productivity gains due to new technologies, better organisation and more highly-skilled workers are achieved.

Economic recession, defined as 0% GDP growth on average in the 2008 – 2012 period, may cause traffic growth to stagnate, meaning that $CO_2$ emissions also stop growing as fast as they have in the past. This could lead to a reduction of 5% in accumulated $CO_2$ emissions in 2020 for the Baseline. However, it is important to avoid the slowdown of technology development over this period, or when traffic grows again $CO_2$ will increase faster.

**Will the strong correlation which has been observed between passenger and freight transport on one side, and GDP and GDP per capita growth on the other side, continue?**

- The estimates worked out show that the answer depends on the segment of demand under consideration: transport inside and outside the EU follows different patterns.

- Transport within the EU tends to grow less than GDP for both freight and passengers.

- Freight transport grows more than passenger transport.

- However, transport with European origins or destinations that takes place outside the EU is expected to grow more than GDP for both freight and passengers.

- Also, within the EU long-distance transport grows more than short-distance transport

- These results were expected. We know that within the EU international transport tends to grow faster than domestic transport. It is a consequence of growing global economic integration. It is not necessarily a result, however, of increasing relations between cross-border regions, since short-distance international trips are not expected to grow as much as long-distance international trips within Europe.

- European economic integration of national borders still matters, as well as language and cultural backgrounds. If a new generation of Europeans is mobile like Americans already are within USA, transport demand in Europe will grow exponentially.

- On the other hand, commuting is expected to remain rather stable while business, personal and leisure trips abroad will grow faster. Tourism coming to the EU will also increase, especially from Asia.

- Road traffic is still expected to remain the dominant mode in passenger transport although it will lose some market share to railways.

- In relation to freight, road transport may be losing share, but just marginally.

- It is expected that SSS will continue to grow in Europe as much as overseas traffic. Therefore, transhipment hubs and secondary ports in Europe may become more important in their regional hinterlands.

- One of the biggest uncertainties in terms of trends is to assess the role of railways. The models obtain high growth rates for passenger railways and to a lesser extent for freight:

    - For freight, estimates show that the highest growth will be for rail freight, followed by SSS and then by road freight transport.

    - For passengers, estimates show that rail passenger transport will grow the most, followed at a distance by intra-EU air transport and road passenger transport.

- Even with this extremely high rate of growth, the modal share of rail passenger transport grows only by a few points, and that of freight does not grow by much more. Nonetheless, these results are produced because of a relatively small increase in long-distance rail trips that may not necessarily result in an increase in the number of trains.

- Rail is an indispensable transportation mode for particular markets and corridors, but a significant modal shift from road to rail will barely happen for most markets. The models applied in TRANSvisions assume that gains in time and cost will automatically translate into traffic increases, which is not always the case. The sector has gone through big changes as it has opened to competition and experienced the implementation of large infrastructure and interoperability programmes such as the HST network or European Railway Traffic Management System (ERTMS).

**Will transport growth be decoupled from environmental impacts, especially $CO_2$ direct emissions?**

- To focus calculations and reflection two arbitrary targets were set: a 10% reduction of $CO_2$ by 2020 and 50% by 2050, the first inspired in the existing targets for non-Emissions Trading Scheme (ETS) sectors as a whole (as no specific $CO_2$ targets exist for transport).

- The models show that with the combination of the following policy instruments it is possible to meet these targets. On this basis, and from the results of the exploratory scenarios, we conclude that it will be more difficult to reach a 10% reduction by 2020 than 50% by 2050. Targets defined in cumulative $CO_2$ emissions could be far more effective in evaluating the alternative policy paths.

- We tend to forget that the environmental footprint of Europe is not limited to its own territory. By adding EU import and export transport as well as travel to and from the EU, the shadow of EU transport over the rest of the planet can be quantified.

- If we include overseas transport, just a fraction of EU freight traffic activity expressed in tonnes-km has both its origin and destination within the EU. Most of the EU's tonnes-km take place outside the EU.

- The footprint of Europe in the rest of the world, measured in terms of $CO_2$ direct emissions due to freight and passenger transport activities, is also high nowadays, just a bit smaller than emissions generated inside the EU.

- Therefore, it is absolutely necessary to think more of European transport as an activity that European citizens and companies do at world level, and not only within Europe.

**Which transport policies could be the most effective in reducing $CO_2$ emissions generated by transport activities over time?**

- The analysed policies included:

  - Vehicle technologies, increasing $CO_2$ emission limits for new vehicles and the introduction of non-fossil fuel vehicles.
  - A reduction of vehicle speeds on roads and motorways and an increase in urban rail transport.
  - Use of pricing mechanisms to increase occupancy rates and load factors.
  - Selective road investments in congested road links.

- It must be said that all of these measures are applied over a baseline that already includes measures in the pipeline such as ETS for aviation, $CO_2$ and cars and the internalisation of external costs for lorries.

- The most effective measures concern vehicle technologies and pricing, with the end of increasing occupancy rates. The measure concerning the reduction in vehicle speeds and public transport is moderately effective. The construction of new roads is the least effective, but still it brings about $CO_2$ reductions due to the easing of congestion.

- The combination of these four measures would allow the reduction of $CO_2$ emissions by 2020 by 10% and by 58% for 2050.

- Future trends are highly sensitive to the political decisions to be made in the coming years. Transport behaviour has a lot of inertia. Infrastructure needs time to be put in place, fleet renewal is slow, RTD results are uncertain. Moreover, the USA or Asia may be able to integrate innovations more easily than Europe.

- The analysis shows that, in the long term, technology and/or changes in behaviour will have an important effect on reducing $CO_2$ emissions, whereas more traditional policy measures are necessary in order to fulfil the 2020 target.

- Since most $CO_2$ emissions (72%) are produced by cars and trucks, policies inducing the renewal of the current fleet towards more energy efficient vehicles will have the most dramatic impact in the mid term.

- Policies focused on improving the productivity of road transport, by increasing load factors and occupancy rates, will also remain crucial to both reduce the social and environmental impacts of transport and to support economic growth.

- Large reductions of $CO_2$ emissions need to involve instruments that can be implemented at a variety of levels of governance including the local.

These conclusions are based on the findings listed in the next section.

## 6.3. *Main findings*

1. In order to predict far-off futures, there is a need to observe long-term historical patterns, and understand the meaning of the 1950-2050 period: **a period of transition** from a mass-industrial, oil-based economy towards a post-carbon society.

2. **1950, five years after World War II, can be considered as a moment where most of current evolutions started** from a relatively low level, in some cases from almost zero. Cities and infrastructure were being rebuilt, there were very few cars, no tourism, many people still worked in the primary sector, the process of European political integration had not started and Europe was divided politically in two, with little social and economic exchange.

3. **2050 has been considered by some authors as a *singularity point* in human history**, since the capacity of computers and electronic communications to manage information will be, if currents trends continue, difficult to imagine. Beyond 2050, infinite information is linked to a similar hypotheses concerning developments in energy, from the *Hydrogen Era* to the *Solar Era*. A world beyond natural constraints, with infinite information and energy is impossible to truly understand, even if likely given current trends.

4. According to most studies, in between 2005 and 2030 and up until 2050, Europe will remain peaceful and democratic, have a stable population, moderate migration, an increasing number of elderly people. This will help decrease the financial sustainability of public pension systems unless there are important economic reforms. The economy will become much less oil-dependent and less based on heavy industry, and will move towards more technology-intensive sectors and services, growing at moderate ratios in relation to Asian or North American economies—so the European share of the world economy, measured in GDP, will slowly be reduced.

   Overseas and passenger and freight traffic will grow rapidly. It is likely that further enlargement processes may happen, in order to increase the size of the EU market. European social and territorial cohesion, and environmental sustainability, is expected to be maintained or even improved, unless public institutions face serious financial problems. More participatory and direct democracy processes are expected. Globalisation at the world level may slow down in the short term, but there is no evidence that it will not continue to do so.

5. **New technologies in energy and in ICT may produce significant productivity gains in the transport sector**, depending on how they are implemented. New technologies, such as electric and highly customised vehicles and intelligent traffic management systems, may reduce congestion while reducing the need to physically expand the capacity of infrastructures, as well as increasing safety and reducing the negative effects of transport on the environment.

6. **Since technological innovation follows a cumulative evolution, we can hardly imagine most of technologies beyond 2030.** It is worth stating that many fundamental concepts and indicators we used may be not relevant in a few decades, such as GDP as an indicator of economic development, or "transport modes" (road, rail, aviation, maritime, IWW). New transport modes may emerge blurring the lines between private cars and public buses or trains, such as car-sharing in cities, using smaller, user-customized, cleaner and more intelligent fleet of vehicles that are automatically driven when running in some parts of the city. However, we cannot avoid remaining attached to current categories, databases and modelling frameworks in order to explain possible future evolutions.

7. Given the relatively high urbanisation of Europe, **transport infrastructures in Europe can not be expanded easily in the next decade**, especially in the central regions, or around major cities and metropolitan areas, at a reasonable economic and environmental cost, even if they are very congested. Because of this, achieving productivity gains in the transport sector and avoiding the increase of congestion costs above the present 1% of GDP, or reducing it, will be increasingly important.

8. **In the long term, say beyond 2030, new materials and more efficient construction processes may allow for specialised transport infrastructures adapted to new type of vehicles**, even in city centres, such as car parks and special urban tunnels for electric vehicles that are driven automatically when travelled across.

9. **A major challenge ahead will therefore be the capacity of European governments at all levels to carry out the necessary structural changes, such as** the opening of transport markets, pricing, education and training, **in order to achieve potential productivity gains from technological innovation.**

10. **Target setting for environmental purposes has become the most determinant policy instrument for the years to come**. In the framework of

the climate and energy package, European institutions have set up legally binding targets for 2020. Some of principle targets are to cut greenhouse gas emissions by 20%, to establish a 20% share for renewable energy and to improve energy efficiency by 20%. The GHG objective could be revised upwards to 30% if a satisfactory international agreement is reached (a 10% reduction in 2020 and 50% in 2050 for transport activities has been considered as a reference for TRANSvisions). In the future, it is likely that environmental targets will be increasingly used as a political instrument at all geographic levels, since they are generally viewed favourable and are relatively easy to monitor.

11. **Environmental targets are also of paramount importance to induce the implementation of more advanced technologies in many sectors, and increasing productivity of the economy especially in transport sector**. At this point, the difficulty of achieving the environmental targets in the transport sector are not related as much to the availability of alternative technologies as it is to the rigidities of the market.

12. **Social indicators, especially those related to safety and privacy will tend to be the most important political goals.** In the coming years, it is expected that social policy-aims will become as operational and effective with concrete targets as the reduction of road accidents already is.

13. Three main reference scenarios, Baseline, High Growth and Low Growth, were defined for the 2005-2030 period. The latest version of the TRANS-TOOLS transport forecast model (November 2008), was applied to explore the most likely evolution of transport demand, according to these three reference mid-term scenarios.

14. TRANS-TOOLS is an advanced 4-steps forecast model, suitable for making a mid-term strategic forecast at the European scale. The scenario specification in TRANS-TOOLS includes assessing zonal data for about 1,440 different transport zones in Europe, as well as data for about 35,000 road links and 5,000 rail links. Further cost specifications related to transport modes and specific network links and nodes are part of the specifications of the model. The TRANS-TOOLS model has been designed mainly for the analysis of infrastructure development, however, it can also be used for analysis of more general time and cost specifications covering the EU-27 and neighbouring countries: EFTA, the Balkans, Russia, Byelorussia, Ukraine and Turkey.

15. TRANS-TOOLS was greatly improved recently, but after using it intensively for the purpose of TRANSvisions, aspects to be further developed became evident: the geographic area for inland transport does not cover northern Africa, and air and maritime networks do not include the rest of the world. Passenger trips with origin or destination outside the EU-27 are included but not explicitly modelled, except for neighbouring countries. In the case of aviation, trips with their origin or destination outside the EU-27 are not

modelled, but EU-27 trip segments are included, in non-direct flights. Freight trips with their origin or destination outside the EU-27 are included as if they had their origin or destination in a European port, except for neighbouring countries. Air freight is not included. There is also no explicit modelling of ferries, but there are included as road and rail links.

16. TRANS-TOOLS lacks a policy-oriented interface able to automatically translate its results into a number of relevant policy-indicators, which would be easier to analyse, complemented by other data and forecasts.

17. The socioeconomic Baseline scenario for 2005-2030 modelled by TRANS-TOOLS was defined as follows: In 2005, the total EU-27 population was about 491m people. In 2020 this is expected to be almost 496m and the population remains almost constant up to 2030 495m, assuming a population growth in the EU-27 as indicated in the official population TREND-forecast 2004 from EUROSTAT at the NUTS2 level. The economic development up to 2030, according to the DG-ECFIN Note 253 of June 2006, will be faster in the eastern part of Europe than in the western part. GDP per capita in the EU-15 in 2005 was about 24,000 EUR in constant 2000 prices, expected to increasing to about 37,000 EUR in 2030. In the EU-12, the GDP per capita was about 5,000 EUR in 2005. This is expected to increase to about 13,000 EUR in 2030. The ratio of GDP per capita in the EU-15 to that in the EU-12 decreases from 4.7 to 2.9.

18. In the Baseline scenario, from 2005-2030 oil prices are assumed to be, on average, at 65$ per barrel, 20% more than in 2005. **The uncertainty in the evolution of oil prices is a major cause of economic instability nowadays, but in the transition towards a post-carbon society, oil prices will lose importance as an economic factor**.

19. **Taxes on oil in 2005 represent roughly 2% of the GDP**. In the long term, as oil become less used in transport, other alternative fiscal revenue generation systems will be needed. A couple examples of these are online pricing based on the actual use of infrastructure and transport services, which is more likely to induce demand self-organisation than oil taxes. In a number of scenarios studied the reduction in public revenue from oil taxation happens very rapidly. This is as an area of opportunity in political terms, since more effective taxation systems can be implemented.

**20.** A **High Growth scenario** has been defined for the 2005-2030 period, with population growing faster than in the Baseline and reaching 527m in 2030. The economy also develops faster at a 2.6% increase in GDP per year. **The TRANS-TOOLS forecast yields an annual increase of traffic of 1.5% for passenger and 2.2% for freight, well below economic growth in the TRANS-TOOLS coverage area.**

21. An alternative **Low Growth scenario** for the 2005-2030 assumes a decrease of population down to 461m in 2030, with the economy growing at a lower 1,3% GDP increase per year. In this case, **forecasted passenger traffic only grows 0.6% annually and freight 0.8%, below economic growth in the TRANS-TOOLS coverage area.**

22. **Four extreme but plausible exploratory scenarios towards a post-carbon society have been defined, having a 2005-2050 horizon**: Induced mobility or Hyper-mobility, Constrained mobility, Decoupled mobility, and Reduced mobility. These exploratory scenarios complement the scenarios previously described as reference scenarios for the 2005-2030 period. Exploratory scenarios are comprehensive, covering all socioeconomic, transport and environmental aspects, and were first defined qualitatively. They were modelled by ad-hoc foresight models based on TRANS-TOOLS results (or *meta-models*) and then validated against other available forecasts.

23. These four scenarios were compared against other scenarios defined in future-based studies, in relation to economic development, social balance and environmental sustainability. While the four scenarios cover economic development and extreme social balance areas (they could be stereotyped as "happy growth", "unhappy growth", "happy decline", "unhappy decline"), all of them attempt to be environmentally friendly.

24. **"Moving together" or Decoupled mobility** is the continuation of the 2005-2030 "*High growth and stable population*" scenario, combining relatively high economic growth with strong social sustainability. **Balanced policies are applied**, with emphasis on pricing and modal shift and public-private partnerships. There is an overall optimism in the capacity of public institutions to implement cost-effective policies, and adapt themselves according to the *subsidiarity principle*.

25. **"Moving less" or Reduced mobility** is the continuation of the 2005-2030 "*Low growth and declining population*" scenario, combining weak economic growth with strong social and environmental sustainability. **Behavioural policies reducing demand for motorised transport are applied.** Strict speed limits on roads and land-use regulations lead to an increase in public transport. Long-distance traffic is reduced.

26. **"Moving alone" or Induced mobility** is independent from reference scenarios. It assumes high growth and a small increase of population due to immigration from 2005 to 2050. It combines strong economic growth with weak social sustainability. There is a strong **emphasis on technology, supply-side management and spontaneous market self-organisation**.

27. **"Stop moving" or Constrained mobility** assumes very high growth and an increase of population due to migration until 2030, and then a "**bottleneck**" is reached because of structural reasons. These might be a lack of public

investment in infrastructure or the failure to implement new technologies, leading to a dramatic reduction of private profitability and hard economic decline. It is attached to a pessimistic vision concerning the capacity of Europeans to carry out structural reforms. From 2030 to 2050, the scenario combines weak economic growth with weak social sustainability. Non-cost-effective regulations and bans are applied to constrain mobility, in order to release congestion and reduce emissions, such as strict and expensively priced Emission Trade Markets. The economy is depressed, and transport prices and taxes cannot be raised. This scenario can be understood as a failing "Moving alone" (or Induced mobility) scenario.

28. **The aim of these four scenarios illustrates that there are different paths toward a post-carbon society**. It may be possible to achieve higher sustainability and economic growth together, if a balanced development of technology or of social organisation is achieved, or if there is a voluntary reduction of mobility. Failure during the process is also possible. There is a fourth scenario that shows the risks of not achieving a technological fix or the necessary structural reforms to facilitate its implementation at the right time. The consistency of these qualitative hypotheses was secured by the use of TRANS-TOOLS 2005-2030 and its meta-models for the 2005-2050 period.

29. **Meta-models are foresight tools that integrate 2005 TRANS-TOOLS data, and are calibrated with TRANS-TOOLS forecasts 2005-2030 and validated against other forecasts for 2020 and 2050.** They are multisectoral, focused on the long-term and dynamic. Meta-models are an approximation of TRANS-TOOLS for 2005-2030 and an extension for 2030-2050. Meta-models also complement TRANS-TOOLS with information not included in its current version but needed for long-term assessment. The meta-model requires less computer resources and can be run intensively under controlled parameters to reveal what affects performance in the system, in this way it is better suited for backcasting exercises. Meta-models can also be understood as a policy-interface for TRANS-TOOLS.

30. **The main objective of the meta-models is to produce $CO_2$ emissions in the 2050 scenario, and trace back the path combining trends and policies to 2005**. While TRANS-TOOLS produces results for a given time horizon (like 2020 or 2030), meta-models produce results for every year during the whole period of study.

31. In order to calibrate meta-models with TRANS-TOOLS, the qualitative narrative of the exploratory scenarios was translated into the TRANS-TOOLS main transport variables in two scenarios: The Decoupled scenario into the "high growth" scenario and the Reduced into a "low growth" scenario. The 2005-2030 baseline was extended to the 2030-2050 period. The other two exploratory scenarios (Induced and Constrained, distant from mainstream tendencies modelled by TRANS-TOOLS) were validated by comparison with the others.

32. The variables calibrated were the absolute values of traffic by mode for passengers and transport provided by TRANS-TOOLS in 2005 and 2030, and validated for 2020, assuming the same values in relation to socioeconomic variables.) For 2020 and 2050 the Baseline scenario was also validated against other available forecasts. Elasticity of transport to GDP for different type of trips, such as total trips within the EU-27 made by residents and tourists and visitors, EU-27 residents travelling within the EU-27 and abroad, etc., were validated against different sources, and finally the $CO_2$ emissions in 2005 was validated against the DG TREN statistical pocketbook values. The main difficulty of the exercise was to compare values corresponding to slightly different indicators that measure the same concept.

33. **Decoupled scenario (Organisation policy-path)**: population is expected to increase to 545m, while the economy measured by GDP will see annual growth of 2.4%. Passenger traffic measured in pax-km will increase by 1.2% per year, while freight will grow faster, at about 1.7% per year. Rail share will increase noticeably from 6% to 20% in the case of passenger share. **There is a gradual process of $CO_2$ reduction, up to 61% in respect to 2005 levels**.

34. **“Moving less” or Reduced mobility (Behavioural policy-path)**: the population is expected to decrease to 431m, while the economy measured in terms of GDP will see a slow 1.2% annual growth. Passenger traffic measured in pax-km will only increase by 0.5% per year, while freight will almost stagnate at 0.2% per year. Share of rail freight will increase from 12% to 17%. **There is a fast process of $CO_2$ reduction, since the early stages, leading to a 61% reduction in 2050**, not much different from the Decoupled scenario.

35. **“Moving alone” or Induced mobility (Technological policy-path):** the population is expected to increase to 545M, while the economy measured in terms of GDP will grow annually by 2.6%. Passenger traffic measured in pax-km will increase by 2.3% per year, while freight will grow faster, at about 2.9% per year. Air share will increase from 7% to 9% in the case of passenger, and road will move from 46% to 50% for freight. **$CO_2$ emissions are reduced mostly because of new technologies, and therefore $CO_2$ still grows during the firsts years but still reaches a reduction of 56% in 2050**.

36. **“Stop moving” or Constrained mobility (Mandatory policy-path)**: the population is expected to decrease to 488m, while the economy measured in terms of GDP will see an average growth of 1.3% per year. Passenger traffic measured in pax-km will increase by 1.1% per year, while freight will grow only 0.6%. Rail share will increase from 6% to 14% in the case of passenger, but road will be dominant for freight, increasing the share up to 52%. **$CO_2$ emissions will rise until 2030 but then will go down– about 36% in respect to 2005 levels**.

37. **The exploratory scenarios are plausible alternative paths to a 50% direct $CO_2$ reduction in 2050** (even the Contrained scenario could be, if adjusted). **It is more difficult to achieve the 10% reduction target in 2020**.

38. **Total passenger motorised transport with origin or destination in the EU-27 (measured in pax-km) will keep growing, following previous patterns**. There is no empiric evidence found against this long-term invariant. Passenger traffic will grow following the travel time and budget constraints (approximately 15% of personal available income allocated in transport, in average) for all scenarios. Depending on GDP per capita and the evolution of transport costs, passengers will travel more or less (in pax-km). This reflects the fact that personal mobility is not purely driven by economic aspects. While daily commuting trips may remain stable, business, personal visits and leisure trips abroad will grow faster.

39. The elasticity of transport to GDP depends very much on the types of trips. When considering trips made by EU-27 residents inside EU-27 territory the growth rate is relatively low, less than 1.3% per year. The addition of trips made in EU-27 territory by non-residents, generally trips with origin or destination outside the EU-27, increases the growth rate slightly up to 1.45% per year. The main difference arises when including the trips made by EU-27 residents outside EU territory, increasing the annual growth up to 2.1%.

40. **In European economic integration, national borders still matter, as well as language and cultural backgrounds.** Only 2% of Europeans live and work in other European countries. Cross-border short-distance traffic remains marginal. International relations between European countries grow less than could be expected, given the geographic proximity and the common market, in relation to the growth of traffic between European countries and countries outside the EU-27.

41. **Total motorised freight transport with origin or destination in the EU-27 (measured in tn-km) will keep growing, following previous patterns,** but the elasticity to GDP changes depending on the scenario. In the case of the Reduced scenario, the elasticity decreases while in the Induced it grows slightly in relation to previous trends. The elasticity has significant differences in relation to type of products.

42. For freight, the elasticity to GDP very much depends on the type of movement considered. When only considering freight with origin and destination within EU-27 territory, the growth rate is low, less than 1.2% per year. The addition of freight with origin or destination in EU-27 neighbouring countries (except northern Africa) increases the growth rate to 2.25% per year, mainly due to the great amount of oil, coal and other fuels moved by sea mode coming from Norway and Russia.

43. **Freight transport for shorter distances is dominated by minerals and building material.** For longer distances, it is more mixed with machinery and other manufacturing, especially for the more industrialised zones. Crude oil, oil derivatives and to a lesser extent solid mineral fuels are important in the long distances.

44. **Passenger transport is largely dominated by regional transport, which includes commuter and urban trips.** The shorter, regional, distances are divided in equal parts between commuter, private and holiday. Private and business gain importance at national level while long-distance transport is dominated by holiday trips. Domestic transport is the one who grows the least and long distance the most.

45. There are no major changes in the relation between trips and trip-km for road passenger traffic, meaning that trips do not become significantly longer or shorter in the future. In almost every scenario, there is a relative reduction of vehicle-km, due to the improvement in occupancy rates. This is not the case of the Induced scenario where development of new private unipersonal vehicles is important. just the opposite happens in the Reduced scenario where there is a reduction on veh-km, even with an increase on pax-km.

46. Important changes are expected in the different transport market segments. **Transport demand with both origin and destination within Europe is expected to grow less than the economy**, for both passengers and freight, and especially in northern and central regions. **Overseas traffic is expected to grow much faster**, measured in pax-km and tn-km, since other measures, such as trips or veh-km, do not necessarily follow the same patterns. A reduction in the number of trips may result in an increase of trips-km if the composition of trips changes and trips have longer distances, producing more or less veh-km depending on the evolution of occupancy ratios and load-factors. This will happen for all scenarios, with different intensities for urban and interurban traffic, in different zones of Europe.

47. **Passenger transport at the regional level (NUTS3) will tend to be decoupled from economic growth, as well as domestic (NUTS0) traffic, that will grow at an even lower rate than regional traffic,** for the Baseline evolution and, with small differences in all the other scenarios. **International passenger trips inside the EU-27 will grow following economic growth (in pax-km), and trips from/to outside the EU-27 will grow faster than economic growth**.

48. Technological improvements leading to faster and cheaper air services between Europe and America, or Asia, may result in greater increases of overseas traffic. Intercontinental flights and flights with neighbouring countries will have an important impact on major European airports. **Large European airports may grow as much as it is feasible, but an interconnected network of medium-size airports and HST connections will likely be needed.**

49. **Freight traffic between the EU-27 and the rest of the world in 2005 represented roughly 86% of the total traffic generated or attracted by the EU-27** (tn-km, including the movements to overseas). Only 14% is freight traffic within the EU-27, with origin and destination within the EU-27. **In 2050, traffic with the rest of the world may represent more than 90%.**

50. **If measured in value instead of weight, freight traffic is likely to grow much faster than GDP** if current trends continue. As a reference, in the 2000-2007 period the GDP grew at 2.1% per year, the weight of freight 2.9% per year and the value of freight 5.5% per year.

51. In 2005, 35% of inland EU-27 freight traffic was imports or exports from overseas. They will be almost 50% in 2030, and in 2050 are expected to grow to 65%. This means that European ports and freight corridors near large ports and urban centres will be increasingly busy. **While many European ports are increasing their infrastructure, the connections to their hinterlands should be upgraded by dedicated freight services to improve their efficiency, mostly by rail in the short term.**

52. **The footprint of Europe in the rest of the world measured in terms of $CO_2$ direct emissions due to transport activities is relatively high in the present,** about 45% of total $CO_2$ emissions generated by both Europeans travelling more often overseas, and imports and exports, **and it is expected to grow in the future.**

53. **The average passenger trip will become longer, as more intra-European trips and relatively less regional and domestic trips will be made**. Trips increase 1% annually in the Baseline scenario up to 2030, while pax-km increases 1.9% in the same period. Pax-km of trips with neighbouring countries grows at 6% annually, increasing the share of total pax-km in the EU-27 from 3% to 9%.

54. **Freight trips will likely become longer as the share of intra-European and extra-EU-27 trips increase against regional and domestic movements**. Lifted tonnes may increase slowly, but the increase in ton-km is much higher for all scenarios, caused by the economic integration of Eastern European countries and the globalisation process, meaning an increase in overseas imports and exports.

55. **The proportion of international European traffic is higher in the North/Centre macro-zone**. It highlights the fact that southern and eastern countries have more national freight traffic, and are still less integrated in the EU market.

56. **Passenger traffic growth is of similar magnitude in the three considered macro-zones**.

57. **Central, northern, southern and eastern European zones have different socioeconomic and territorial characteristics, and therefore transport demand is likely to evolve differently in the coming decades**. Specific processes to adapt common European policies to diverse European geography is therefore needed.

58. **In the southern countries (Portugal, Spain, Italy and Greece) trips from outside the EU-27 will grow the most** and the least in the North/Centre (the EU-15 excepts Portugal, Spain, Italy and Greece and the East).

59. **In central and northern regions, domestic freight traffic will remain stable, decoupled from economic growth, while traffic originated or having a destination outside the EU-27 grow faster than the economy**, for the Baseline, Induced, and Decoupled scenarios.

60. **Eastern countries will have the biggest increase of freight transport** (4.3% **ton-km** per year), while the South will grow less (1.58% per year) and the North/Centre even loses some traffic, -0.3% per year in the Baseline scenario in 2030.

61. **Freight transport between the zones increases most from/to the eastern countries to the rest**, with the East-South exchanges growing at 4.1% per year and East-North/Centre growing at 3.3% per year. The South-North/Centre relation grows at a more modest rate of 1.1% per year in the Baseline scenario (2030).

62. **Freight traffic with neighbouring countries grows most in the eastern countries** at a rate of 4.1% per year. In the South this rate is 2.7% and in the North/Centre 2,3%,

63. **Roads used by private cars and trucks will slowly decline, but still will be the dominant transport mode in the future**. This is assuming vehicles and roads play a similar role in 2050 to the one they play in 2005)**.** In 2005, road traffic represented 87% of passenger traffic, pax-km not including trips to overseas. It may be 84% in 2030 and 82% in 2050 in the Baseline scenario. Based on these figures, policies aiming for a modal shift from road to other modes will be increasingly important in particular corridors and segments of the market. **Policies focused on improving the productivity of and reducing the need for road transport will be critical in both reducing the social and environmental impacts of transport and supporting economic growth**.

64. **Roads may be losing share in relation to freight transport, but just marginally, from 43% in 2005 down to 42% in 2030 and 40% in 2050.** This is common to all exploratory scenarios except for the Induced scenario, where the share will increase to 47% in 2050, meaning that maritime and IWW slightly lose market. In all scenarios then, road share is between 40% and 47%.

On the other hand, it is expected that the road freight market, being extremely competitive, will be able to take advantage of technological innovation faster than other modes if properly regulated.

65. **Cars and trucks in 2050 will be much less energy-intensive and carbon-dependent, and will be lighter, safer, much better equipped with ICT, customised for trip purposes (urban or interurban, number of passengers, etc) with diversified ownership agreements**. A similar evolution may happen with trucks, to the point that hybrid modes may emerge in between roads and door-to-door private transport, and scheduled rail and public services. In the short term, for the Baseline scenario, fossil fuel-based vehicles may likely improve their efficiency 12%, and non-fossil fuel-based vehicles share will rise to 4.5% in 2020. Thirty years later, also in the Baseline, these figures will be 39% and 22%, respectively. As a comparison, in the Induced scenario 70% of vehicles may be non-fossil fuel based in 2050. ICT applied to vehicles should also result in better operations management.

66. **Since 72% of $CO_2$ emissions are produced by cars and trucks, policies inducing the renewal of the current fleet will have the most dramatic impact in the mid term**. Policy, if implemented in the short term, will only deliver results in the mid term, when the fleet is renewed and "gross-polluters" removed from the market. Thus regulation on vehicle technologies is the most powerful instrument available to reduce $CO_2$ emissions in all scenarios especially in those scenarios where a significant increase of road traffic is expected.

67. **The evolution from oil-based vehicles to hybrid and electrical vehicles will cause a dramatic reduction on the public revenue collected by oil taxation**. However, different scenarios may have very different evolutions. Oil taxation represented 1.9% of the GDP in the EU-27 in 2005, but it might become less than 0.3% in 2050 (Induced scenario with low oil dependence) or increase to 2.3% (Constrained scenario). Depending on the scenario, governments should accelerate the implementation of alternative taxation schemes, such as online pricing including full cost recovery of infrastructure costs as well as externalities, especially in the Induced and Decoupled scenarios.

68. **Rail has a significant growth potential for long-distance passenger trips.** Rail passenger grows in pax-km from having a share of 10% for long-distance inter-NUTS3 trips in 2005 to almost 35% in 2050 in the Reduced scenario. In all scenarios, the amount of freight growth is lower but still significant: from 24% to 34%. This tendency assumes that rail will be competitive enough to take advantage of expected cost and time savings in order to capture more traffic.

69. **Rail passenger traffic will likely grow before that of freight, in the 2005-2030 period, putting pressure on freight traffic given the capacity constraints of railway infrastructure** in those corridors where long-distance

passenger trains are not yet segregated. In the short term, passenger rail will increase due to HST investments, and the increase in demand for long-distance trips in pax-km.

**70. Rail may increase its share in long-distance passenger trips against aviation**. **For domestic flights, HST may compete effectively between large European cities, especially in the central and northern zones.** Rail increases its share for passengers from 7% to 12% in 2030, and 14% in 2050 for the Baseline scenario. In the case of the Induced scenario more emphasis is made on air mode than rail, thus air share increases from 7% in 2005 to 9% in 2050. For the Decoupled scenario rail increases its share to 12.5% in 2030 and 23% in 2050, while road share is reduced to 83% in 2030 and 74% in 2050. This modal share strategy would require a major improvement of railways in terms of capacity and services.

71. Rail trips increase just 4.8% in the period 2005-2030 for the Baseline scenario, but in terms of pax-km it increases by 2.4 times, as trips become much longer. This does not imply a high increase of train-km, as many of these new trips can be covered by already running services, depending on the evolution of occupancy ratios in long-distance rail services.

72. **Rail increases its share in all scenarios for freight**: for the Baseline scenario, it goes from 12% in 2005 to 14% in 2030 and 17% in 2050. Its share increases to 19% in the Decoupled scenario.

73. **In the long term, rail freight may grow because of the high growth of goods imported and exported overseas**. Rail is expected to be competitive for overseas traffic moving from/to large ports and main consumption centres. External trade is expected to increase significantly**,** so there is a good chance for rail as the loads will tend to concentrate in ever fewer points, such as main ports, and thus rail services can gain share by connecting these freight terminals. In congested corridors linked to large industrial centres and ports, freight trains services will tend to be segregated in dedicated lines in the long term.

74. **Inter-continental air services will increase faster than other markets,** up to 156% in 2050 for the Baseline against 20% for intra-EU-27 aviation. In the Induced scenario, inter-continental flights will grow 240% by 2050. For inter-continental air services, new technologies providing faster and cheaper services may likely emerge in the coming decades, resulting in a dramatic increase in trips.

75. **Short-sea shipping and *feedering* will be increasingly efficient as inland transport becomes more congested**, or there is no alternative dedicated rail service available. It is expected that SSS will continue to grow in Europe as

much as overseas traffic. *Transhipment* hubs and secondary ports in Europe may become more important in their regional hinterlands.

76. **Europe's footprint in maritime transport outside EU territory is very high**. The external segment of trips is 34 times bigger than the internal EU-27 one, in ton-km, as there are many relations with far-off countries.

77. **Europe's footprint in air transport outside EU territory is important albeit at a smaller scale**. The external segment of trips is 1.6 times bigger than the internal EU-27 one, considering the segment of extra-EU flights within the EU-27 as internal, always in pax-km. In 2050, it will be 3.6 times bigger in the Baseline scenario.

78. **While direct $CO_2$ emissions are expected to decrease (depending on the scenario), indirect $CO_2$ emissions are expected to grow** from 25.5MT in 2005 to 45 mt in 2050 in the Baseline. Total $CO_2$ emissions (direct and indirect) generated by transport in 2005 within the EU-27 was 1.038MT (1,012MT direct), of which 89% is due to traffic, which includes traffic by road, rail, IWW, maritime and air, moving in EU territory. In 2030, for the Baseline, the total will likely be 1.011MT (973MT direct), and for the 2050 the total 826MT (775MT direct).

79. **Indirect $CO_2$ emissions by vehicles not using fossil fuels will increase significantly in all scenarios.** This is due to the presence of fossil fuels in the primary generation of electricity. In 2005, they accounted for a mere 2.5% of total transport emissions, coming from electricity consumed by rails. However, indirect emissions could rise up to 26% in the case of the Induced scenario in 2050 due to the high share of clean vehicles (70% of the fleet). A higher share of rail also increases indirect emissions.

80. **Direct $CO_2$ emissions due to transport (those modes using carbon-based fuels: road, air and maritime) will increase steadily in the Baseline scenario, reaching a maximum of +8.4% in 2015, followed by a slow decrease with +6.1% in 2020, -3,9% in 2030 and down to -19,6% in 2050 compared to 2005 levels**. In the exploratory scenarios the $CO_2$ levels are further reduced by more than 10% in 2020 and more than 50% in 2050, except in the Constrained scenario, where the emissions rise up to a maximum of +23% in 2020, and reduce to -37% in 2050.

81. **Economic recession in the short term may stagnate traffic growth, meaning that $CO_2$ emissions may be reduced if the Baseline technological innovations are maintained**. This could lead to a reduction of 5% in accumulated $CO_2$ emissions in 2020 for the Baseline and up to 9% in the Induced scenario.

82. **If technological development is not slowed down due to the recession, lower economic growth will result also in lower traffic growth producing a**

**net reduction in $CO_2$ emissions**. However, technology implementation may slow down because of the recession, as firms and states cut their RTD investments, firms take less innovation risks and the renewal of vehicle fleets is slowed down significantly. In that case, when the recession is over and the traffic grows again, $CO_2$ will increase faster, leading to up to 30% more accumulated emissions, for the Induced scenario, 2050.

83. **If the current binding rules for emission ratios of vehicles are implemented, direct emissions of $CO_2$ due to transport are expected to be reduced by 3.9% for the Baseline in 2030 and by up to 20% in 2050**. However, emissions will be over 2005 levels for almost all of the 2005-2030 period, with a maximum of +8.4% in 2015 and back to +0% in 2026.

84. **Regional traffic inside NUTS3 generates 41% of road emissions in 2005, so a reduction of 50% of urban emissions would yield a 19% reduction in total direct transport emissions.**

85. Several policy packages have been defined and applied in the Baseline scenario to obtain paths for the reduction of direct $CO_2$ emissions due to transport. It has to be pointed out that the testing of measures offered in this study is not exhaustive.

86. **Direct $CO_2$ for transport within the EU-27 is reduced by 4% in 2020 and by 23% in 2050 if technological measures are adopted**, such as the reduction of emission ratios for new vehicles and the introduction of non-fossil fuel vehicles. This implies a renovation of the fleet leading to a reduction of $CO_2$ emissions for cars from 196 down to 159g/km in 2020, plus about 15% of the fleet not using fossil fuels. Values for 2050 go down to 98g/km, plus about 40% of the fleet not using fossil fuels.

87. **Policies aiming to facilitate the market implementation of new technologies in vehicles are the most efficient measures to reduce $CO_2$ emissions**. However, it implies a major change in the fleet of vehicles, so an early implementation might require strong policy enforcements.

88. **Direct $CO_2$ emissions are reduced by 3% in 2020 and 13% in 2050 if a policy package based on regulatory measures is adopted.** These could be a reduction of maximum speeds in the whole road network, 100km/h on motorways and 80km/h on trunk roads, strict land use planning to avoid urban sprawl , which in turn encourages urban public transport. This package, provided that enough urban rail capacity exists or is provided, increases the urban rail share from 6% in 2005 to 10% in 2020 and 28% in 2050, instead of the Baseline values of 7% in 2020 and 8% in 2050.

89. **Limiting speeds is moderately effective, as it can yield almost a 5% reduction**, depending on the amount of existing traffi, but is quite difficult to implement from a political point of view. The limitation of speeds might

90. **The $CO_2$ emissions are reduced by 2% in 2020 and 22% in 2050, applying a policy package that includes pricing mechanisms to increase the average occupancy of cars, load factor of trucks and long distance rail modal share**. This package increases the urban car occupancy by up to 50% and the interurban car occupancy by up to 30% more than the Baseline. Truck loads increase by up to 20% instead of the 10% of the Baseline. Passenger rail share increases by 3% in relation to Baseline while freight rail share increases by 2%.

91. **If occupancy rates and load-factors in vehicles increase in urban and interurban passenger and freight trips, then increases in transport demand may not necessarily produce more congestion**. This is true because it may not produce an increase on **veh-km** (just in the number of trips, or trips-km) which are directly linked to congestion and environmental impacts, such as $CO_2$ emissions. Occupancy for urban car trips rises from 1.4 to 2.1 and for interurban from 2 to 2.5 in the Reduced scenario, which has the most extreme variation. As a reference, the truck load factor increases by up to 25% in the Decoupled scenario in 2050.

92. Pricing policies applied to long-distance traffic require more time than other policies to produce results in terms of $CO_2$ reduction due to the time it takes for the market to adjust, but it is the most effective. Pricing does not require expensive investment in new infrastructures, so it might be the most cost-effective solution to reduce $CO_2$ emissions. This will be the case if transport operators and travellers can reorganise their travel patterns according to the new prices and do not translate transport costs to other sectors. Innovative pricing schemes such as online pricing may produce results in the short term but require investments in ICT, and technologies may not be fully available yet.

93. In the context of the adoption of the Greening Transport Package it was shown that the introduction of charges for air pollution, noise and congestion in road freight transport could reduce $CO_2$ emissions by 2.1% and by 2.8% if private cars were included in the charging scheme.

94. **Other policies tested to reduce $CO_2$ emissions consist of road investments aiming to reduce congestion on roads by 20%. This policy would produce an average reduction of about 1% of $CO_2$ emissions**. Easing of ongestion could encourage more traffic in the mid term, however, and have a negative impact in the end, depending on pricing and other complementary policies.

95. **If the four policy packages are applied all together, then a net reduction of 10.2% of direct $CO_2$ emissions is obtained by 2020, in relation to 2005 $CO_2$ emissions. For the year 2050, the reduction is 58%.**

96. **The 2050 reduction target is likely to be achieved, since the different paths represented by the exploratory scenarios are plausible, but it seems relatively difficult to achieve the 2020 target unless new technologies are implemented faster than expected, in vehicles or ICT for traffic management and/or pricing**.

97. On the other hand, **the achievement of $CO_2$ 2020 targets is highly sensitive to the policies now being implemented.**

98. **The direct $CO_2$ emissions due to transport activities accumulated by each scenario over time is, however, very different:** In relation to the Baseline, the differences are as follows: -15% Induced; +5% Contrained; -21% Decoupled and -26% Reduced.

**99. Defining targets based on accumulated emissions instead of relative annual reductions and monitoring it over time, instead of just two milestones, will facilitate a better discrimination between different scenarios, not to mention the effectiveness of the policies included in each one.**

**100. Future trends are highly sensitive to political decisions to be made in the coming years, since we are in a transition period.** Policies may produce an *acceleration* of current trends—especially in relation to technological innovation—or can alter main tendencies. This is a major challenge for Europe in comparison with the USA or Asia, where, for different reasons, institutions and markets are able to integrate innovations more easily.

# 7. Appendix I: Results for Baseline and Exploratory scenarios 2005-2050

This appendix provides a synthetic review of the main results obtained by applying the TRANS-TOOLS model and the TRANS-TOOLS meta-models to the different scenarios to the selected years 2005, 2020, 2030, and 2050. The 2005-2030 period is based on TRANS-TOOLS model, and 2030-2050 on the meta-models.

**2005-2050 TRANS-TOOLS Meta-model Baseline Scenario**

| | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| **Total population** | 491,999,371 | 494,733,795 | 491,110,000 | 486,218,917 |
| **Annual population growth** | - | 0.04% | -0.01% | -0.03% |
| **Total GDP B€** | 9,853,475 | 14,228,276 | 17,338,098 | 24,359,922 |
| **Annual GDP growth** | - | 2.5% | 2.3% | 2.0% |
| **EU-27 intra-NUTS3 passenger trafic** | | | | |
| Road passenger 1000Mpax-km | 3,433 | 4,398 | 4,743 | 5,048 |
| Rail passenger 1000Mpax-km | 215 | 241 | 272 | 318 |
| **EU-27 inter-NUTS3 traffic** | | | | |
| Road passenger 1000Mpax-km | 1,491 | 1,755 | 1,825 | 1,921 |
| Rail passenger 1000Mpax-km | 161 | 250 | 387 | 526 |
| Air passenger 1000Mpax-km | 320 | 368 | 298 | 315 |
| **Extra-EU-27 passenger traffic** | | | | |
| Extra-EU-27 passenger distance | 4,773 | 5,015 | 5,177 | 5,500 |
| Extra-EU-27 passenger EU distance | 500 | 500 | 500 | 500 |
| Air passenger in EU airspace 1000Mpax-km | 68 | 95 | 113 | 151 |
| Air passenger outside EU airspace 1000Mpax-km | 651 | 950 | 1,167 | 1,664 |
| **EU-27 intra-NUTS2 freight traffic** | | | | |
| Road freight 1000M/ton-km | 395 | 407 | 458 | 465 |
| **EU-27 inter-NUTS2 traffic** | | | | |
| Road freight 1000M/ton-km | 1,316 | 1,656 | 1,984 | 2,347 |
| Rail freight 1000M/ton-km | 447 | 644 | 796 | 1,222 |
| **Maritime freight traffic** | | | | |
| Sea freight EU-27 and NCT 1000M/ton-km[4] | 1,525 | 2,223 | 2,645 | 2,949 |
| Sea freight outside EU-27 and NCT 1000M/ton-km | 52,022 | 75,309 | 91,820 | 129,104 |
| **Annual EU-27 intra-NUTS3 passenger trafic variation** | | | | |

[4] * Includes SSS

## 2005-2050 TRANS-TOOLS Meta-model Baseline Scenario

| | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| Road passenger | - | 1.7% | 1.3% | 0.9% |
| Rail passenger | - | 0.8% | 1.0% | 0.9% |
| **Annual EU-27 inter-NUTS3 trafic variation** | | | | |
| Road passenger | - | 1.1% | 0.8% | 0.6% |
| Rail passenger | - | 3.0% | 3.6% | 2.7% |
| Air passenger | - | 0.9% | -0.3% | 0.0% |
| **Annual Extra-EU-27 passenger trafic variation** | | | | |
| Extra-EU-27 air passenger | - | 2.5% | 2.3% | 2.1% |
| **Annual EU-27 intra-NUTS2 freight trafic variation** | | | | |
| Road freight | - | 0.2% | 0.6% | 0.4% |
| **Annual EU-27 inter-NUTS2 trafic variation** | | | | |
| Road freight | - | 1.5% | 1.7% | 1.3% |
| Rail freight | - | 2.5% | 2.3% | 2.3% |
| **Annual Maritime freight traffic variation** | | | | |
| Sea freight EU-27 and NCT | - | 2.5% | 2.2% | 1.5% |
| Sea freight outside EU-27 and NCT | - | 2.5% | 2.3% | 2.0% |
| **EU-27 trafic** | | | | |
| Passenger 1000Mpax-km | 5,619 | 7,012 | 7,526 | 8,129 |
| Freight 1000M/ton-km | 3,683 | 4,930 | 5,883 | 6,983 |
| **Annual EU-27 trafic variation** | | | | |
| Passenger | - | 1.5% | 1.2% | 0.8% |
| Freight | - | 2.0% | 1.9% | 1.4% |
| **Passenger Rail share for long distance inland traffic** | 9.7% | 12.4% | 17.5% | 21.5% |
| **Freight Rail share for long distance inland traffic** | 25.3% | 28.0% | 28.6% | 34.2% |
| **Energy consumed by road oil-based transport inMToe** | 362 | 384 | 378 | 291 |
| **Average taxes on oil in €/litre** | 0.61 | 0.87 | 1.05 | 1.40 |
| **Taxes on oil by transport in M€** | 184,216 | 279,822 | 330,105 | 338,933 |
| **% Renewable in primary electricity generation** | 15 | 21 | 21 | 25 |
| **% Nuclear in primary electricity generation** | 35 | 38 | 38 | 40 |
| **Car $CO_2$ emission ratio in $gCO_2$/km** | 196 | 171 | 152 | 119 |
| **Truck $CO_2$ emission ratio in $gCO_2$/km** | 966 | 937 | 918 | 889 |
| **% non-fossil fuel vehicles** | 0% | 4% | 7% | 22% |
| **Energy consumption reduction per km in rails** | - | 13% | 22% | 40% |
| **Energy consumption reduction per km in ships** | - | 16% | 27% | 49% |

## 2005-2050 TRANS-TOOLS Meta-model Baseline Scenario

| | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| **Energy consumption reduction per km in airplanes** | - | 21% | 34% | 62% |
| **Car occupancy in urban trips pax/veh** | 1.40 | 1.43 | 1.46 | 1.50 |
| **Car occupancy in interurban trips pax/veh** | 2.0 | 2.17 | 2.28 | 2.50 |
| **Truck occupancy in ton/veh** | 7.0 | 7.26 | 7.43 | 7.78 |
| **Direct $CO_2$ emission variation 2005-2020** | - | 6% | -4% | -23% |
| **Indirect $CO_2$ emission variation 2005-2020** | - | 37% | 52% | 77% |
| **Total $CO_2$ emission variation 2005-2020** | - | 7% | -3% | -21% |
| **Direct cumulative $CO_2$ emissions 2005-2020** | - | 17,126 | 27,320 | 44,892 |
| **Indirect cumulative $CO_2$ emissions 2005-2020** | - | 493 | 863 | 1,714 |
| **Total cumulative $CO_2$ emissions 2005-2020** | - | 17,618 | 28,183 | 46,606 |

**Table 23: Results 2005-2050 baseline**

## 2005-2050 **TRANS-TOOLS** Meta-model Decoupled Scenario

| | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| **Total population** | 491,999,371 | 512,630,655 | 527,286.472 | 545,598,557 |
| **Annual population growth** | - | 0.27% | 0.28% | 0.23% |
| **Total GDP B€** | 9,853,475 | 15,308,650 | 19,093,763 | 29,051,343 |
| **Annual GDP growth** | - | 3.0% | 2.7% | 2.4% |
| **EU-27 intra-NUTS3 passenger trafic** | | | | |
| Road passenger 1000Mpax-km | 3,433 | 4,655 | 5,103 | 5,185 |
| Rail passenger 1000Mpax-km | 215 | 277 | 316 | 1,164 |
| **EU-27 inter-NUTS3 trafic** | | | | |
| Road passenger 1000Mpax-km | 1,491 | 1,800 | 1,846 | 2,200 |
| Rail passenger 1000Mpax-km | 161 | 378 | 589 | 864 |
| Air passenger 1000Mpax-km | 320 | 381 | 348 | 345 |
| **Extra-EU-27 passenger trafic** | | | | |
| Extra-EU-27 passenger distance | 4,773 | 5,182 | 5,455 | 6,000 |
| Extra-EU-27 passenger EU distance | 500 | 500 | 500 | 500 |
| Air passenger in EU airspace 1000Mpax-km | 68 | 97 | 114 | 148 |
| Air passenger outside EU airspace 1000Mpax-km | 651 | 1,008 | 1,242 | 1,777 |
| **EU-27 intra-NUTS2 freight trafic** | | | | |
| Road freight 1000M/ton-km | 395 | 422 | 482 | 494 |
| **EU-27 inter-NUTS2 trafic** | | | | |
| Road freight 1000M/ton-km | 1,316 | 1,714 | 2,114 | 2,599 |
| Rail freight 1000M/ton-km | 447 | 692 | 894 | 1,471 |

## 2005-2050 **TRANS-TOOLS** Meta-model Decoupled Scenario

| | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| **Maritime freight traffic** | | | | |
| Sea freight EU-27 and NCT 1000M/ton-km[5] | 1,525 | 2,352 | 2,862 | 3,476 |
| Sea freight outside EU-27 and NCT 1000M/ton-km | 52,022 | 81,158 | 101,488 | 154,835 |
| **Annual EU-27 intra-NUTS3 passenger trafic variation** | | | | |
| Road passenger | - | 2.1% | 1.6% | 0.9% |
| Rail passenger | - | 1.7% | 1.6% | 3.8% |
| **Annual EU-27 inter-NUTS3 trafic variation** | | | | |
| Road passenger | - | 1.3% | 0.9% | 0.9% |
| Rail passenger | - | 5.9% | 5.3% | 3.8% |
| Air passenger | - | 1.2% | 0.3% | 0.2% |
| **Annual Extra-EU-27 passenger trafic variation** | | | | |
| Extra-EU-27 air passenger | - | 2.9% | 2.6% | 2.2% |
| **Annual EU-27 intra-NUTS2 freight trafic variation** | | | | |
| Road freight | - | 0.4% | 0.8% | 0.5% |
| **Annual EU-27 inter-NUTS2 trafic variation** | | | | |
| Road freight | - | 1.8% | 1.9% | 1.5% |
| Rail freight | - | 3.0% | 2.8% | 2.7% |
| **Annual Maritime freight traffic variation** | | | | |
| Sea freight EU-27 and NCT | - | 2.9% | 2.6% | 1.8% |
| Sea freight outside EU-27 and NCT | - | 3.0% | 2.7% | 2.5% |
| **EU-27 trafic** | | | | |
| Passenger 1000Mpax-km | 5,619 | 7,491 | 8,202 | 9,759 |
| Freight 1000M/ton-km | 3,683 | 5,181 | 6,352 | 8,039 |
| **Annual EU-27 trafic variation** | | | | |
| Passenger | - | 1.9% | 1.5% | 1.2% |
| Freight | - | 2.3% | 2.2% | 1.7% |
| **Passenger Rail share for long distance inland traffic** | 9.7% | 17.4% | 24.2% | 28.2% |
| **Freight Rail share for long distance inland traffic** | 25.3% | 28.8% | 29.7% | 36.1% |
| **Energy consumed by road oil-based transport inMToe** | 362 | 313 | 247 | 130 |
| **Average taxes on oil in €/litre** | 0.61 | 0.94 | 1.16 | 1.60 |
| **Taxes on oil by transport in M€** | 184,216 | 245,206 | 239,004 | 173,406 |
| **% Renewable in primary electricity generation** | 15 | 29 | 29 | 40 |
| **% Nuclear in primary electricity generation** | 35 | 35 | 35 | 35 |
| **Car $CO_2$ emission ratio in $gCO_2/km$** | 196 | 157 | 135 | 98 |

[5] * Includes SSS

## 2005-2050 **TRANS-TOOLS** Meta-model Decoupled Scenario

| | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| **Truck $CO_2$ emission ratio in $gCO_2/km$** | 966 | 776 | 668 | 483 |
| **% non-fossil fuel vehicles** | 0% | 17% | 31% | 55% |
| **Energy consumption reduction per km in rails** | - | 13% | 22% | 40% |
| **Energy consumption reduction per km in ships** | - | 16% | 27% | 49% |
| **Energy consumption reduction per km in airplanes** | - | 24% | 40% | 71% |
| **Car occupancy in urban trips pax/veh** | 1.40 | 1.47 | 1.51 | 1.60 |
| **Car occupancy in interurban trips pax/veh** | 2.0 | 2.03 | 2.06 | 2.10 |
| **Truck occupancy in ton/veh** | 7.0 | 7.58 | 7.97 | 8.75 |
| **Direct $CO_2$ emission variation 2005-2020** | - | -13% | -31% | -61% |
| **Indirect $CO_2$ emission variation 2005-2020** | - | 64% | 112% | 206% |
| **Total $CO_2$ emission variation 2005-2020** | - | -11% | -28% | -55% |
| **Direct cumulative $CO_2$ emissions 2005-2020** | - | 15,744 | 23,495 | 34213 |
| **Indirect cumulative $CO_2$ emissions 2005-2020** | - | 529 | 1,013 | 2,372 |
| **Total cumulative $CO_2$ emissions 2005-2020** | - | 16,273 | 24,507 | 36,585 |

**Table 24: Results 2005-2050 Decoupled**

## 2005-2050 **TRANS-TOOLS** Meta-model Reduced Scenario

| | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| **Total population** | 491,999,371 | 482,577,527 | 461,401,130 | 431,090,794 |
| **Annual population growth** | - | -0.13% | -0.26% | -0.29% |
| **Total GDP B€** | 9,853,475 | 12,506,248 | 13,574,743 | 17,091,935 |
| **Annual GDP growth** | - | 1.6% | 1.3% | 1.2% |
| **EU-27 intra-NUTS3 passenger trafic** | | | | |
| Road passenger 1000Mpax-km | 3,433 | 3,876 | 3,759 | 3,863 |
| Rail passenger 1000Mpax-km | 215 | 235 | 301 | 423 |
| **EU-27 inter-NUTS3 trafic** | | | | |
| Road passenger 1000Mpax-km | 1,491 | 1,755 | 1,825 | 1,921 |
| Rail passenger 1000Mpax-km | 161 | 225 | 325 | 449 |
| Air passenger 1000Mpax-km | 320 | 319 | 247 | 295 |
| **Extra-EU-27 passenger trafic** | | | | |
| Extra-EU-27 passenger distance | 4,773 | 4,849 | 4,899 | 5,000 |
| Extra-EU-27 passenger EU distance | 500 | 500 | 500 | 500 |
| Air passenger in EU airspace 1000Mpax-km | 68 | 77 | 77 | 63 |
| Air passenger outside EU airspace 1000Mpax-km | 651 | 744 | 750 | 634 |
| **EU-27 intra-NUTS2 freight trafic** | | | | |

## 2005-2050 **TRANS-TOOLS** Meta-model Reduced Scenario

| | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| Road freight 1000M/ton-km | 395 | 343 | 339 | 264 |
| **EU-27 inter-NUTS2 trafic** | | | | |
| Road freight 1000M/ton-km | 1,316 | 1,387 | 1,467 | 1,290 |
| Rail freight 1000M/ton-km | 447 | 564 | 595 | 698 |
| **Maritime freight traffic** | | | | |
| Sea freight EU-27 and NCT 1000M/ton-km[6] | 1,525 | 1,950 | 2,062 | 1,861 |
| Sea freight outside EU-27 and NCT 1000M/ton-km | 52,022 | 66,328 | 72,179 | 91,121 |
| **Annual EU-27 intra-NUTS3 passenger trafic variation** | | | | |
| Road passenger | - | 0.8% | 0.4% | 0.3% |
| Rail passenger | - | 0.6% | 1.4% | 1.5% |
| **Annual EU-27 inter-NUTS3 trafic variation** | | | | |
| Road passenger | - | 1.1% | 0.8% | 0.6% |
| Rail passenger | - | 2.3% | 2.9% | 2.3% |
| Air passenger | - | 0.0% | -1.0% | -0.2% |
| **Annual Extra-EU-27 passenger trafic variation** | | | | |
| Extra-EU-27 air passenger | - | 0.9% | 0.6% | -0.1% |
| **Annual EU-27 intra-NUTS2 freight trafic variation** | | | | |
| Road freight | - | -0.9% | -0.6% | -0.9% |
| **Annual EU-27 inter-NUTS2 trafic variation** | | | | |
| Road freight | - | 0.3% | 0.4% | 0.0% |
| Rail freight | - | 1.6% | 1.2% | 1.0% |
| **Annual Maritime freight traffic variation** | | | | |
| Sea freight EU-27 and NCT | - | 1.7% | 1.2% | 0.4% |
| Sea freight outside EU-27 and NCT | - | 1.6% | 1.3% | 1.3% |
| **EU-27 trafic** | | | | |
| Passenger 1000Mpax-km | 5,619 | 6,410 | 6,457 | 6,950 |
| Freight 1000M/ton-km | 3,683 | 4,244 | 4,463 | 4,114 |
| **Annual EU-27 trafic variation** | | | | |
| Passenger | - | 0.9% | 0.6% | 0.5% |
| Freight | - | 0.9% | 0.8% | 0.2% |
| **Passenger Rail share for long distance inland traffic** | 9.7% | 11.4% | 15.1% | 18.9% |
| **Freight Rail share for long distance inland traffic** | 25.3% | 28.9% | 28.9% | 35.1% |
| **Energy consumed by road oil-based transport inMToe** | 362 | 298 | 246 | 182 |
| **Average taxes on oil in €/litre** | 0.61 | 1.01 | 1.27 | 1.80 |
| **Taxes on oil by transport in M€** | 184,216 | 249,650 | 260,322 | 273,525 |

[6] * Includes SSS

## 2005-2050 **TRANS-TOOLS** Meta-model Reduced Scenario

| | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| **% Renewable in primary electricity generation** | 15 | 18 | 18 | 20 |
| **% Nuclear in primary electricity generation** | 35 | 35 | 35 | 35 |
| **Car $CO_2$ emission ratio in $gCO_2$/km** | 196 | 165 | 148 | 137 |
| **Truck $CO_2$ emission ratio in $gCO_2$/km** | 966 | 815 | 728 | 676 |
| **% non-fossil fuel vehicles** | 0% | 12% | 19% | 35% |
| **Energy consumption reduction per km in rails** | - | 13% | 22% | 40% |
| **Energy consumption reduction per km in ships** | - | 16% | 27% | 49% |
| **Energy consumption reduction per km in airplanes** | - | 17% | 28% | 50% |
| **Car occupancy in urban trips pax/veh** | 1.40 | 1.63 | 1.79 | 2.10 |
| **Car occupancy in interurban trips pax/veh** | 2.0 | 2.17 | 2.28 | 2.50 |
| **Truck occupancy in ton/veh** | 7.0 | 8.00 | 8.67 | 10.00 |
| **Direct $CO_2$ emission variation 2005-2020** | - | -20% | -40% | -61% |
| **Indirect $CO_2$ emission variation 2005-2020** | - | 51% | 73% | 95% |
| **Total $CO_2$ emission variation 2005-2020** | - | -18% | -37% | -57% |
| **Direct cumulative $CO_2$ emissions 2005-2020** | - | 15,339 | 22,292 | 32,007 |
| **Indirect cumulative $CO_2$ emissions 2005-2020** | - | 511 | 930 | 1,893 |
| **Total cumulative $CO_2$ emissions 2005-2020** | - | 15,851 | 23,222 | 33,900 |

**Table 25: Results 2005-2050 Reduced**

## 2005-2050 **TRANS-TOOLS** Meta-model Induced Scenario

| | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| **Total population** | 491,999,371 | 513,731,529 | 524,036,455 | 545,740,798 |
| **Annual population growth** | - | 0.29% | 0.25% | 0.23% |
| **Total GDP B€** | 9,853,475 | 16,242,184 | 19,971,630 | 31,717,532 |
| **Annual GDP growth** | - | 3.4% | 2.9% | 2.6% |
| **EU-27 intra-NUTS3 passenger trafic** | | | | |
| Road passenger 1000Mpax-km | 3,433 | 5,537 | 6,579 | 9,888 |
| Rail passenger 1000Mpax-km | 215 | 283 | 270 | 303 |
| **EU-27 inter-NUTS3 trafic** | | | | |
| Road passenger 1000Mpax-km | 1,491 | 2,180 | 2,509 | 3,460 |
| Rail passenger 1000Mpax-km | 161 | 316 | 413 | 858 |
| Air passenger 1000Mpax-km | 320 | 539 | 657 | 1,262 |
| **Extra-EU-27 passenger trafic** | | | | |
| Extra-EU-27 passenger distance | 4,773 | 5,349 | 5,732 | 6,500 |

## 2005-2050 **TRANS-TOOLS** Meta-model Induced Scenario

| | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| Extra-EU-27 passenger EU distance | 500 | 500 | 500 | 500 |
| Air passenger in EU airspace 1000Mpax-km | 68 | 103 | 119 | 170 |
| Air passenger outside EU airspace 1000Mpax-km | 651 | 1,098 | 1,368 | 2,207 |
| **EU-27 intra-NUTS2 freight trafic** | | | | |
| Road freight 1000M/ton-km | 395 | 544 | 635 | 872 |
| **EU-27 inter-NUTS2 trafic** | | | | |
| Road freight 1000M/ton-km | 1,316 | 2,249 | 2,923 | 5,843 |
| Rail freight 1000M/ton-km | 447 | 779 | 986 | 1,868 |
| **Maritime freight traffic** | | | | |
| Sea freight EU-27 and NCT 1000M/ton-km[7] | 1,525 | 2,544 | 3,082 | 4,733 |
| Sea freight outside EU-27 and NCT 1000M/ton-km | 52,022 | 86,103 | 106,093 | 168,837 |
| **Annual EU-27 intra-NUTS3 passenger trafic variation** | | | | |
| Road passenger | - | 3.2% | 2.6% | 2.4% |
| Rail passenger | - | 1.9% | 0.9% | 0.8% |
| **Annual EU-27 inter-NUTS3 trafic variation** | | | | |
| Road passenger | - | 2.6% | 2.1% | 1.9% |
| Rail passenger | - | 4.6% | 3.9% | 3.8% |
| Air passenger | - | 3.5% | 2.9% | 3.1% |
| **Annual Extra-EU-27 passenger trafic variation** | | | | |
| Extra-EU-27 air passenger | - | 3.5% | 2.9% | 2.7% |
| **Annual EU-27 intra-NUTS2 freight trafic variation** | | | | |
| Road freight | - | 2.2% | 1.9% | 1.8% |
| **Annual EU-27 inter-NUTS2 trafic variation** | | | | |
| Road freight | - | 3.6% | 3.2% | 3.4% |
| Rail freight | - | 3.8% | 3.2% | 3.2% |
| **Annual Maritime freight traffic variation** | | | | |
| Sea freight EU-27 and NCT | - | 3.5% | 2.9% | 2.5% |
| Sea freight outside EU-27 and NCT | - | 3.4% | 2.9% | 2.7% |
| **EU-27 trafic** | | | | |
| Passenger 1000Mpax-km | 5,619 | 8,855 | 10,428 | 15,771 |
| Freight 1000M/ton-km | 3,683 | 6,115 | 7,626 | 13,316 |
| **Annual EU-27 trafic variation** | | | | |
| Passenger | - | 3.1% | 2.5% | 2.3% |
| Freight | - | 3.4% | 3.0% | 2.9% |
| **Passenger Rail share for long distance inland traffic** | 9.7% | 12.7% | 14.1% | 19.9% |
| **Freight Rail share for long distance inland** | 25.3% | 25.7% | 25.2% | 24.2% |

[7] * Includes SSS

## 2005-2050 **TRANS-TOOLS** Meta-model Induced Scenario

| | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| **traffic** | | | | |
| **Energy consumed by road oil-based transport inMToe** | 362 | 333 | 244 | 99 |
| **Average taxes on oil in €/litre** | 0.61 | 0.81 | 0.94 | 1.20 |
| **Taxes on oil by transport in M€** | 184,216 | 223,609 | 191,035 | 98,612 |
| **% Renewable in primary electricity generation** | 15 | 26 | 26 | 35 |
| **% Nuclear in primary electricity generation** | 35 | 43 | 43 | 50 |
| **Car $CO_2$ emission ratio in $gCO_2$/km** | 196 | 143 | 111 | 59 |
| **Truck $CO_2$ emission ratio in $gCO_2$/km** | 966 | 704 | 545 | 290 |
| **% non-fossil fuel vehicles** | 0% | 20% | 37% | 70% |
| **Energy consumption reduction per km in rails** | - | 13% | 22% | 40% |
| **Energy consumption reduction per km in ships** | - | 16% | 27% | 49% |
| **Energy consumption reduction per km in airplanes** | - | 26% | 43% | 78% |
| **Car occupancy in urban trips pax/veh** | 1.40 | 1.30 | 1.23 | 1.10 |
| **Car occupancy in interurban trips pax/veh** | 2.0 | 1.83 | 1.72 | 1.50 |
| **Truck occupancy in ton/veh** | 7.0 | 7.41 | 7.69 | 8.24 |
| **Direct $CO_2$ emission variation 2005-2020** | - | -3% | -25% | -56% |
| **Indirect $CO_2$ emission variation 2005-2020** | - | 70% | 119% | 369% |
| **Total $CO_2$ emission variation 2005-2020** | - | -1% | -22% | -46% |
| **Direct cumulative $CO_2$ emissions 2005-2020** | - | 16,580 | 25,173 | 36,805 |
| **Indirect cumulative $CO_2$ emissions 2005-2020** | - | 535 | 1,033 | 2,719 |
| **Total cumulative $CO_2$ emissions 2005-2020** | - | 17,115 | 26,206 | 39,524 |

**Table 26: Results 2005-2050 Induced**

## 2005-2050 **TRANS-TOOLS** Meta-model Constrained Scenario

| | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| **Total population** | 491,999,371 | 514,190,744 | 517,483,715 | 488,212,797 |
| **Annual population growth** | - | 0.29% | 0.20% | -0.02% |
| **Total GDP B€** | 9,853,475 | 16,810,516 | 18,639,495 | 17,868,710 |
| **Annual GDP growth** | - | 3.6% | 2.6% | 1.3% |
| **EU-27 intra-NUTS3 passenger trafic** | | | | |
| Road passenger 1000Mpax-km | 3,433 | 5,849 | 6,244 | 5,411 |
| Rail passenger 1000Mpax-km | 215 | 341 | 555 | 596 |

| | | | | |
|---|---|---|---|---|
| **EU-27 inter-NUTS3 trafic** | | | | |
| Road passenger 1000Mpax-km | 1,491 | 2,315 | 2,415 | 1,945 |
| Rail passenger 1000Mpax-km | 161 | 334 | 456 | 696 |
| Air passenger 1000Mpax-km | 320 | 581 | 689 | 633 |
| **Extra-EU-27 passenger trafic** | | | | |
| Extra-EU-27 passenger distance | 4,773 | 4,849 | 4,899 | 5,000 |
| Extra-EU-27 passenger EU distance | 500 | 500 | 500 | 500 |
| Air passenger in EU airspace 1000Mpax-km | 68 | 111 | 109 | 62 |
| Air passenger outside EU airspace 1000Mpax-km | 651 | 1,078 | 1,067 | 617 |
| **EU-27 intra-NUTS2 freight trafic** | | | | |
| Road freight 1000M/ton-km | 395 | 560 | 563 | 340 |
| **EU-27 inter-NUTS2 trafic** | | | | |
| Road freight 1000M/ton-km | 1,316 | 2,338 | 2,646 | 2,189 |
| Rail freight 1000M/ton-km | 447 | 812 | 895 | 780 |
| **Maritime freight traffic** | | | | |
| Sea freight EU-27 and NCT 1000M/ton-km[8] | 1,525 | 2,583 | 2,621 | 1,485 |
| Sea freight outside EU-27 and NCT 1000M/ton-km | 52,022 | 89,104 | 98,851 | 94,520 |
| **Annual EU-27 intra-NUTS3 passenger trafic variation** | | | | |
| Road passenger | - | 3.6% | 2.4% | 1.0% |
| Rail passenger | - | 3.1% | 3.9% | 2.3% |
| **Annual EU-27 inter-NUTS3 trafic variation** | | | | |
| Road passenger | - | 3.0% | 1.9% | 0.6% |
| Rail passenger | - | 5.0% | 4.3% | 3.3% |
| Air passenger | - | 4.1% | 3.1% | 1.5% |
| **Annual Extra-EU-27 passenger trafic variation** | | | | |
| Extra-EU-27 air passenger | - | 3.4% | 2.0% | -0.1% |
| **Annual EU-27 intra-NUTS2 freight trafic variation** | | | | |
| Road freight | - | 2.4% | 1.4% | -0.3% |
| **Annual EU-27 inter-NUTS2 trafic variation** | | | | |
| Road freight | - | 3.9% | 2.8% | 1.1% |
| Rail freight | - | 4.1% | 2.8% | 1.2% |
| **Annual Maritime freight traffic variation** | | | | |
| Sea freight EU-27 and NCT | - | 3.6% | 2.2% | -0.1% |
| Sea freight outside EU-27 and NCT | - | 3.7% | 2.6% | 1.3% |
| **EU-27 trafic** | | | | |
| Passenger 1000Mpax-km | 5,619 | 9,420 | 10,359 | 9,281 |
| Freight 1000M/ton-km | 3,683 | 6,294 | 6,725 | 4,794 |
| **Annual EU-27 trafic variation** | | | | |
| Passenger | - | 3.5% | 2.5% | 1.1% |
| Freight | - | 3.6% | 2.4% | 0.6% |

[8] * Includes SSS

| | | | | |
|---|---|---|---|---|
| **Passenger Rail share for long distance inland traffic** | 9.7% | 12.6% | 15.9% | 26.3% |
| **Freight Rail share for long distance inland traffic** | 25.3% | 25.8% | 25.3% | 26.3% |
| **Energy consumed by road oil-based transport inMToe** | 362 | 460 | 404 | 246 |
| **Average taxes on oil in €/litre** | 0.61 | 1.07 | 1.38 | 2.00 |
| **Taxes on oil by transport in M€** | 184,216 | 411,455 | 465,648 | 409,789 |
| **% Renewable in primary electricity generation** | 15 | 29 | 29 | 40 |
| **% Nuclear in primary electricity generation** | 35 | 38 | 38 | 40 |
| **Car $CO_2$ emission ratio in $gCO_2$/km** | 196 | 171 | 156 | 129 |
| **Truck $CO_2$ emission ratio in $gCO_2$/km** | 966 | 843 | 770 | 638 |
| **% non-fossil fuel vehicles** | 0% | 13% | 22% | 31% |
| **Energy consumption reduction per km in rails** | - | 13% | 22% | 40% |
| **Energy consumption reduction per km in ships** | - | 16% | 27% | 49% |
| **Energy consumption reduction per km in airplanes** | - | 18% | 29% | 53% |
| **Car occupancy in urban trips pax/veh** | 1.40 | 1.47 | 1.51 | 1.60 |
| **Car occupancy in interurban trips pax/veh** | 2.0 | 1.85 | 1.90 | 2.00 |
| **Truck occupancy in ton/veh** | 7.0 | 7.26 | 7.43 | 7.78 |
| **Direct $CO_2$ emission variation 2005-2020** | - | 23% | 6% | -36% |
| **Indirect $CO_2$ emission variation 2005-2020** | - | 72% | 114% | 94% |
| **Total $CO_2$ emission variation 2005-2020** | - | 24% | 9% | -33% |
| **Direct cumulative $CO_2$ emissions 2005-2020** | - | 18,124 | 29,839 | 46,677 |
| **Indirect cumulative $CO_2$ emissions 2005-2020** | - | 532 | 1,038 | 2,132 |
| **Total cumulative $CO_2$ emissions 2005-2020** | - | 18,656 | 30,876 | 48,809 |

**Table 27: Results 2005-2050 Constrained**

# 8. Appendix II: Results for exploratory scenarios 2005-2050

This appendix provides a synthetic review of the main results of TRANS-TOOLS and meta-models for the different exploratory scenarios considered, and the full period 2005-2050.

## 8.1. *Results for the 2005-2020 period*

### 2005-2020 Main results

| | 2005 | Baseline | Decoupled mobility | Reduced mobility | Induced mobility | Constrained mobility |
|---|---|---|---|---|---|---|
| **Total population** | 491,999,371 | 494,733,795 | 512,630,655 | 482,577,527 | 513,731,529 | 514,190,744 |
| **Annual population growth** | - | 0.04% | 0.27% | -0.13% | 0.29% | 0.29% |
| **Total GDP B€ *** | 9,853,475 | 14,228,276 | 15,308,650 | 12,506,248 | 16,242,184 | 16,810,516 |
| **Annual GDP growth *[9]** | - | 2.5% | 3.0% | 1.6% | 3.4% | 3.6% |
| **EU-27 intra-NUTS3 passenger traffic** | | | | | | |
| Road passenger 1000Mpax-km | 3,433 | 4,398 | 4,655 | 3,876 | 5,537 | 5,849 |
| Rail passenger 1000Mpax-km | 215 | 241 | 277 | 235 | 283 | 341 |
| **EU-27 inter-NUTS3 traffic** | | | | | | |
| Road passenger 1000Mpax-km | 1,491 | 1,755 | 1,800 | 1,755 | 2,180 | 2,315 |
| Rail passenger 1000Mpax-km | 161 | 250 | 378 | 225 | 316 | 334 |
| Air passenger 1000Mpax-km | 320 | 368 | 381 | 319 | 539 | 581 |
| **Extra-EU-27 passenger traffic** | | | | | | |
| Air passenger in EU airspace 1000Mpax-km | 68 | 95 | 97 | 77 | 103 | 111 |
| Air passenger outside EU airspace 1000Mpax-km | 651 | 950 | 1,008 | 744 | 1,098 | 1,078 |
| **EU-27 intra-NUTS2 freight traffic** | | | | | | |
| Road freight 1000M/ton-km | 395 | 407 | 422 | 343 | 544 | 560 |
| **EU-27 inter-NUTS2 traffic** | | | | | | |
| Road freight 1000M/ton-km | 1,316 | 1,656 | 1,714 | 1,387 | 2,249 | 2,338 |
| Rail freight 1000M/ton-km | 447 | 644 | 692 | 564 | 779 | 812 |
| **Maritime freight traffic** | | | | | | |
| Sea freight EU-27 and NCT 1000M/ton-km[10] | 1,525 | 2,223 | 2,352 | 1,950 | 2,544 | 2,583 |
| Sea freight outside EU-27 and NCT 1000M/ton-km | 52,022 | 75,309 | 81,158 | 66,328 | 86,103 | 89,104 |
| **Annual EU-27 intra-NUTS3 passenger traffic variation** | | | | | | |
| Road passenger | - | 1.7% | 2.1% | 0.8% | 3.2% | 3.6% |
| Rail passenger | - | 0.8% | 1.7% | 0.6% | 1.9% | 3.1% |
| **Annual EU-27 inter-NUTS3 traffic variation** | | | | | | |
| Road passenger | - | 1.1% | 1.3% | 1.1% | 2.6% | 3.0% |
| Rail passenger | - | 3.0% | 5.9% | 2.3% | 4.6% | 5.0% |
| Air passenger | - | 0.9% | 1.2% | 0.0% | 3.5% | 4.1% |
| **Annual Extra-EU-27 passenger traffic variation** | | | | | | |
| Extra-EU-27 air passenger | - | 2.5% | 2.9% | 0.9% | 3.5% | 3.4% |
| **Annual EU-27 intra-NUTS2 freight traffic variation** | | | | | | |
| Road freight | - | 0.2% | 0.4% | -0.9% | 2.2% | 2.4% |
| **Annual EU-27 inter-NUTS2 traffic variation** | | | | | | |
| Road freight | - | 1.5% | 1.8% | 0.3% | 3.6% | 3.9% |
| Rail freight | - | 2.5% | 3.0% | 1.6% | 3.8% | 4.1% |
| **Annual Maritime freight traffic variation** | | | | | | |
| Sea freight EU-27 and NCT | - | 2.5% | 2.9% | 1.7% | 3.5% | 3.6% |

[9] * GDP of the whole area covered by TRANS-TOOLS
[10] * Includes SSS

## 2005-2020 Main results

| | 2005 | Baseline | Decoupled mobility | Reduced mobility | Induced mobility | Constrained mobility |
|---|---|---|---|---|---|---|
| Sea freight outside EU-27 and NCT | - | 2.5% | 3.0% | 1.6% | 3.4% | 3.7% |
| **EU-27 traffic** | | | | | | |
| Passenger 1000Mpax-km | 5,619 | 7,012 | 7,491 | 6,410 | 8,855 | 9,420 |
| Freight 1000M/ton-km | 3,683 | 4,930 | 5,181 | 4,244 | 6,115 | 6,294 |
| **Annual EU-27 traffic variation** | | | | | | |
| Passenger | - | 1.5% | 1.9% | 0.9% | 3.1% | 3.5% |
| Freight | - | 2.0% | 2.3% | 0.9% | 3.4% | 3.6% |
| **Passenger Rail share for long distance inland traffic** | 9.7% | 12.4% | 17.4% | 11.4% | 12.7% | 12.6% |
| **Freight Rail share for long distance inland traffic** | 25.3% | 28.0% | 28.8% | 28.9% | 25.7% | 25.8% |
| **Energy consumed by road oil-based transport inMToe** | 362 | 384 | 313 | 298 | 333 | 460 |
| **Average taxes on oil in €/litre** | 0.61 | 0.87 | 0.94 | 1.01 | 0.81 | 0.81 |
| **Taxes on oil by transport in M€** | 184,216 | 279,822 | 245,206 | 249,650 | 223,609 | 310,508 |
| **% Renewable in primary electricity generation** | 15 | 21 | 29 | 18 | 26 | 29 |
| **% Nuclear in primary electricity generation** | 35 | 38 | 35 | 35 | 43 | 38 |
| **Car $CO_2$ emission ratio in $gCO_2$/km** | 196 | 171 | 157 | 165 | 143 | 171 |
| **Truck $CO_2$ emission ratio in $gCO_2$/km** | 966 | 937 | 776 | 815 | 704 | 843 |
| **% non-fossil fuel vehicles** | 0% | 4.4% | 16.9% | 12.3% | 20.4% | 12.7% |
| **Energy consumption reduction per km in rails** | - | 13% | 15% | 11% | 17% | 11% |
| **Energy consumption reduction per km in ships** | - | 16% | 19% | 13% | 21% | 14% |
| **Energy consumption reduction per km in airplanes** | - | 21% | 24% | 17% | 26% | 18% |
| **Car occupancy in urban trips pax/veh** | 1.40 | 1.43 | 1.47 | 1.63 | 1.30 | 1.47 |
| **Car occupancy in interurban trips pax/veh** | 2.0 | 2.03 | 2.17 | 2.17 | 1.83 | 1.85 |
| **Truck load in ton/veh** | 7.0 | 7.26 | 7.58 | 8.00 | 7.41 | 7.26 |
| **Direct $CO_2$ emission variation 2005-2020** | - | 6% | -13% | -20% | -3% | 23% |
| **Indirect $CO_2$ emission variation 2005-2020** | - | 37% | 64% | 51% | 70% | 72% |
| **Total $CO_2$ emission variation 2005-2020** | - | 7% | -11% | -18% | -1% | 24% |
| **Direct cumulative $CO_2$ emissions 2005-2020** | - | 17,126 | 15,744 | 15,339 | 16,580 | 18,124 |
| **Indirect cumulative $CO_2$ emissions 2005-2020** | - | 493 | 529 | 511 | 535 | 532 |
| **Total cumulative $CO_2$ emissions 2005-2020** | - | 17,618 | 16,273 | 15,851 | 17,115 | 18,656 |

**Table 28: 2005-2020 Meta-model main results**

## 8.2. *Results for the 2005-2030 period*

## 2005-2030 Main results

| | 2005 | Baseline | Decoupled mobility | Reduced mobility | Induced mobility | Constrained mobility |
|---|---|---|---|---|---|---|
| **Total population** | 491,999,371 | 491,110,000 | 527,286,472 | 461,401,130 | 524,036,455 | 517,483,715 |
| **Annual population growth** | - | -0.01% | 0.28% | -0.26% | 0.25% | 0.20% |
| **Total GDP B€**[11] | 9,853,475 | 17,338,098 | 19,093,763 | 13,574,743 | 19,971,630 | 18,639,495 |
| **Annual GDP growth** | - | 2.3% | 2.7% | 1.3% | 2.9% | 2.6% |
| **EU-27 intra-NUTS3 passenger traffic** | | | | | | |
| Road passenger 1000Mpax-km | 3,433 | 4,743 | 5,103 | 3,759 | 6,579 | 6,244 |
| Rail passenger 1000Mpax-km | 215 | 272 | 316 | 301 | 270 | 555 |
| **EU-27 inter-NUTS3 traffic** | | | | | | |
| Road passenger 1000Mpax-km | 1,491 | 1,825 | 1,846 | 1,825 | 2,509 | 2,415 |
| Rail passenger 1000Mpax-km | 161 | 387 | 589 | 325 | 413 | 456 |
| Air passenger 1000Mpax-km | 320 | 298 | 348 | 247 | 657 | 689 |
| **Extra-EU-27 passenger traffic** | | | | | | |
| Air passenger in EU airspace 1000Mpax-km | 68 | 113 | 114 | 77 | 119 | 109 |
| Air passenger outside EU airspace 1000Mpax-km | 651 | 1,167 | 1,242 | 750 | 1,368 | 1,067 |
| **EU-27 intra-NUTS2 freight traffic** | | | | | | |
| Road freight 1000M/ton-km | 395 | 458 | 482 | 339 | 635 | 563 |
| **EU-27 inter-NUTS2 traffic** | | | | | | |
| Road freight 1000M/ton-km | 1,316 | 1,984 | 2,114 | 1,467 | 2,923 | 2,646 |
| Rail freight 1000M/ton-km | 447 | 796 | 894 | 595 | 986 | 895 |
| **Maritime freight traffic** | | | | | | |
| Sea freight EU-27 and NCT 1000M/ton-km[12] | 1,525 | 2,645 | 2,862 | 2,062 | 3,082 | 2,621 |
| Sea freight outside EU-27 and NCT 1000M/ton-km | 52,022 | 91,820 | 101,488 | 72,179 | 106,093 | 98,851 |
| **Annual EU-27 intra-NUTS3 passenger traffic variation** | | | | | | |
| Road passenger | - | 1.3% | 1.6% | 0.4% | 2.6% | 2.4% |
| Rail passenger | - | 1.0% | 1.6% | 1.4% | 0.9% | 3.9% |
| **Annual EU-27 inter-NUTS3 traffic variation** | | | | | | |
| Road passenger | - | 0.8% | 0.9% | 0.8% | 2.1% | 1.9% |
| Rail passenger | - | 3.6% | 5.3% | 2.9% | 3.9% | 4.3% |
| Air passenger | - | -0.3% | 0.3% | -1.0% | 2.9% | 3.1% |
| **Annual Extra-EU-27 passenger traffic variation** | | | | | | |
| Extra-EU-27 air passenger | - | 2.3% | 2.6% | 0.6% | 2.9% | 2.0% |
| **Annual EU-27 intra-NUTS2 freight traffic variation** | | | | | | |
| Road freight | - | 0.6% | 0.8% | -0.6% | 1.9% | 1.4% |
| **Annual EU-27 inter-NUTS2 traffic variation** | | | | | | |
| Road freight | - | 1.7% | 1.9% | 0.4% | 3.2% | 2.8% |
| Rail freight | - | 2.3% | 2.8% | 1.2% | 3.2% | 2.8% |
| **Annual Maritime freight traffic variation** | | | | | | |
| Sea freight EU-27 and NCT | - | 2.2% | 2.6% | 1.2% | 2.9% | 2.2% |

[11] GDP of the whole area covered by TRANS-TOOLS
[12] * Includes SSS

## 2005-2030 Main results

| | 2005 | Baseline | Decoupled mobility | Reduced mobility | Induced mobility | Constrained mobility |
|---|---|---|---|---|---|---|
| Sea freight outside EU-27 and NCT | - | 2.3% | 2.7% | 1.3% | 2.9% | 2.6% |
| **EU-27 traffic** | | | | | | |
| Passenger 1000Mpax-km | 5,619 | 7,526 | 8,202 | 6,457 | 10,428 | 10,359 |
| Freight 1000M/ton-km | 3,683 | 5,883 | 6,352 | 4,463 | 7,626 | 6,725 |
| **Annual EU-27 traffic variation** | | | | | | |
| Passenger | - | 1.2% | 1.5% | 0.6% | 2.5% | 2.5% |
| Freight | - | 1.9% | 2.2% | 0.8% | 3.0% | 2.4% |
| **Passenger Rail share for long distance inland traffic** | 9.7% | 17.5% | 24.2% | 15.1% | 14.1% | 15.9% |
| **Freight Rail share for long distance inland traffic** | 25.3% | 28.6% | 29.7% | 28.9% | 25.2% | 25.3% |
| **Energy consumed by road oil-based transport inMToe** | 362 | 378 | 247 | 246 | 244 | 404 |
| **Average taxes on oil in €/litre** | 0.61 | 1.05 | 1.16 | 1.27 | 0.94 | 1.38 |
| **Taxes on oil by transport in M€** | 184,216 | 330,105 | 239,004 | 260,322 | 191,035 | 465,648 |
| **% Renewable in primary electricity generation** | 15 | 21 | 29 | 18 | 26 | 29 |
| **% Nuclear in primary electricity generation** | 35 | 38 | 35 | 35 | 43 | 38 |
| **Car $CO_2$ emission ratio in $gCO_2$/km** | 196 | 152 | 135 | 148 | 111 | 156 |
| **Truck $CO_2$ emission ratio in $gCO_2$/km** | 966 | 918 | 668 | 728 | 545 | 770 |
| **% non-fossil fuel vehicles** | 0% | 6.9% | 31.4% | 19.2% | 37.3% | 21.8% |
| **Energy consumption reduction per km in rails** | - | 22% | 26% | 18% | 28% | 19% |
| **Energy consumption reduction per km in ships** | - | 27% | 32% | 22% | 35% | 23% |
| **Energy consumption reduction per km in airplanes** | - | 34% | 40% | 28% | 43% | 29% |
| **Car occupancy in urban trips pax/veh** | 1.40 | 1.46 | 1.51 | 1.79 | 1.23 | 1.51 |
| **Car occupancy in interurban trips pax/veh** | 2.0 | 2.06 | 2.28 | 2.28 | 1.72 | 1.90 |
| **Truck load in ton/veh** | 7.0 | 7.43 | 7.97 | 8.67 | 7.69 | 7.43 |
| **Direct $CO_2$ emission variation 2005-2020** | - | -4% | -31% | -40% | -25% | 6% |
| **Indirect $CO_2$ emission variation 2005-2020** | - | 52% | 112% | 73% | 119% | 114% |
| **Total $CO_2$ emission variation 2005-2020** | - | -3% | -28% | -37% | -22% | 9% |
| **Direct cumulative $CO_2$ emissions 2005-2020** | - | 27,320 | 23,495 | 22,292 | 25,173 | 29,839 |
| **Indirect cumulative $CO_2$ emissions 2005-2020** | - | 863 | 1,013 | 930 | 1,033 | 1,038 |
| **Total cumulative $CO_2$ emissions 2005-2020** | - | 28,183 | 24,507 | 23,222 | 26,206 | 30,876 |

**Table 29: 2005-2030 Meta-model main results**

## 8.3. *Results for the 2005-2050 period*

## 2005-2050 Main results

| | 2005 | Baseline | Decoupled mobility | Reduced mobility | Induced mobility | Constrained mobility |
|---|---|---|---|---|---|---|
| **Total population** | 491,999,371 | 486,218,917 | 545,598,557 | 431,090,794 | 545,740,798 | 488,212,797 |
| **Annual population growth** | - | -0.03% | 0.23% | -0.29% | 0.23% | -0.02% |
| **Total GDP B€**[13] | 9,853,475 | 24,359,922 | 29,051,343 | 17,091,935 | 31,717,532 | 17,868,710 |
| **Annual GDP growth** | - | 2.0% | 2.4% | 1.2% | 2.6% | 1.3% |
| **EU-27 intra-NUTS3 passenger traffic** | | | | | | |
| Road passenger 1000Mpax-km | 3,433 | 5,048 | 5,185 | 3,863 | 9,888 | 5,411 |
| Rail passenger 1000Mpax-km | 215 | 318 | 1,164 | 423 | 303 | 596 |
| **EU-27 inter-NUTS3 traffic** | | | | | | |
| Road passenger 1000Mpax-km | 1,491 | 1,921 | 2,200 | 1,921 | 3,460 | 1,945 |
| Rail passenger 1000Mpax-km | 161 | 526 | 864 | 449 | 858 | 696 |
| Air passenger 1000Mpax-km | 320 | 315 | 345 | 295 | 1,262 | 633 |
| **Extra-EU-27 passenger traffic** | | | | | | |
| Air passenger in EU airspace 1000Mpax-km | 68 | 151 | 148 | 63 | 170 | 62 |
| Air passenger outside EU airspace 1000Mpax-km | 651 | 1,664 | 1,777 | 634 | 2,207 | 617 |
| **EU-27 intra-NUTS2 freight traffic** | | | | | | |
| Road freight 1000M/ton-km | 395 | 465 | 494 | 264 | 872 | 340 |
| **EU-27 inter-NUTS2 traffic** | | | | | | |
| Road freight 1000M/ton-km | 1,316 | 2,347 | 2,599 | 1,290 | 5,843 | 2,189 |
| Rail freight 1000M/ton-km | 447 | 1,222 | 1,471 | 698 | 1,868 | 780 |
| **Maritime freight traffic** | | | | | | |
| Sea freight EU-27 and NCT 1000M/ton-km[14] | 1,525 | 2,949 | 3,476 | 1,861 | 4,733 | 1,485 |
| Sea freight outside EU-27 and NCT 1000M/ton-km | 52,022 | 129,104 | 154,835 | 91,121 | 168,837 | 94,520 |
| **Annual EU-27 intra-NUTS3 passenger traffic variation** | | | | | | |
| Road passenger | - | 0.9% | 0.9% | 0.3% | 2.4% | 1.0% |
| Rail passenger | - | 0.9% | 3.8% | 1.5% | 0.8% | 2.3% |
| **Annual EU-27 inter-NUTS3 traffic variation** | | | | | | |
| Road passenger | - | 0.6% | 0.9% | 0.6% | 1.9% | 0.6% |
| Rail passenger | - | 2.7% | 3.8% | 2.3% | 3.8% | 3.3% |
| Air passenger | - | 0.0% | 0.2% | -0.2% | 3.1% | 1.5% |
| **Annual Extra-EU-27 passenger traffic variation** | | | | | | |
| Extra-EU-27 air passenger | - | 2.1% | 2.2% | -0.1% | 2.7% | -0.1% |
| **Annual EU-27 intra-NUTS2 freight traffic variation** | | | | | | |
| Road freight | - | 0.4% | 0.5% | -0.9% | 1.8% | -0.3% |
| **Annual EU-27 inter-NUTS2 traffic variation** | | | | | | |
| Road freight | - | 1.3% | 1.5% | 0.0% | 3.4% | 1.1% |
| Rail freight | - | 2.3% | 2.7% | 1.0% | 3.2% | 1.2% |
| **Annual Maritime freight traffic variation** | | | | | | |
| Sea freight EU-27 and NCT | - | 1.5% | 1.8% | 0.4% | 2.5% | -0.1% |

[13] GDP of the whole area covered by TRANS-TOOLS
[14] * Includes SSS

## 2005-2050 Main results

| | 2005 | Baseline | Decoupled mobility | Reduced mobility | Induced mobility | Constrained mobility |
|---|---|---|---|---|---|---|
| Sea freight outside EU-27 and NCT | - | 2.0% | 2.5% | 1.3% | 2.7% | 1.3% |
| **EU-27 traffic** | | | | | | |
| Passenger 1000Mpax-km | 5,619 | 8,129 | 9,759 | 6,950 | 15,771 | 9,281 |
| Freight 1000M/ton-km | 3,683 | 6,983 | 8,039 | 4,114 | 13,316 | 4,794 |
| **Annual EU-27 traffic variation** | | | | | | |
| Passenger | - | 0.8% | 1.2% | 0.5% | 2.3% | 1.1% |
| Freight | - | 1.4% | 1.7% | 0.2% | 2.9% | 0.6% |
| **Passenger Rail share for long distance inland traffic** | 9.7% | 21.5% | 28.2% | 18.9% | 19.9% | 26.3% |
| **Freight Rail share for long distance inland traffic** | 25.3% | 34.2% | 36.1% | 35.1% | 24.2% | 26.3% |
| **Energy consumed by road oil-based transport inMToe** | 362 | 291 | 130 | 182 | 99 | 246 |
| **Average taxes on oil in €/litre** | 0.61 | 1.40 | 1.60 | 1.80 | 1.20 | 2.00 |
| **Taxes on oil by transport in M€** | 184,216 | 338,933 | 173,406 | 273,525 | 98,612 | 409,789 |
| **% Renewable in primary electricity generation** | 15 | 25 | 40 | 20 | 35 | 40 |
| **% Nuclear in primary electricity generation** | 35 | 40 | 35 | 35 | 50 | 40 |
| **Car $CO_2$ emission ratio in $gCO_2$/km** | 196 | 119 | 98 | 137 | 59 | 129 |
| **Truck $CO_2$ emission ratio in $gCO_2$/km** | 966 | 889 | 483 | 676 | 290 | 638 |
| **% non-fossil fuel vehicles** | 0% | 21.8% | 54.5% | 35.0% | 70.0% | 31.0% |
| **Energy consumption reduction per km in rails** | - | 40% | 46% | 33% | 51% | 34% |
| **Energy consumption reduction per km in ships** | - | 49% | 57% | 40% | 62% | 42% |
| **Energy consumption reduction per km in airplanes** | - | 62% | 71% | 50% | 78% | 53% |
| **Car occupancy in urban trips pax/veh** | 1.40 | 1.50 | 1.60 | 2.10 | 1.10 | 1.60 |
| **Car occupancy in interurban trips pax/veh** | 2.0 | 2.10 | 2.50 | 2.50 | 1.50 | 2.00 |
| **Truck load in ton/veh** | 7.0 | 7.78 | 8.75 | 10.00 | 8.24 | 7,78 |
| **Direct $CO_2$ emission variation 2005-2020** | - | -23% | -61% | -61% | -56% | -36% |
| **Indirect $CO_2$ emission variation 2005-2020** | - | 77% | 206% | 95% | 369% | 94% |
| **Total $CO_2$ emission variation 2005-2020** | - | -21% | -55% | -57% | -46% | -33% |
| **Direct cumulative $CO_2$ emissions 2005-2020** | - | 44,892 | 34,213 | 32,007 | 36,805 | 46,677 |
| **Indirect cumulative $CO_2$ emissions 2005-2020** | - | 1,714 | 2,372 | 1,893 | 2,719 | 2,132 |
| **Total cumulative $CO_2$ emissions 2005-2020** | - | 46,606 | 36,585 | 33,900 | 39,524 | 48,809 |

**Table 30: 2005-2050 Meta-model main results**

# 9. Appendix III: Results of predictive scenarios for freight transport

In this appendix, results obtained by TRANS-TOOLS on freight traffic 2005-2030 for the Baseline scenario are presented.

TRANS-TOOLS freight traffic results have been analysed according to the NSTR category as well as the origin/destination of trips.

There are five different types of trips considered:

- Regional: intra-NUTS2 trips.
- Domestic: rest of trips with origin and destination inside the same country.
- Intra-Zone: trips with origin and destination inside the same macrozone, South (Portugal, Italy, Greece, Spain), North/Centre (rest of the EU-15), East (rest of the EU-27).
- Inter-Zone: trips with origin and destination in different macrozones
- Extra-EU: trips with origin or destination outside the EU-27, in one of the neighbouring countries.

It should be noted that the South zone lacks geographic continuity, apart from the cases of Spain and Portugal: the three southern European peninsulas have no land connections. Intra-zone trips in the South zone should therefore be lower than in the other zones.

## 9.1. *Analysis of freight traffic (all modes included) in 2005*

Freight transport in the shorter distances is dominated by building minerals and material. In the longer distances, it is more mixed with machinery and other manufacturing gaining weight, especially for more industrialised zones. Crude oil, oil derivatives and to a lesser extent solid mineral fuels are important in the long distances.

Passenger transport is largely dominated by regional transport which includes commuter and urban trips. The shorter distances (regional) are divided in equal parts between commuter, private and holiday. Private and business gain weight at national level while long-distance transport is dominated by holiday trips. Domestic transport is the one that grows the least and long-distance the most.

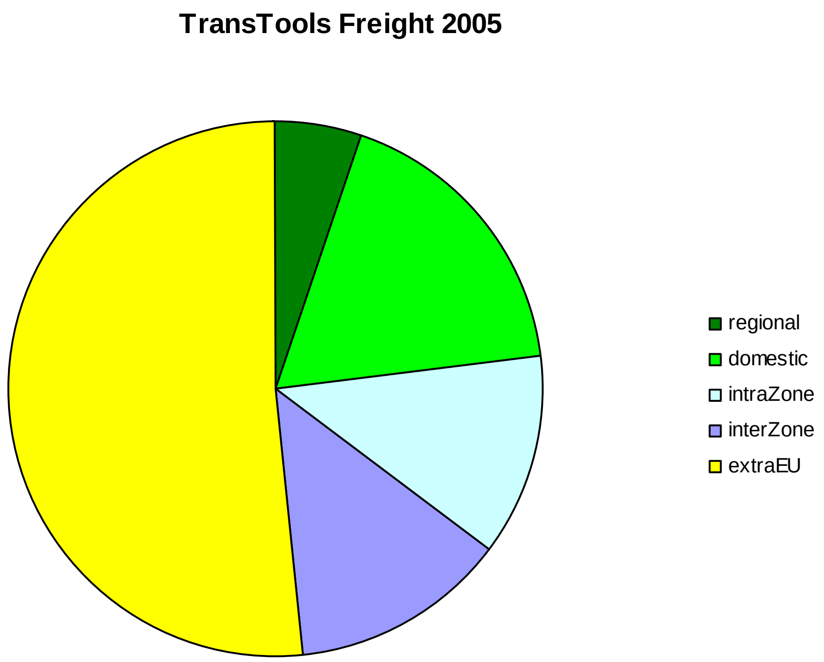



**Figure 112: TRANS-TOOLS 2005 Freight Ton-km geographic distribution according to distance of trip (all modes included)**

Geographic distribution of EU-27 ton-km from TRANS-TOOLS 2005, including road, rail, IWW and SSS as well as maritime traffic with neighbouring countries. Extra-EU traffic has a big share of total trips due to maritime traffic of oil and derivatives.

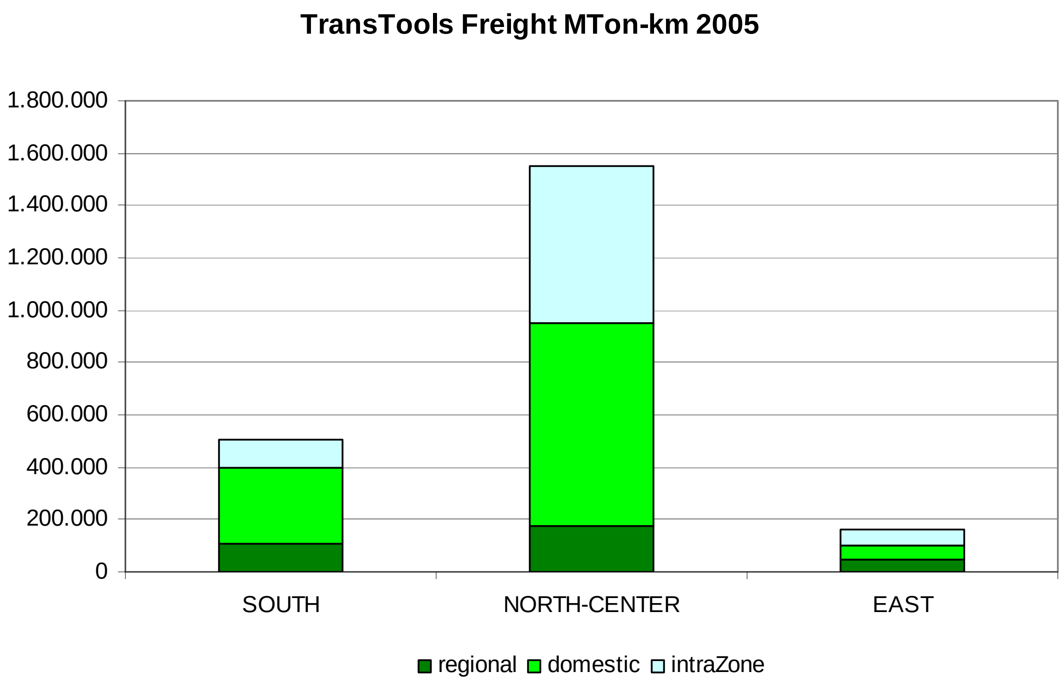



**Figure 113: TRANS-TOOLS 2005 Freight Ton-km volume of short and mid-distance trips according to European macrozone (all modes included)**

Freight volumes in ton-km from TRANS-TOOLS 2005, including road, rail, IWW and SSS as well as maritime traffic with neighbouring countries, according to European macrozone. The total volume of North/Centre MacroZone is much higher than the other two macrozones.

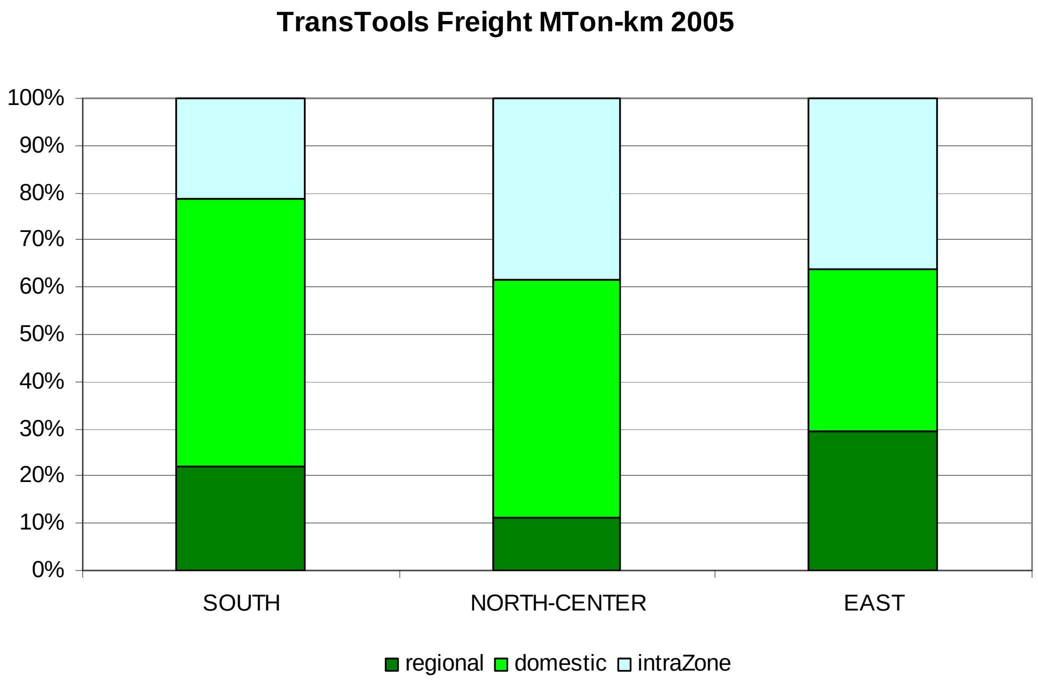



**Figure 114: TRANS-TOOLS 2005 Freight Ton-km distribution of short and mid-distance trips according to European macrozone (all modes included)**

Share of freight volumes according to length of trip in ton-km from TRANS-TOOLS 2005, including road, rail, IWW and SSS as well as maritime traffic with neighbouring countries, divided by European macrozones. The proportion of international European traffic is higher in North/Centre macrozone. It highlights the fact that southern and eastern countries have more national freight traffic, and are still less integrated in the EU market.

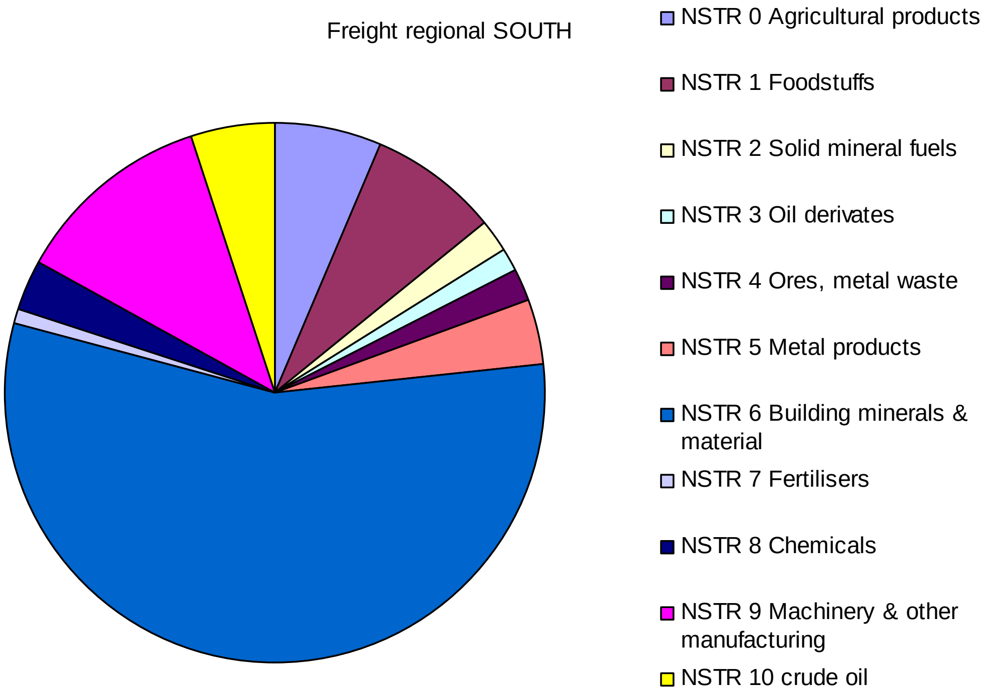



**Figure 115: TRANS-TOOLS 2005 Regional Freight NSTR distribution for South macrozone (all modes included)**

Distribution of regional freight ton-km 2005 according to NSTR 1digit classification for South Europe, including road, rail, IWW and SSS. The main regional commodity in this macrozone is building materials, accounting for more than 55% of total. This is due to the relative high specific weight of this type of commodity.

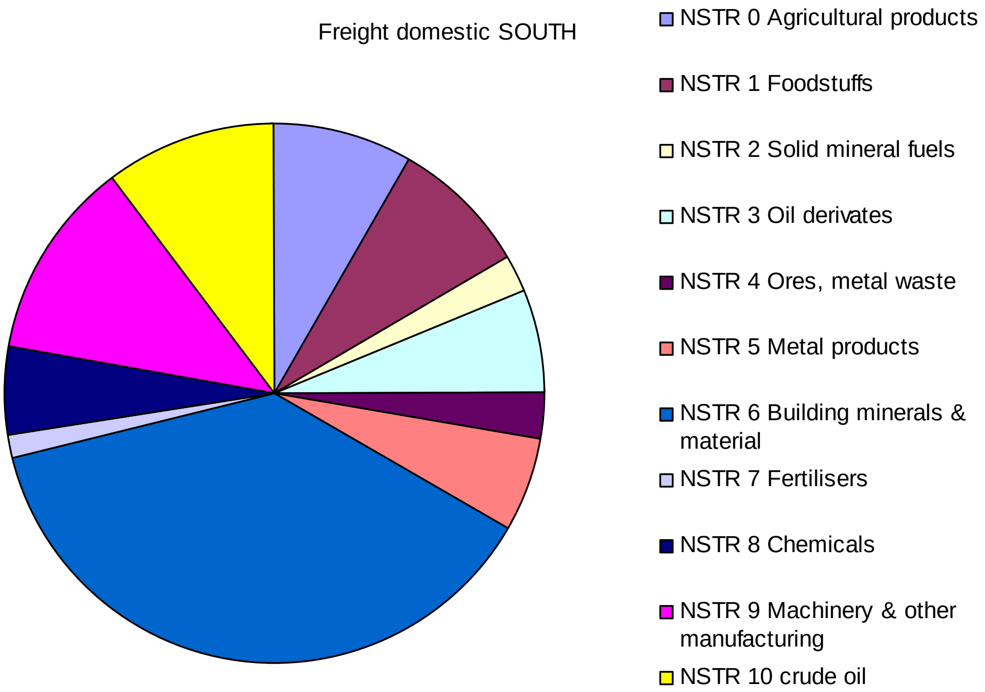



**Figure 116: TRANS-TOOLS 2005 Domestic Freight NSTR distribution for South macrozone (all modes included)**

Distribution of domestic freight ton-km 2005 according to NSTR 1digit classification for South Europe, including road, rail, IWW and SSS. In the case of domestic freight, building materials lose share but are still the main commodity. Crude oil and derivatives as well as manufacturing are segments that grow the most.

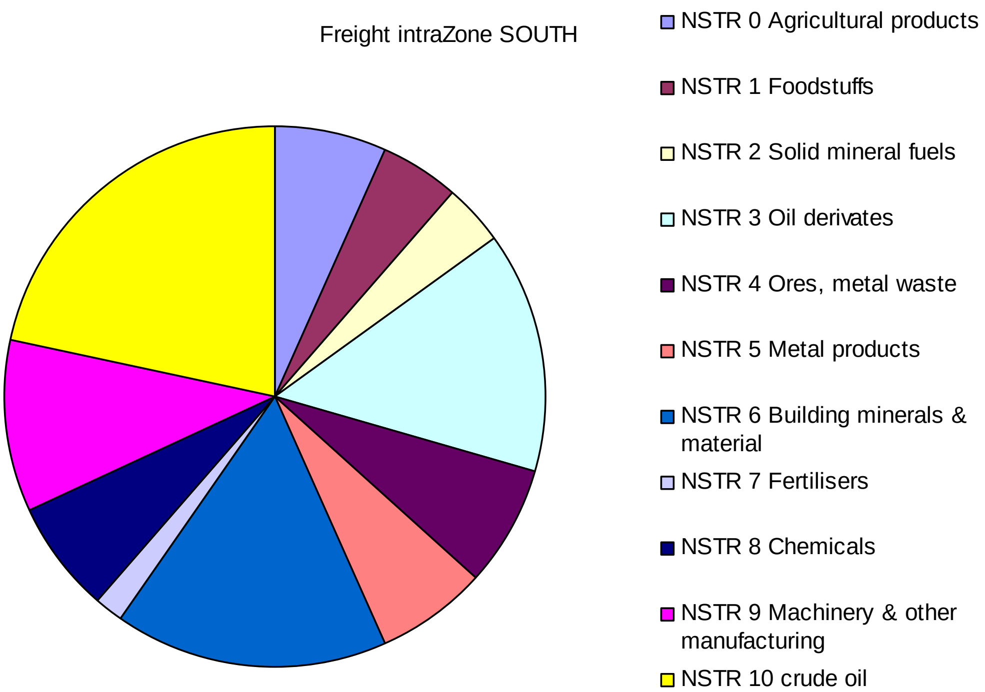



**Figure 117: TRANS-TOOLS 2005 Intra-Zone Freight NSTR distribution for South macrozone (all modes included)**

Distribution of Intra-Zone freight ton-km 2005 according to NSTR 1digit classification for South Europe, including road, rail, IWW and SSS. Oil products become the most important when analyzing traffic of the southern macroregion.

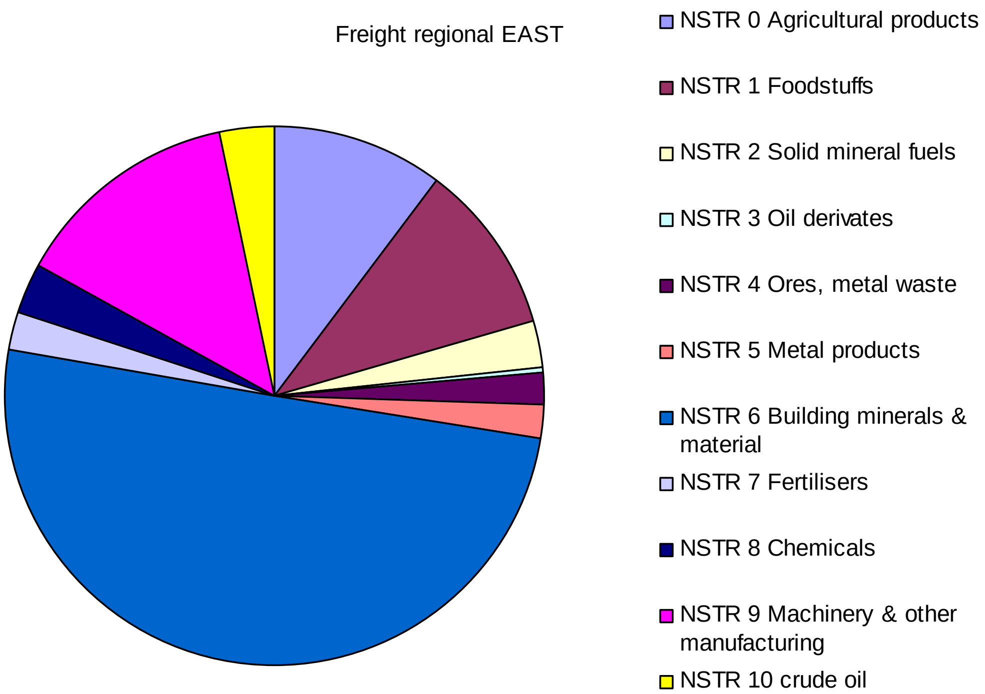



**Figure 118: TRANS-TOOLS 2005 Regional Freight NSTR distribution for East macrozone (all modes included)**

Distribution of regional freight ton-km 2005 according to NSTR 1digit classification for Eastern Europe, including road, rail, IWW and SSS. Building materials account for 50% of total freight, but compared with the East macrozone the share of agricultural products and foodstuffs is understandably higher.

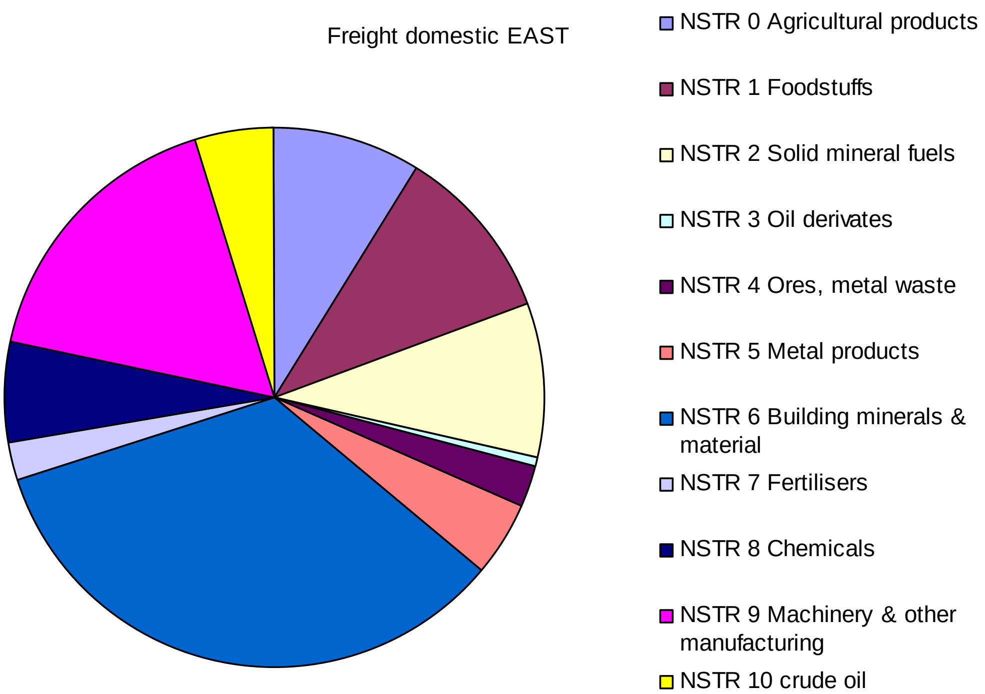



**Figure 119: TRANS-TOOLS 2005 Domestic Freight NSTR distribution for East macrozone (all modes included)**

Distribution of domestic freight ton-km 2005 according to NSTR 1digit classification for East Europe, including road, rail, IWW and SSS. Building materials still account for the highest share, but the most remarkable value is the higher share of solid mineral fuels.

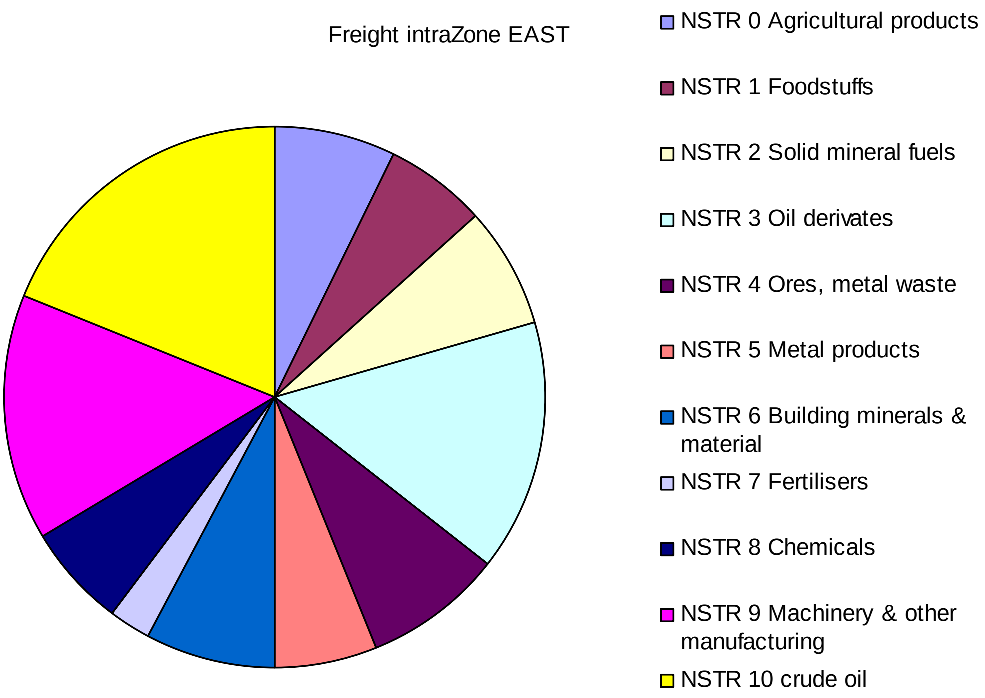



**Figure 120: TRANS-TOOLS 2005 Intra-Zone Freight NSTR distribution for East macrozone (all modes included)**

Distribution of intra-zone freight ton-km 2005 according to NSTR 1digit classification for East Europe, including road, rail, IWW and SSS.

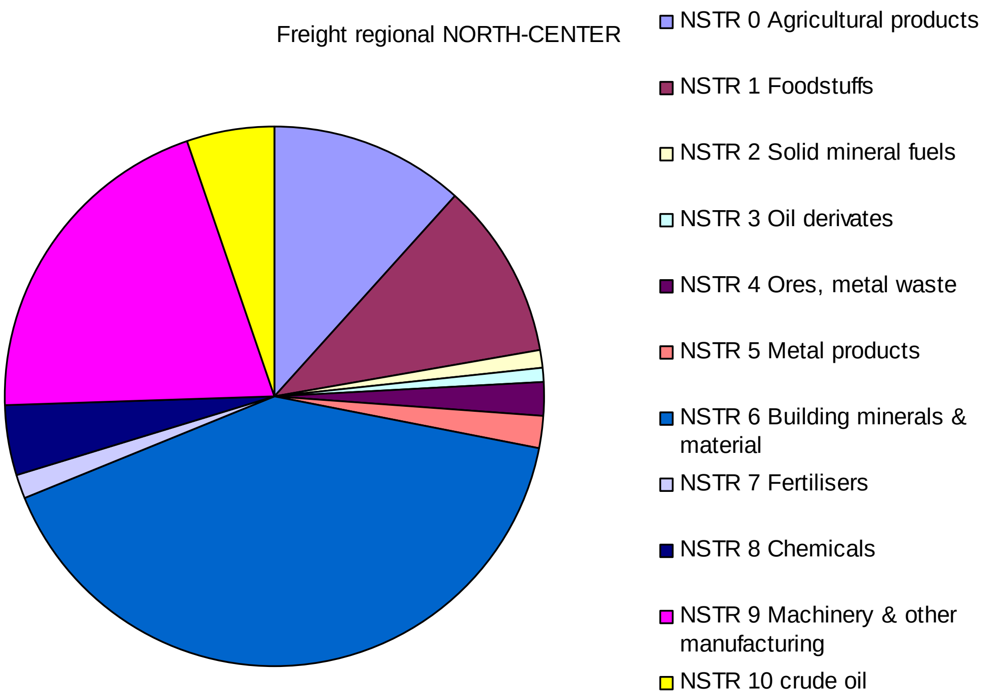



**Figure 121: TRANS-TOOLS 2005 Regional Freight NSTR distribution for North/Centre macrozone (all modes included)**

Distribution of regional freight ton-km 2005 according to NSTR 1digit classification for North/Centre Europe, including road, rail, IWW and SSS. Compared to the other two macrozones the share of manufacturing is considerably higher, while building materials have less weight in the total.

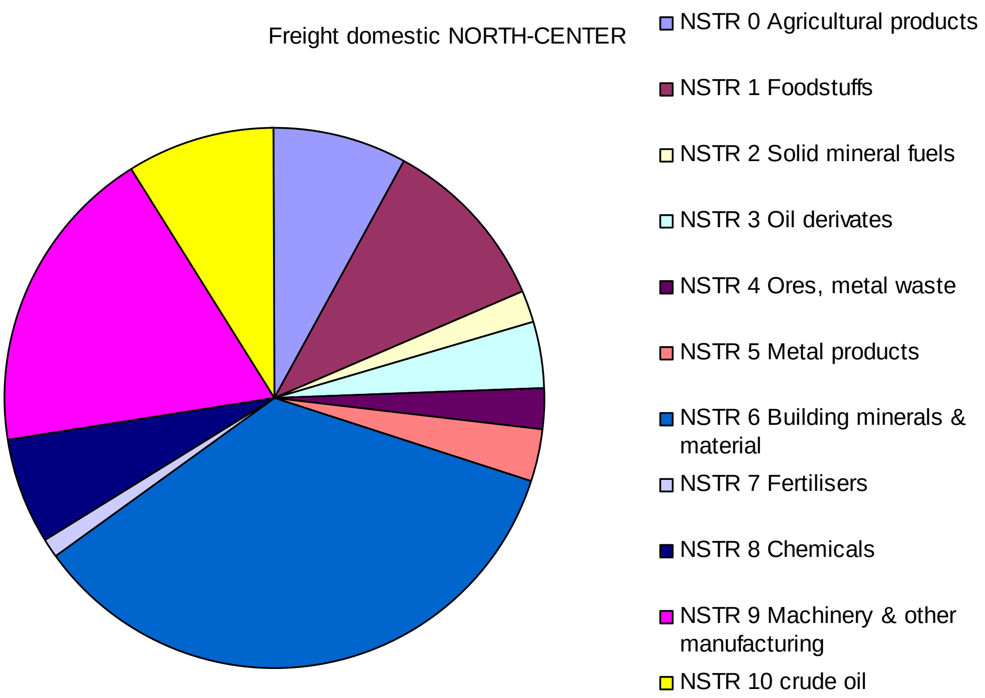



**Figure 122 TRANS-TOOLS 2005 Domestic Freight NSTR distribution for North/Centre macrozone (all modes included)**

Distribution of domestic freight ton-km 2005 according to NSTR 1digit classification for North/Centre Europe, including road, rail, IWW and SSS.

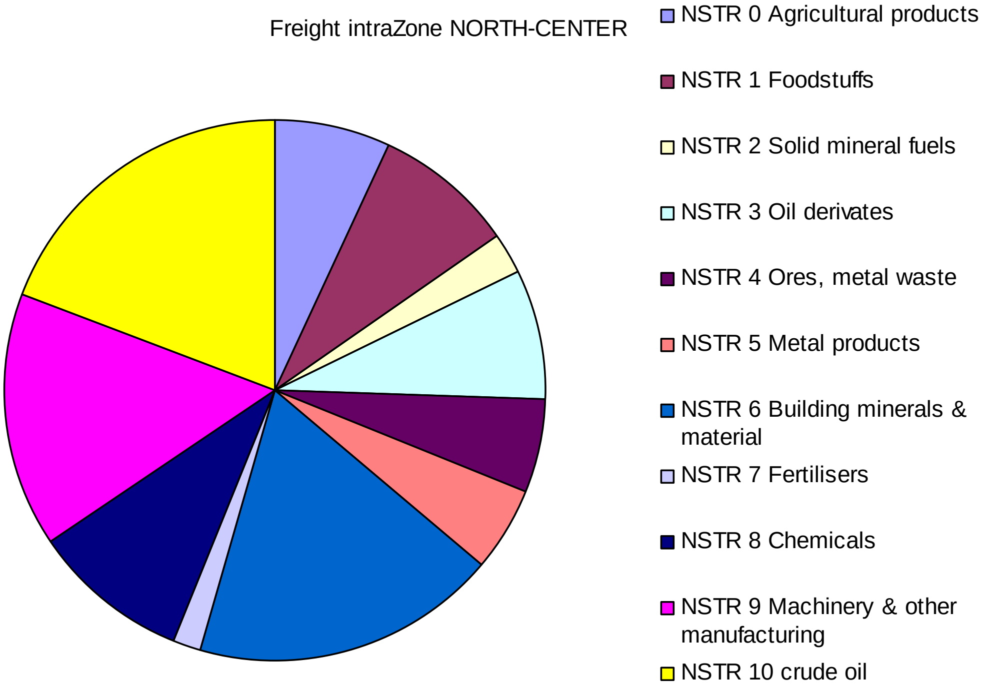



**Figure 123: TRANS-TOOLS 2005 Intra-Zone Freight NSTR distribution for North/Centre macrozone (all modes included)**

Distribution of intra-zone freight ton-km 2005 according to NSTR 1digit classification for North/Centre Europe, including road, rail, IWW and SSS. The share of building materials is more than twice of the share in the East macrozone.

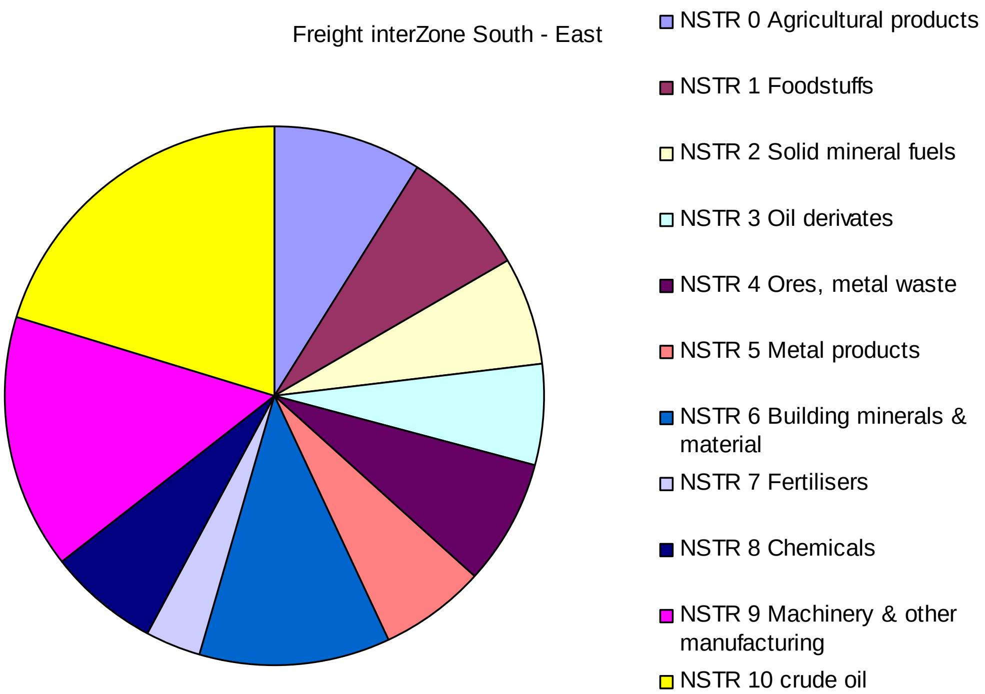



**Figure 124: TRANS-TOOLS 2005 Inter-zone Freight NSTR distribution for South / East relations (all modes included)**

Distribution of inter-zone freight ton-km 2005 according to NSTR 1digit classification for South / East relations, including road, rail, IWW and SSS. Crude oil stands as the commodity with the highest share.

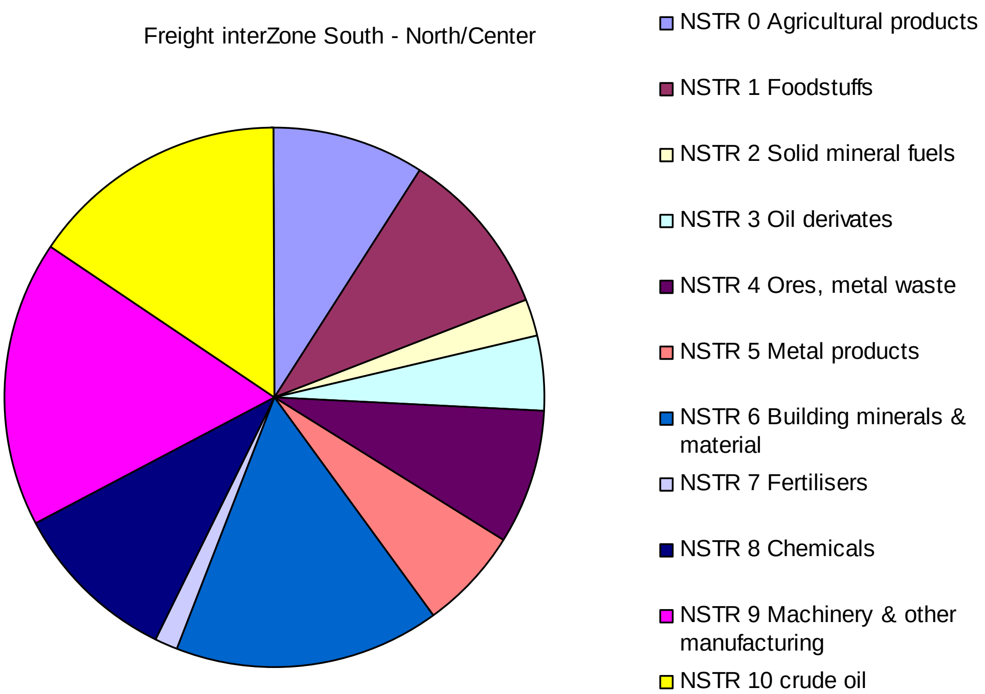



**Figure 125: TRANS-TOOLS 2005 Inter-zone Freight NSTR distribution for South / North/Centre relations (all modes included)**

Distribution of inter-zone freight ton-km 2005 according to NSTR 1digit classification for South / North/Centre relations, including road, rail, IWW and SSS. Crude oil, manufacturing and building materials stand as the commodities with the highest share.

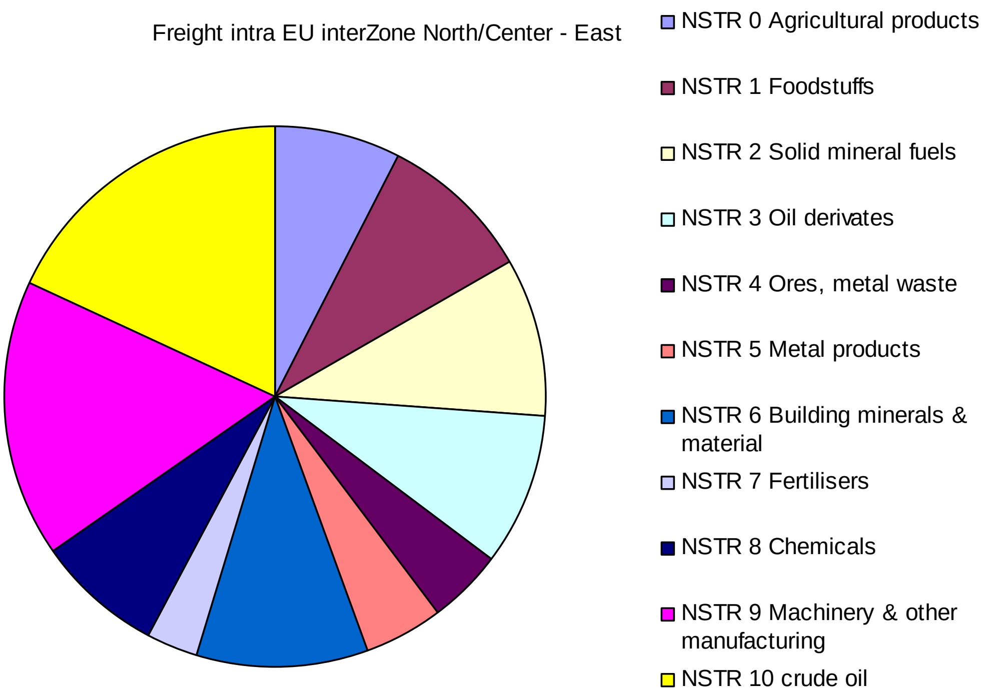



**Figure 126: TRANS-TOOLS 2005 Inter-zone Freight NSTR distribution for East / North/Centre relations (all modes included)**

Distribution of inter-zone freight ton-km 2005 according to NSTR 1digit classification for East / North/Centre relations, including road, rail, IWW and SSS. Crude oil, and manufacturing stand as the commodities with the highest share.

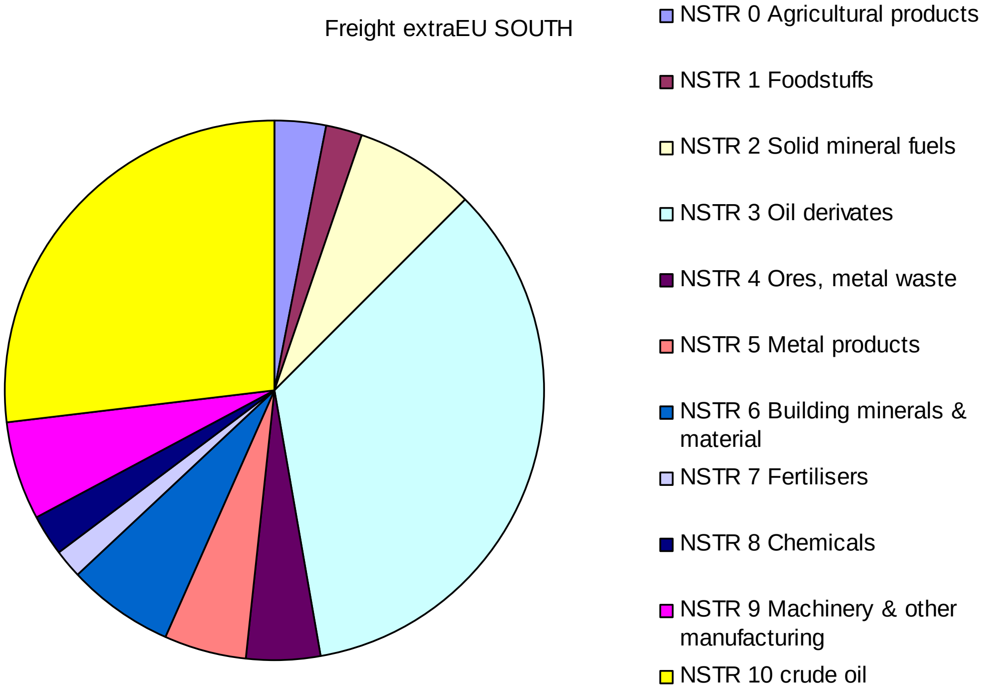



**Figure 127: TRANS-TOOLS 2005 Extra-EU Freight NSTR distribution for South macrozone (all modes included)**

Distribution of extra-EU freight ton-km 2005 for South macrozone according to NSTR 1digit classification for traffic with non-EU-27 countries, including road, rail, IWW and SSS as well as maritime traffic with neighbouring countries. Crude oil and derivatives account for more than 60% of total freight.

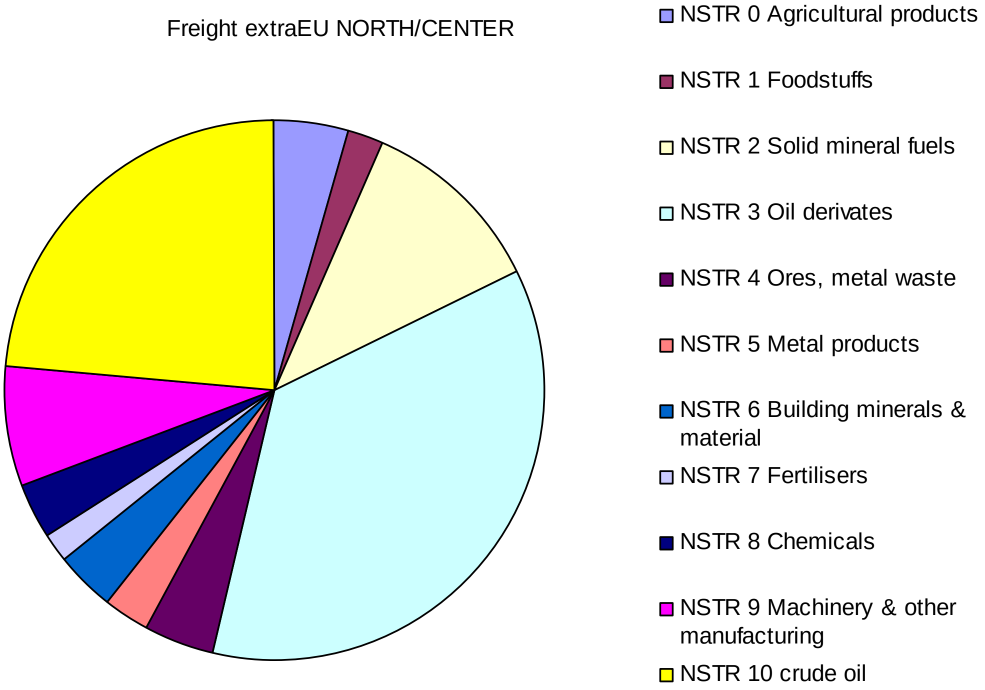



**Figure 128: TRANS-TOOLS 2005 Extra-EU Freight NSTR distribution for North/Centre macrozone (all modes included)**

Distribution of extra-EU freight ton-km 2005 for North/Centre macrozone according to NSTR 1digit classification for traffic with non-EU-27 countries, including road, rail, IWW and SSS as well as maritime traffic with neighbouring countries. Compared to the values of the East macrozone the proportion of solid mineral fuels almost doubles.

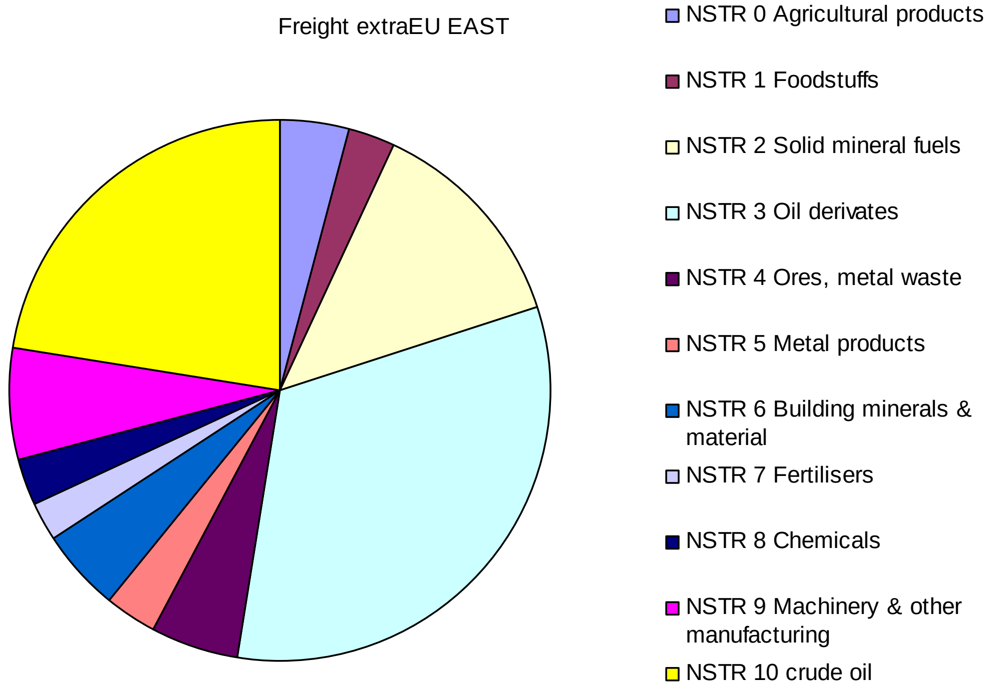



**Figure 129: TRANS-TOOLS 2005 Extra-EU Freight NSTR distribution for East macrozone (all modes included)**

Distribution of extra-EU freight ton-km 2005 for East macrozone according to NSTR 1digit classification for traffic with non-EU-27 countries, including road, rail, IWW and SSS as well as maritime traffic with neighbouring countries.

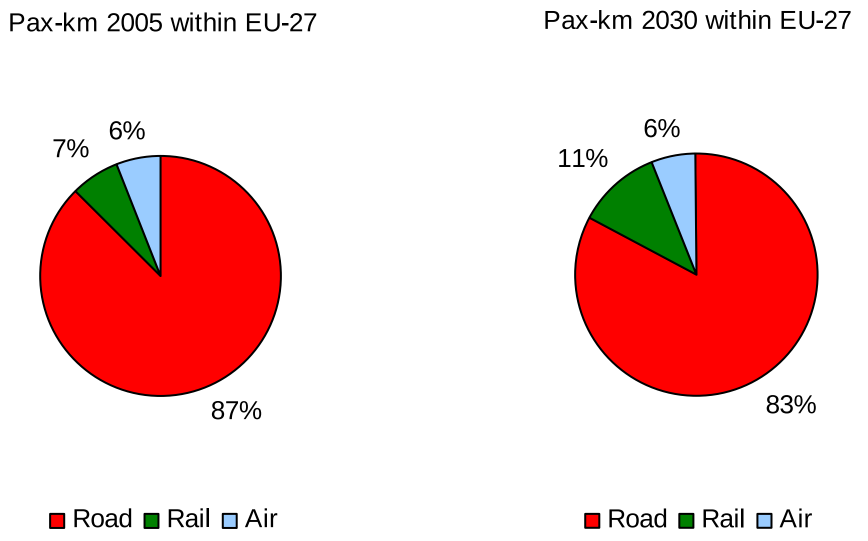



**Figure 130: Modal shift of paseenger traffic TRANS-TOOLS 2005-2030 baseline**

## 9.2. *Analysis of freight traffic (all modes included) for the baseline in 2030*

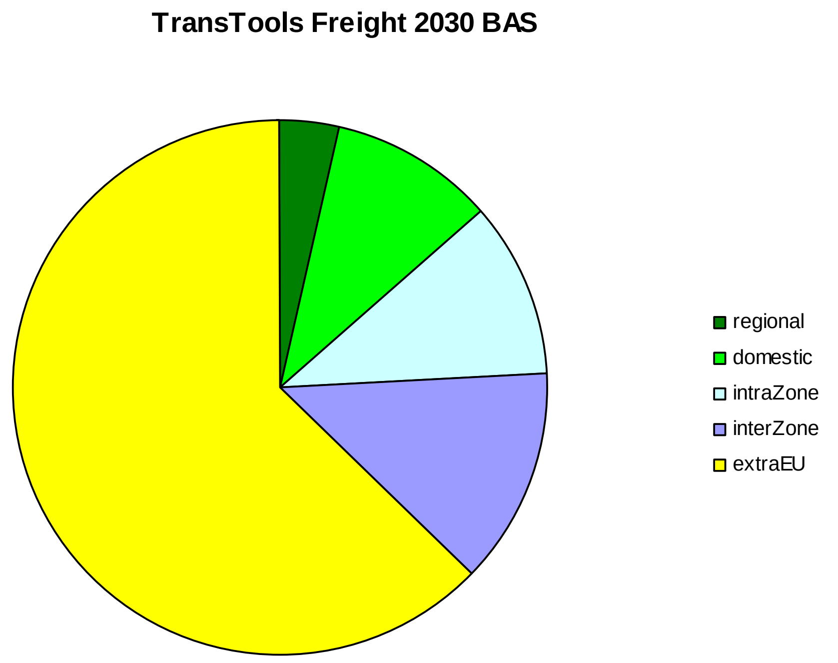



**Figure 131: TRANS-TOOLS 2030 Baseline Freight Ton-km geographic distribution according to distance of trip (all modes included)**

Geographic distribution of EU-27 ton-km from TRANS-TOOLS 2030 baseline, including road, rail, IWW and SSS as well as maritime traffic with neighbouring countries. Extra-EU traffic has a big share of total trips due to maritime traffic of oil and derivatives. This share is more important than in the 2005 figures.

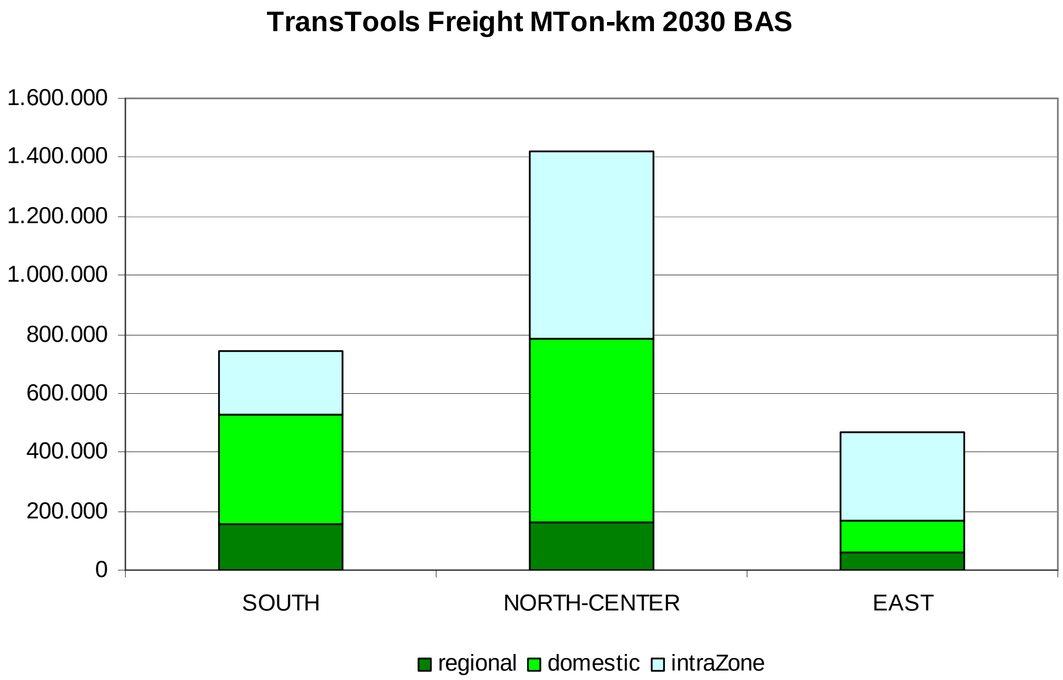



**Figure 132: TRANS-TOOLS 2030 Baseline Freight Ton-km volume of short and mid-distance trips according to European macrozone (all modes included)**

Freight volumes in ton-km from TRANS-TOOLS 2030 baseline, including road, rail, IWW and SSS as well as maritime traffic with neighbouring countries, in the European macrozone. Total volume of South macrozone increases in relation to the other macrozones

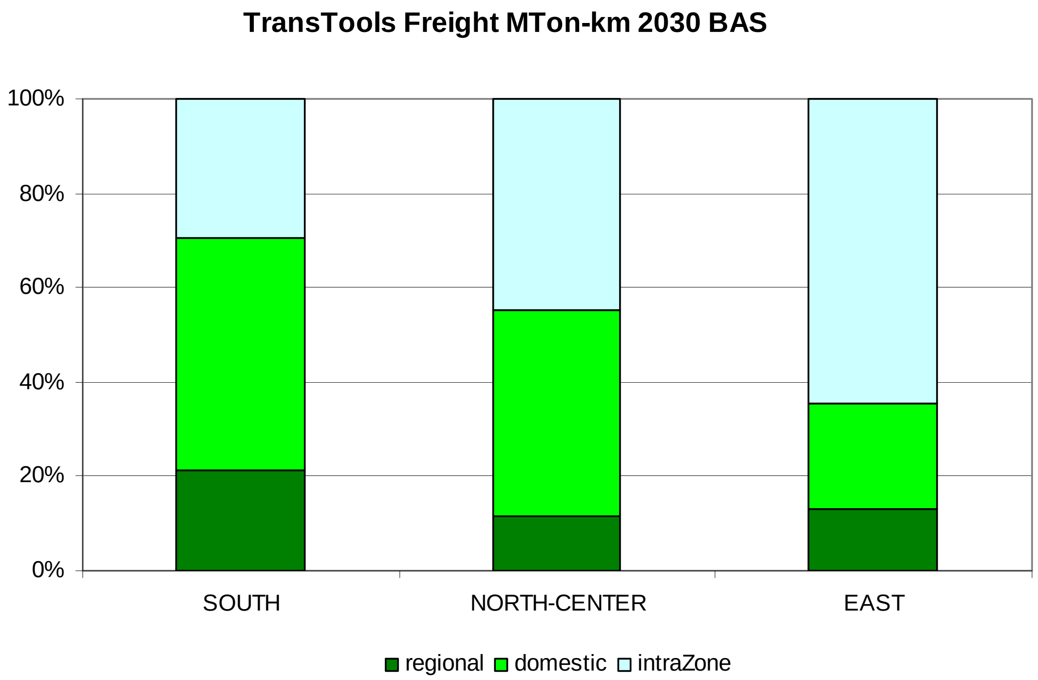



**Figure 133: TRANS-TOOLS 2030 Baseline Freight Ton-km distribution of short and mid-distance trips according to European macrozone (all modes included)**

Share of freight volumes according to length of trip in ton-km from TRANS-TOOLS 2030 baseline, including road, rail, IWW and SSS as well as maritime traffic with neighbouring countries, divided by European macrozones. The share of intra-Zone traffic in East macrozone increases, showing the strengthening of European relations for these countries.

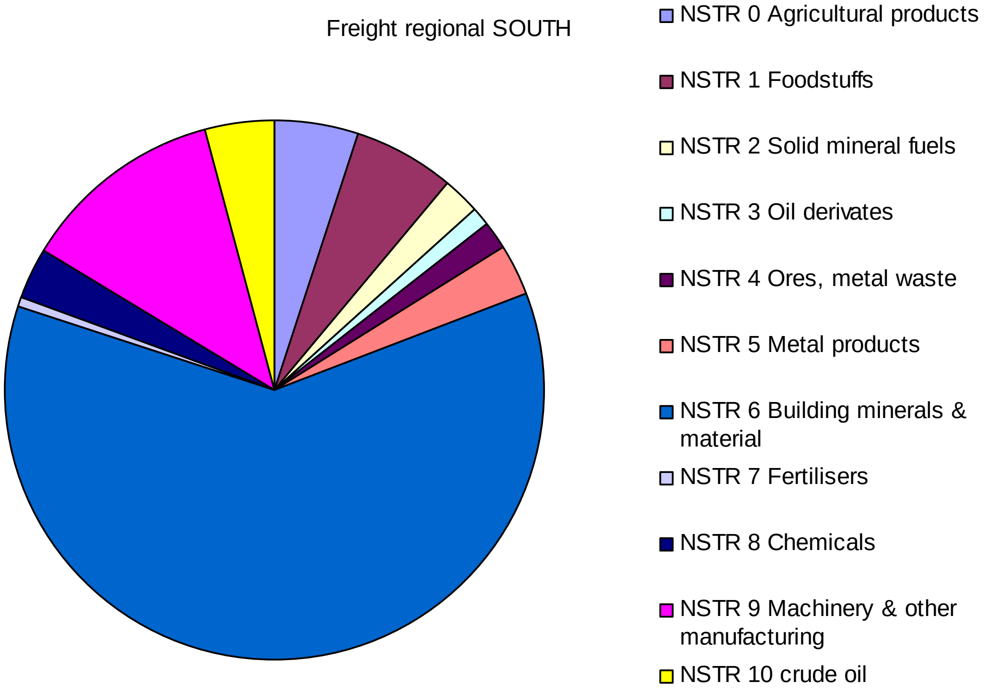



**Figure 134: TRANS-TOOLS 2030 Baseline Regional Freight NSTR distribution for South macrozone (all modes included)**

Distribution of regional freight ton-km 2030 baseline according to NSTR 1digit classification for South Europe, including road, rail, IWW and SSS.

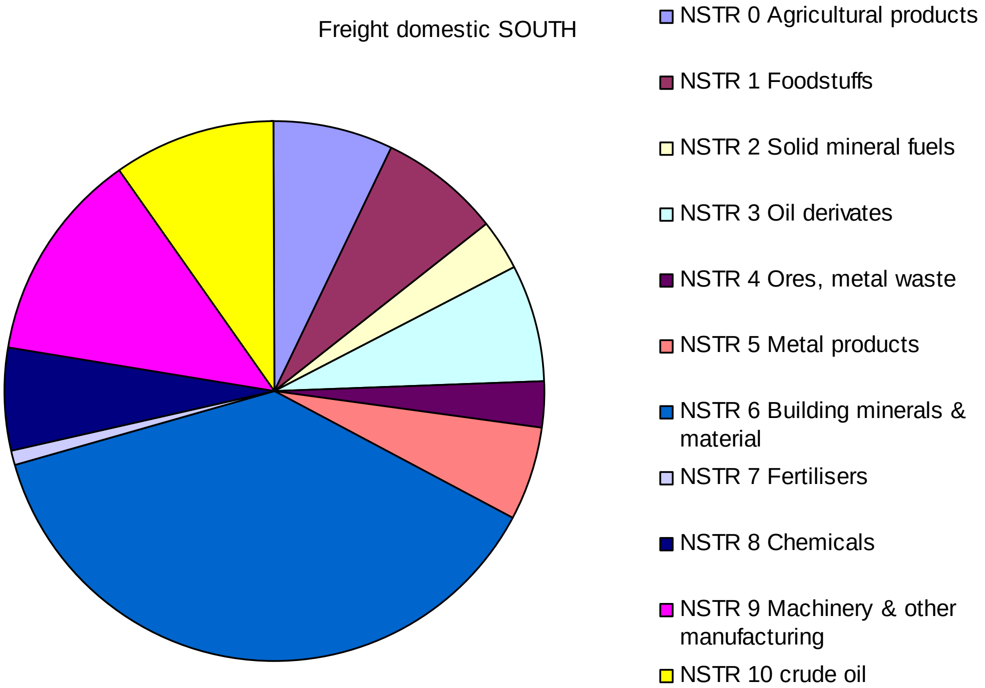



**Figure 135: TRANS-TOOLS 2030 Baseline Domestic Freight NSTR distribution for South macrozone (all modes included)**

Distribution of domestic freight ton-km 2030 baseline according to NSTR 1digit classification for South Europe, including road, rail, IWW and SSS.

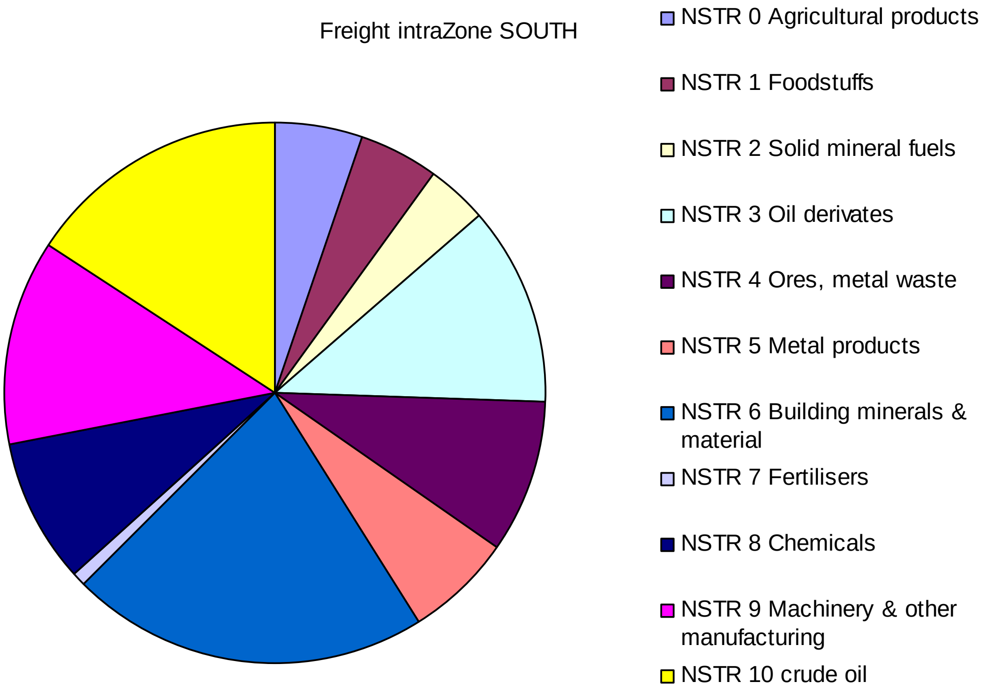



**Figure 136: TRANS-TOOLS 2030 Baseline Intra-Zone Freight NSTR distribution for South macrozone (all modes included)**

Distribution of intra-zone freight ton-km 2030 baseline according to NSTR 1digit classification for South Europe, including road, rail, IWW and SSS.

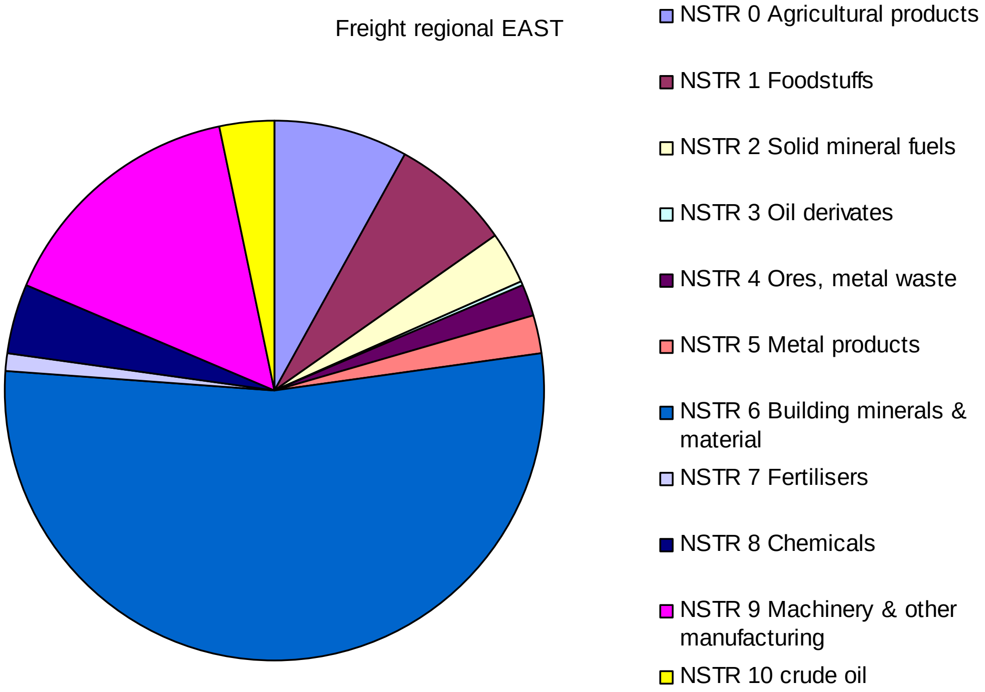



**Figure 137: TRANS-TOOLS 2030 Baseline Regional Freight NSTR distribution for East macrozone (all modes included)**

Distribution of regional freight ton-km 2030 baseline according to NSTR 1digit classification for North/Centre Europe, including road, rail, IWW and SSS.

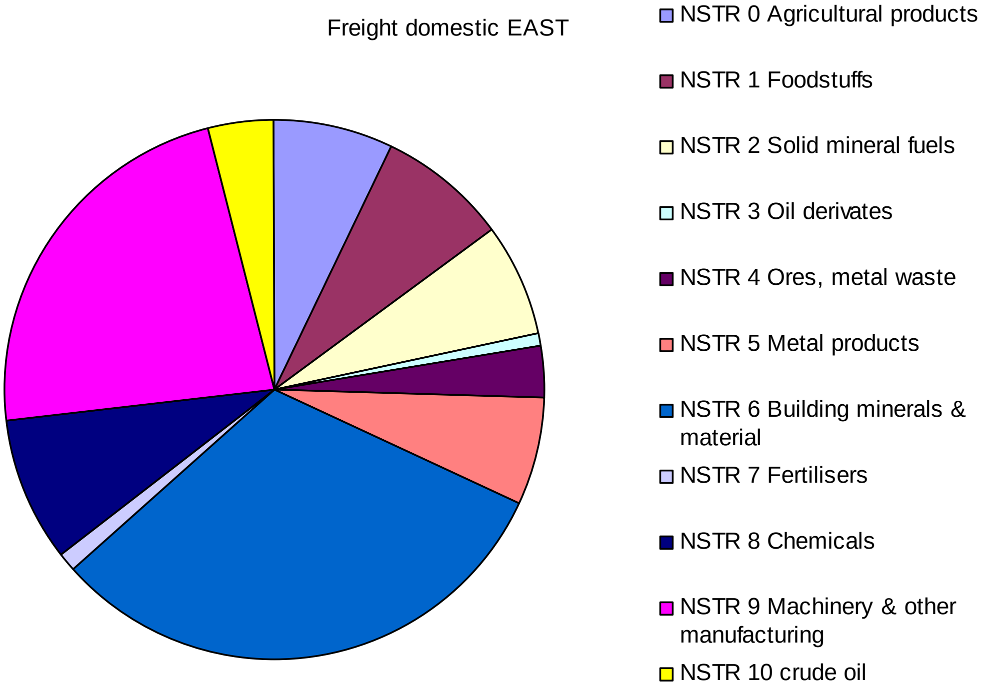


**Figure 138: TRANS-TOOLS 2030 Baseline Domestic Freight NSTR distribution for East macrozone (all modes included)**

Distribution of domestic freight ton-km 2030 baseline according to NSTR 1digit classification for North/Centre Europe, including road, rail, IWW and SSS.

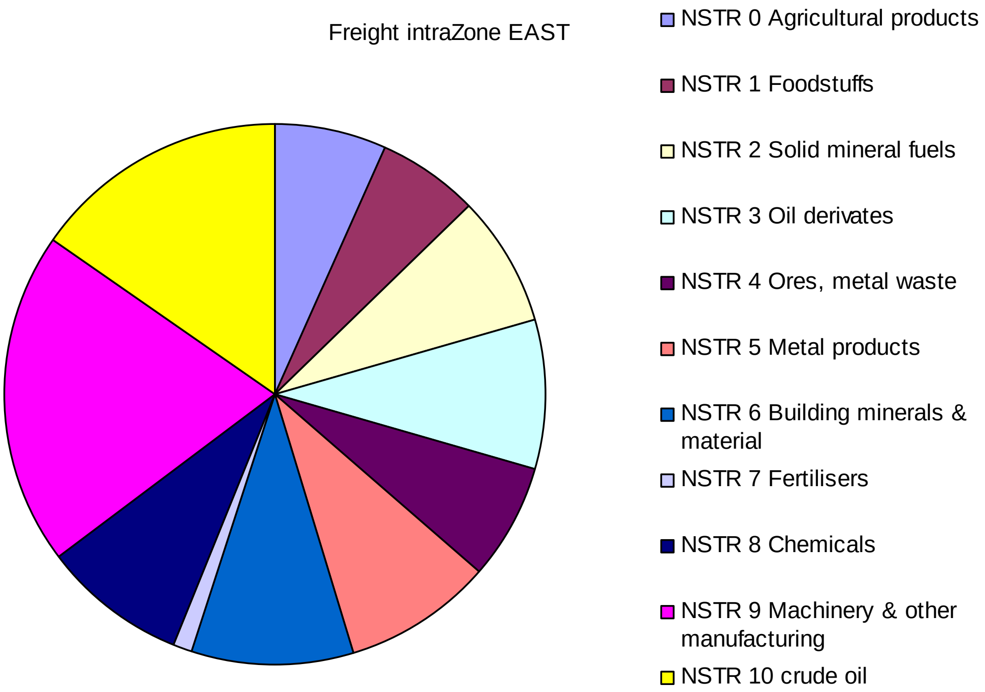



**Figure 139: TRANS-TOOLS 2030 Baseline Intra-Zone Freight NSTR distribution for East macrozone (all modes included)**

Distribution of freight intra-zone ton-km 2030 baseline according to NSTR 1digit classification for North/Centre Europe, including road, rail, IWW and SSS.

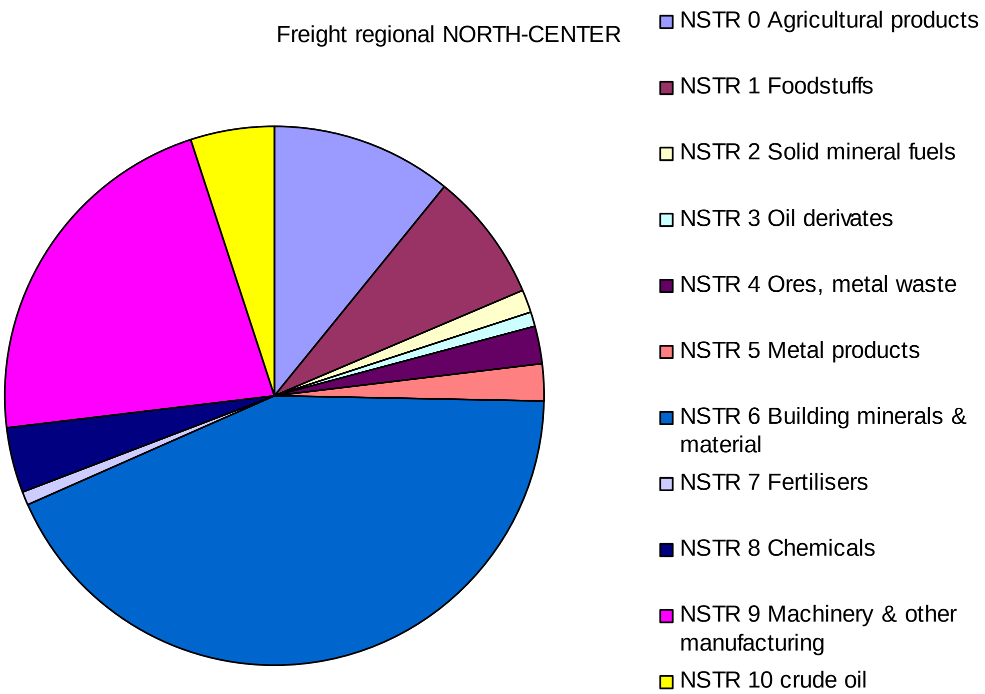



**Figure 140 :TRANS-TOOLS 2030 Baseline Regional Freight NSTR distribution for North/Centre macrozone (all modes included)**

Distribution of freight regional ton-km 2030 baseline according to NSTR 1digit classification for East Europe, including road, rail, IWW and SSS.

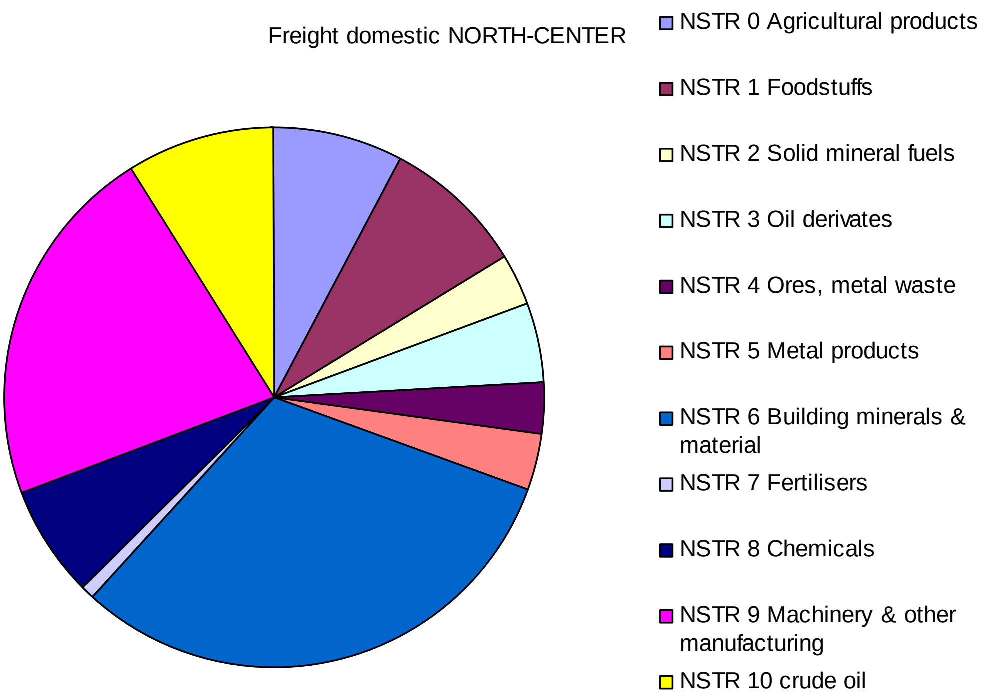



**Figure 141: TRANS-TOOLS 2030 Baseline Domestic Freight NSTR distribution for North/Centre macrozone (all modes included)**

Distribution of freight domestic ton-km 2030 baseline according to NSTR 1digit classification for East Europe, including road, rail, IWW and SSS.

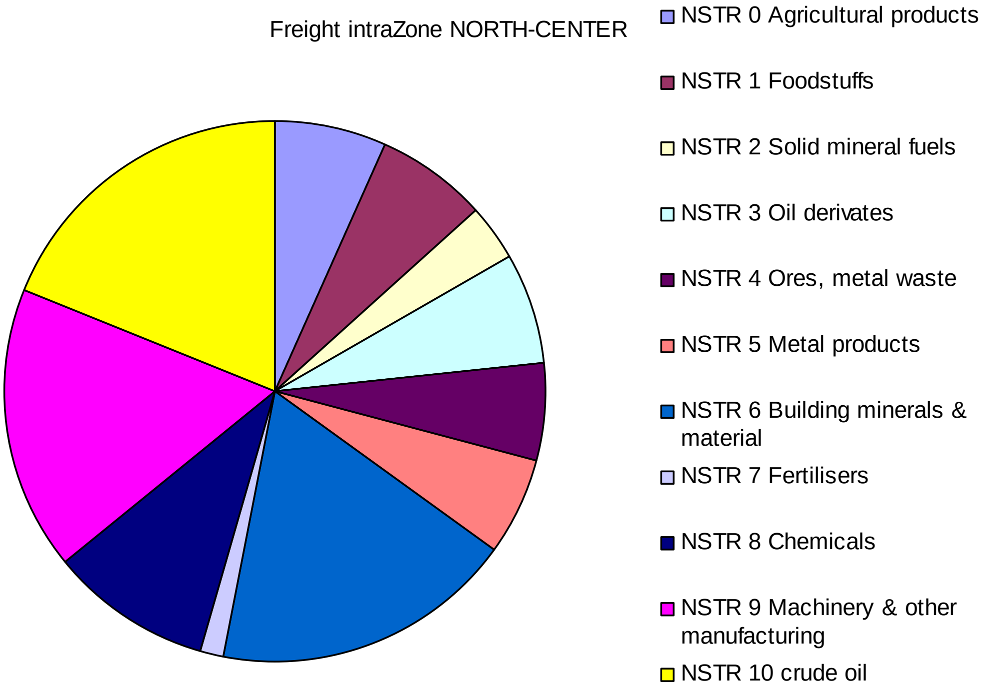



**Figure 142: TRANS-TOOLS 2030 Baseline Intra-Zone Freight NSTR distribution for North/Centre macrozone (all modes included)**

Distribution of freight intra-zone ton-km 2030 baseline according to NSTR 1digit classification for East Europe, including road, rail, IWW and SSS.

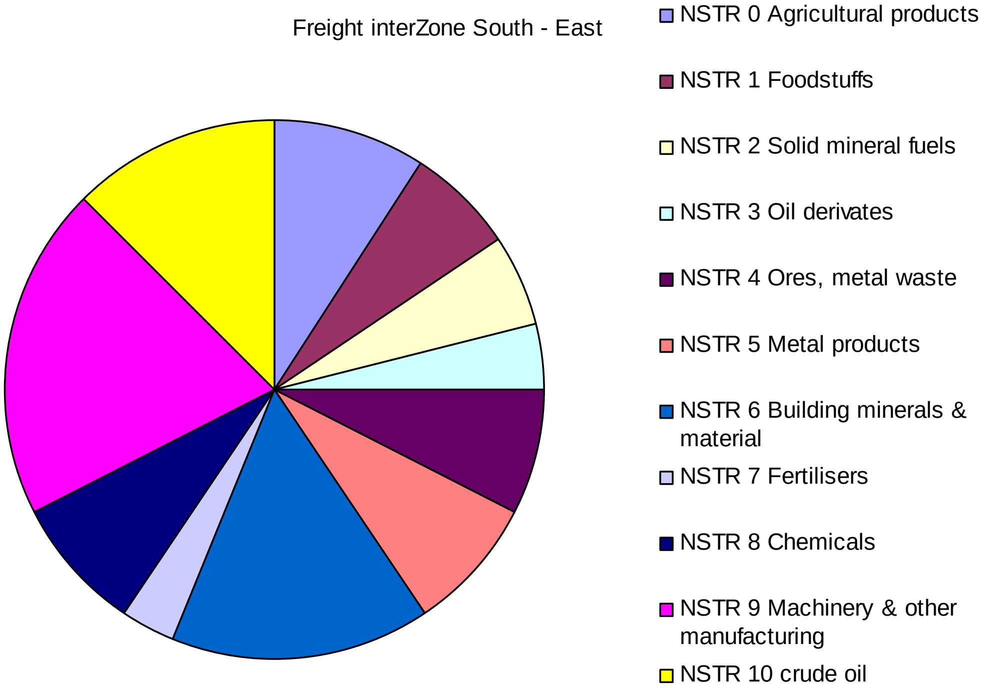


**Figure 143: TRANS-TOOLS 2030 Baseline Inter-zone Freight NSTR distribution for South / East relations (all modes included)**

Distribution of inter-zone freight ton-km 2030 baseline according to NSTR 1digit classification for traffic of South / East relations, including road, rail, IWW and SSS.

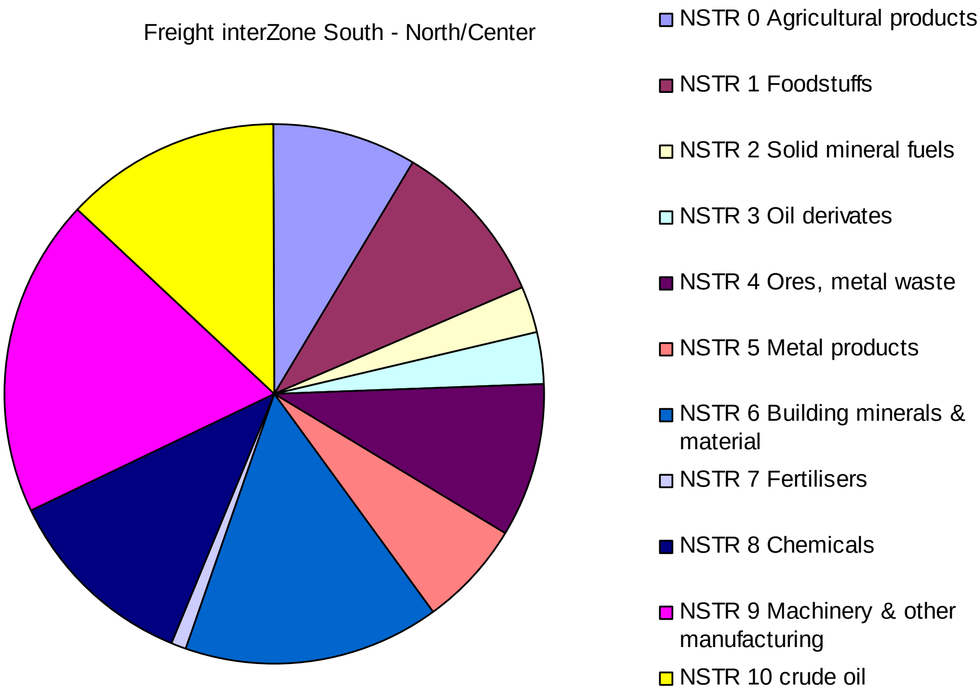



**Figure 144: TRANS-TOOLS 2030 Baseline Inter-zone Freight NSTR distribution for South / North/Centre relations (all modes included)**

Distribution of inter-zone freight ton-km 2030 baseline according to NSTR 1digit classification for traffic of South / North/Centre relations, including road, rail, IWW and SSS.

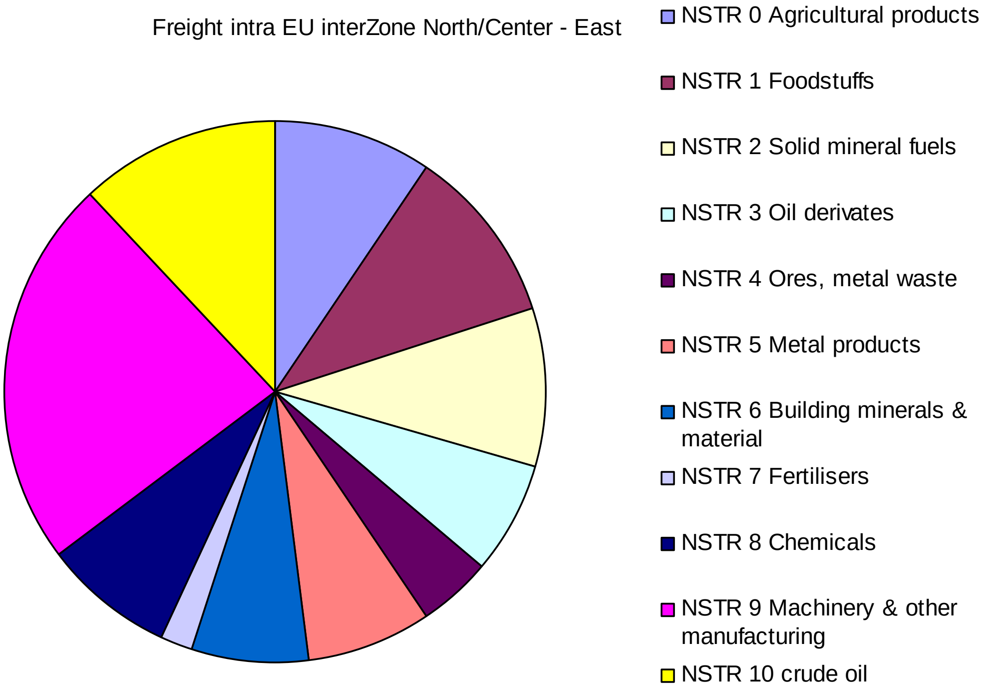



**Figure 145: TRANS-TOOLS 2030 Baseline Inter-zone Freight NSTR distribution for East / North/Centre relations (all modes included)**

Distribution of inter-zone freight ton-km 2030 baseline according to NSTR 1digit classification for traffic of North/Centre / East relations, including road, rail, IWW and SSS.

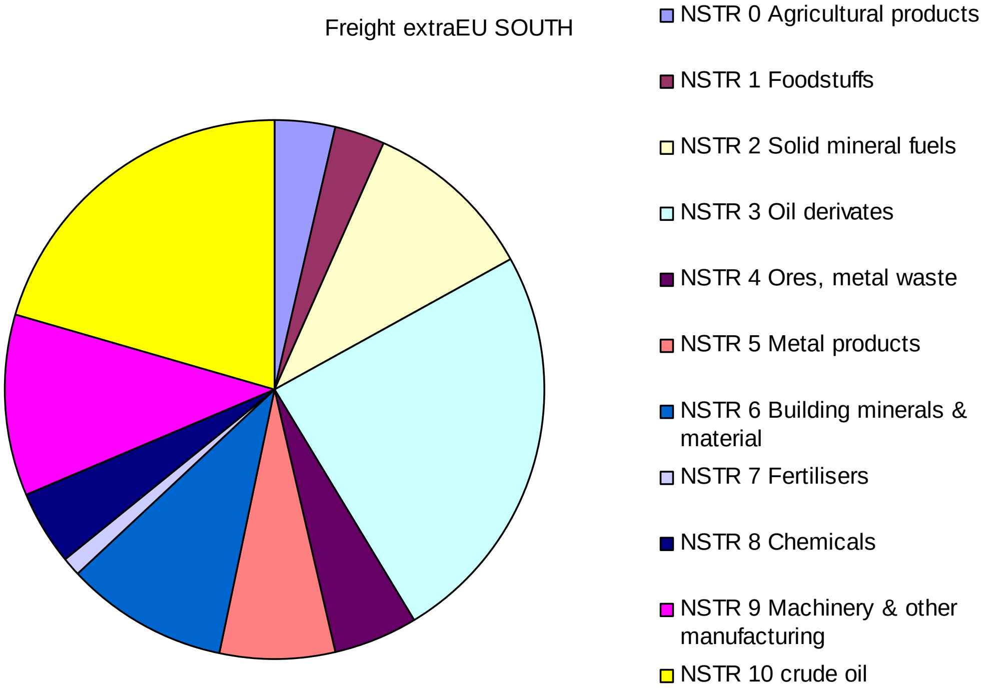



**Figure 146: TRANS-TOOLS 2030 Baseline Extra-EU Freight NSTR distribution for South macrozone (all modes included)**

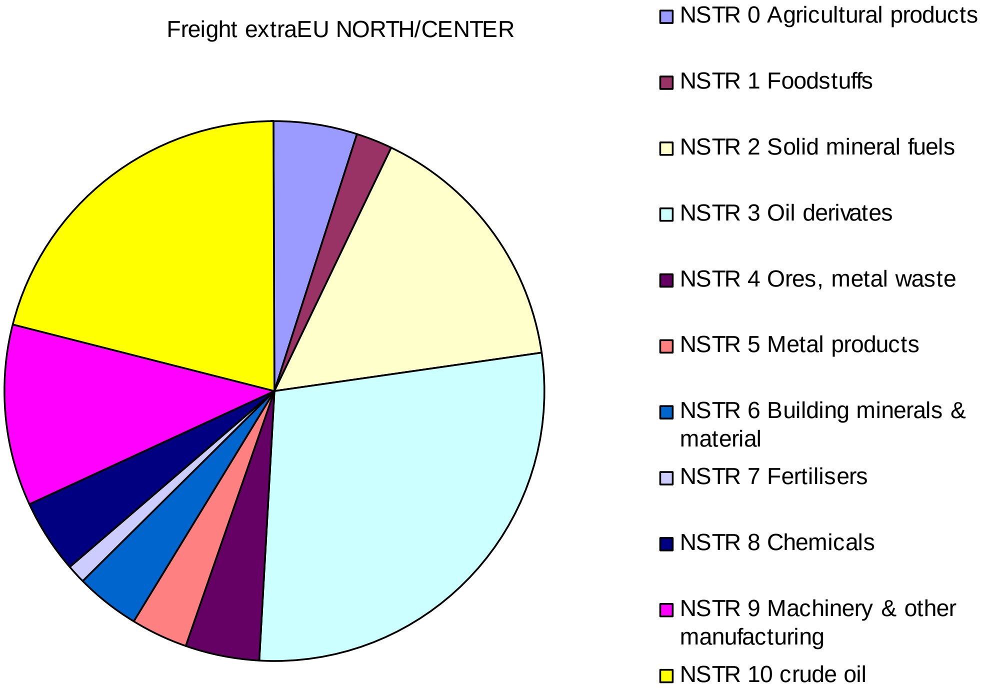



**Figure 147: TRANS-TOOLS 2030 Baseline Extra-EU Freight NSTR distribution for North/Centre macrozone (all modes included)**

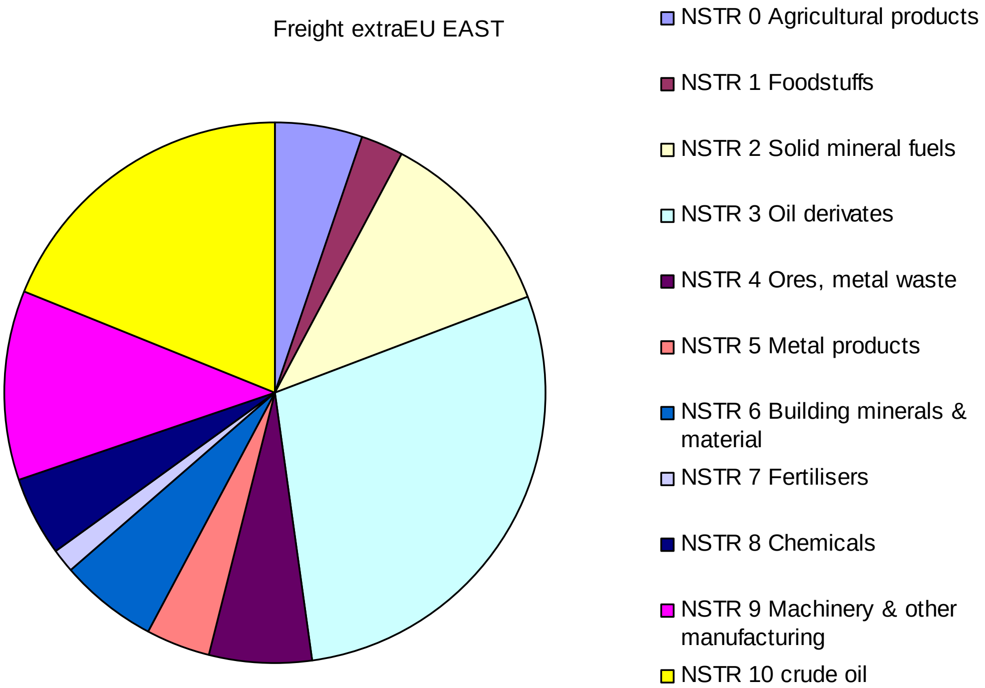



**Figure 148: TRANS-TOOLS 2030 Baseline Extra-EU Freight NSTR distribution for East macrozone (all modes included)**

Distribution of freight ton-km 2030 baseline according to NSTR 1digit classification for traffic with non-EU-27 countries, including road, rail, IWW and SSS as well as maritime traffic with neighbouring countries.

## 9.3. *Analysis of freight traffic (only inland traffic included) in 2005*

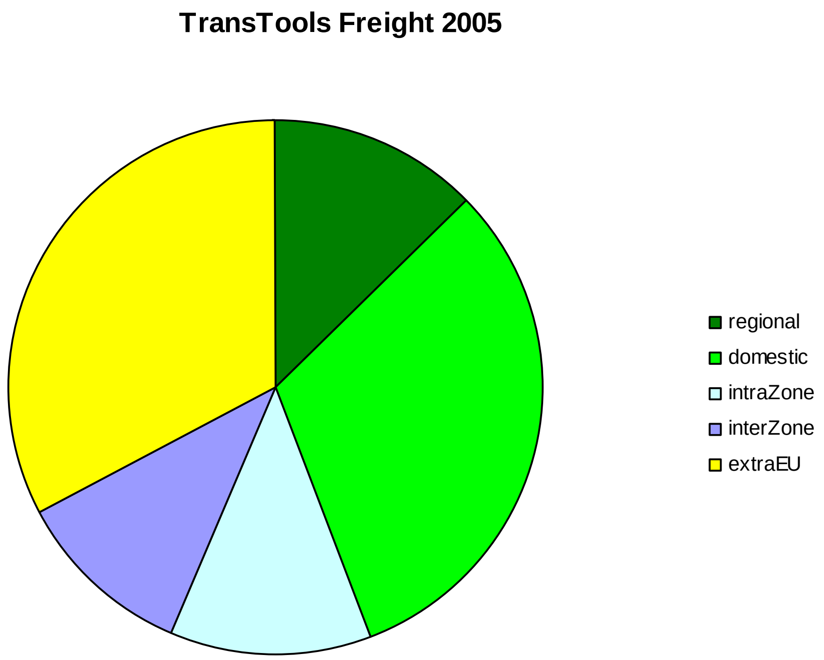



**Figure 149: TRANS-TOOLS 2005 Freight Ton-km geographic distribution according to distance of trip (only inland traffic included)**

Geographic distribution of EU-27 ton-km from TRANS-TOOLS 2005, including inland traffic (road, rail, and IWW). Excluding the maritime mode reduces the share of extra-EU traffic.

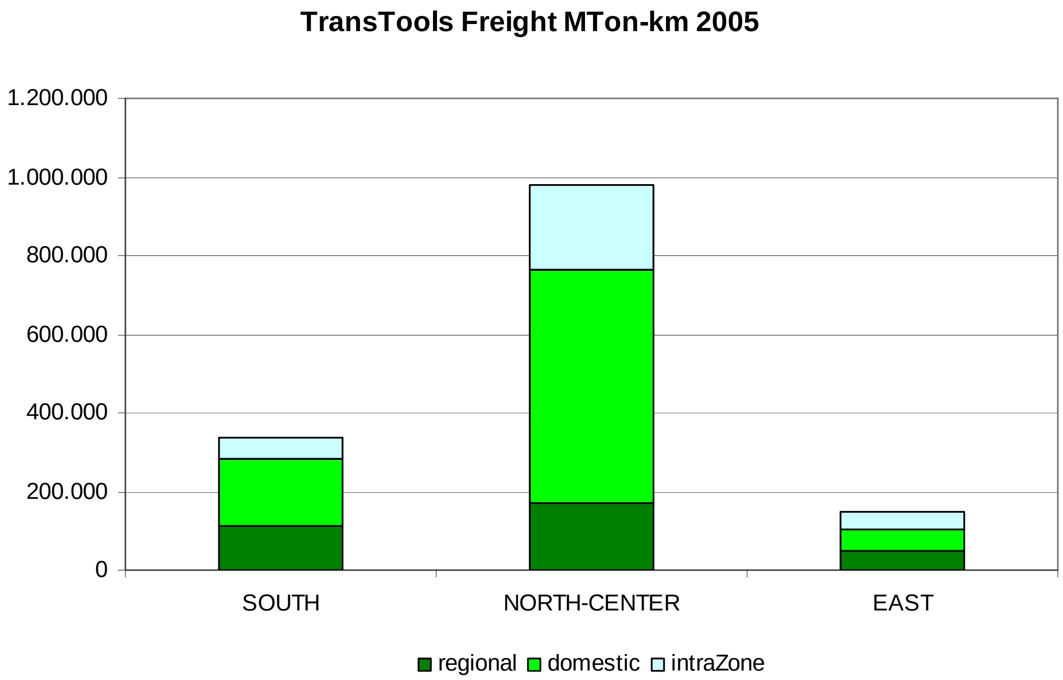



**Figure 150: TRANS-TOOLS 2005 Freight Ton-km volume of short and mid-distance trips according to European macrozone (only inland traffic included)**

Freight volumes in ton-km from TRANS-TOOLS 2005, including inland traffic (road, rail, and IWW), according to European macrozone.

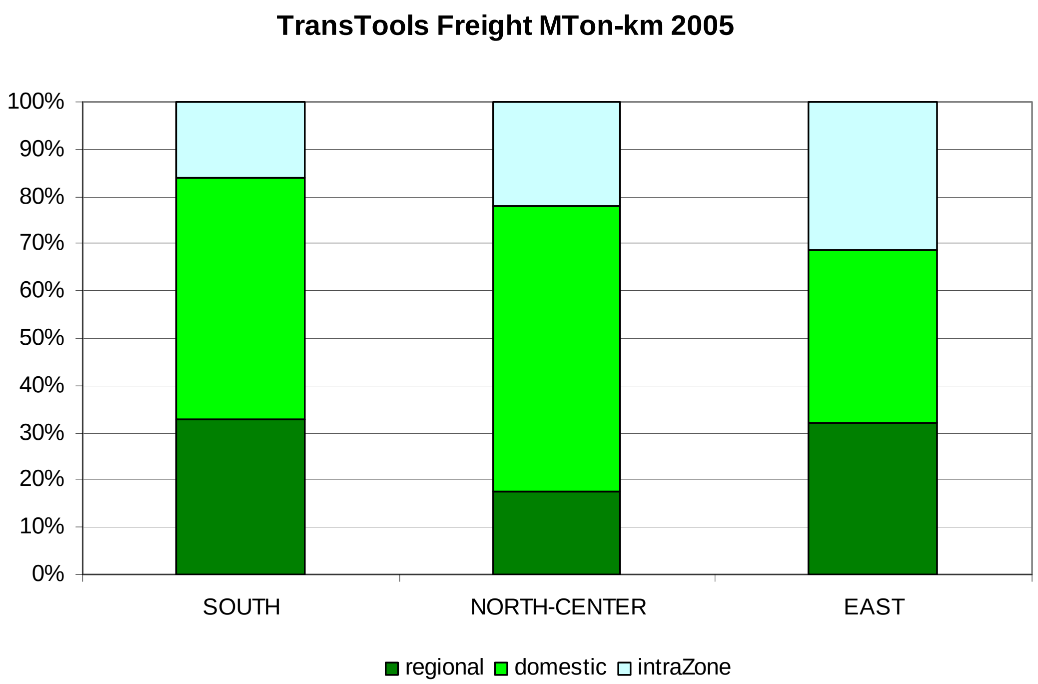



**Figure 151: TRANS-TOOLS 2005 Freight Ton-km distribution of short and mid-distance trips according to European macrozone (only inland traffic included)**

Share of freight volumes according to length of trip in ton-km from TRANS-TOOLS 2005, including inland traffic (road, rail, and IWW), divided by European macrozones.

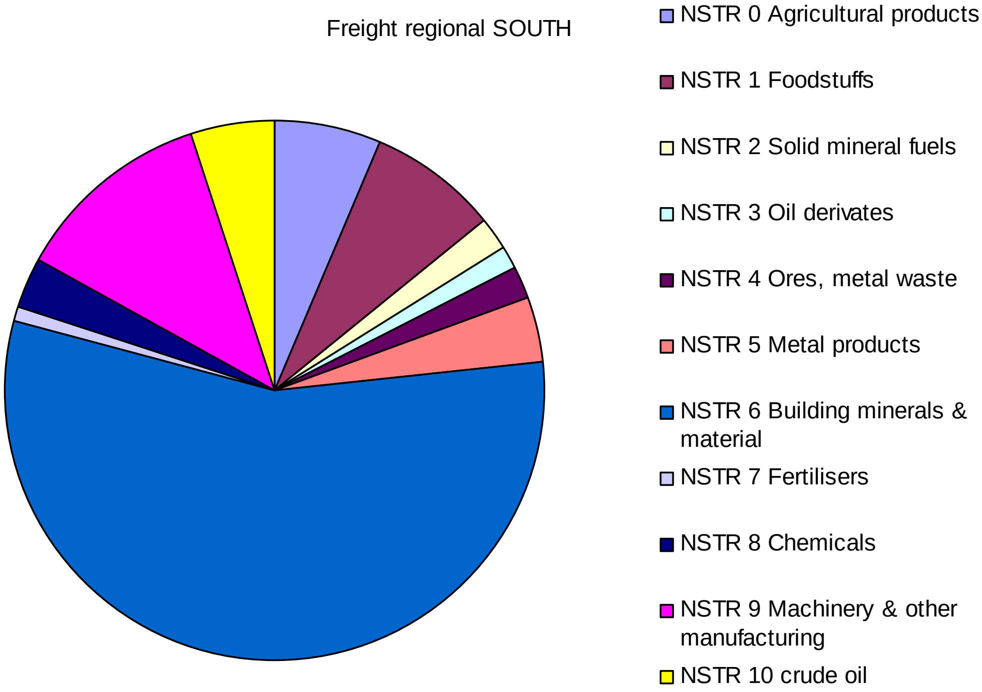



**Figure 152: TRANS-TOOLS 2005 Regional Freight NSTR distribution for South macrozone (only inland traffic included)**

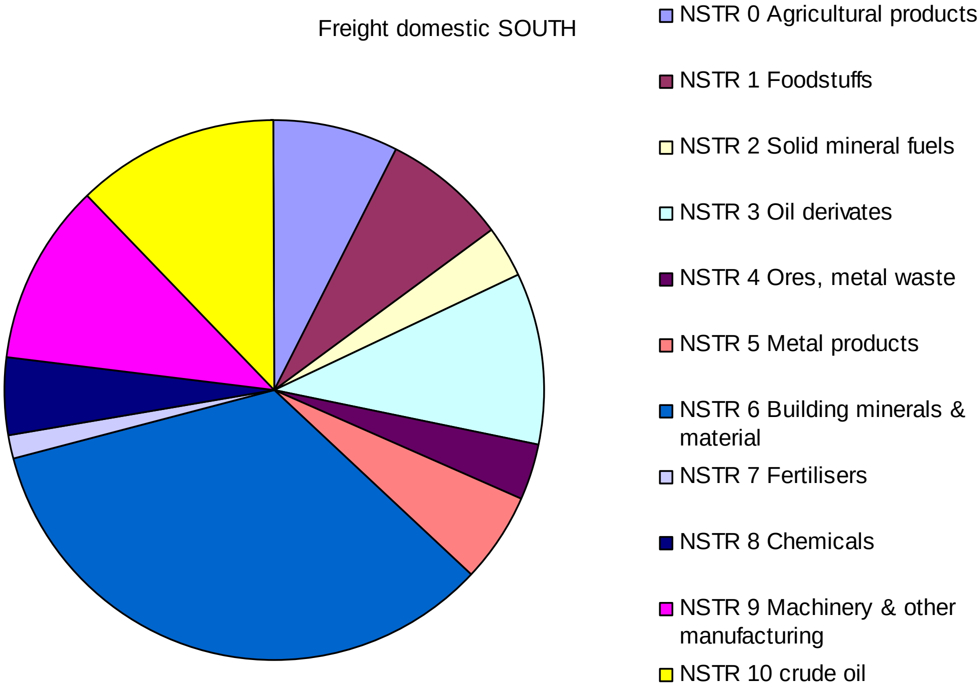



**Figure 153: TRANS-TOOLS 2005 Domestic Freight NSTR distribution for South macrozone (only inland traffic included)**

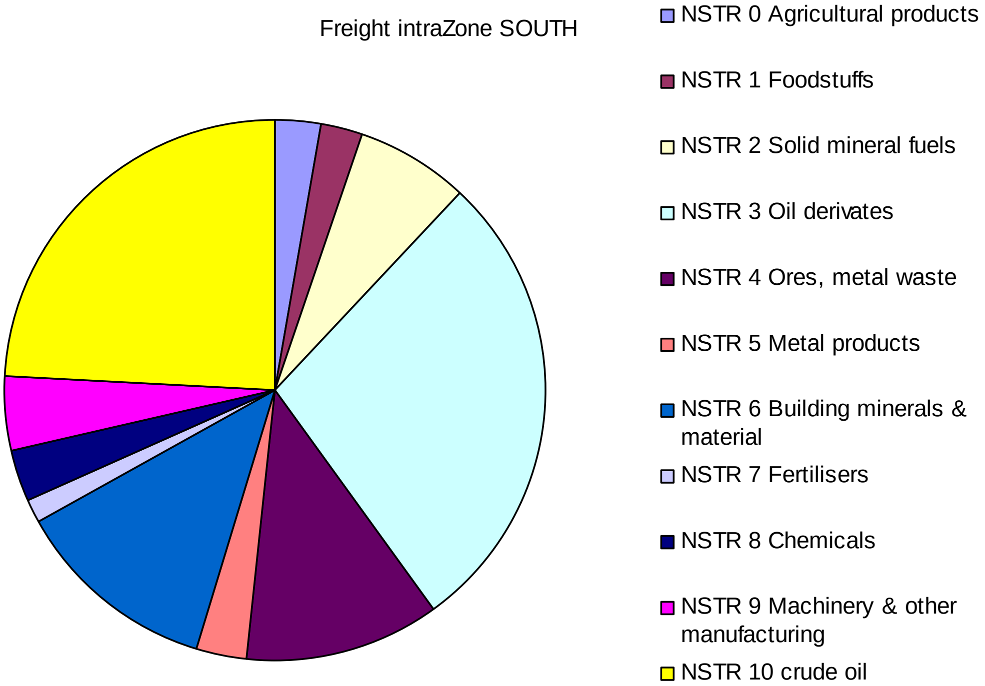



**Figure 154: TRANS-TOOLS 2005 Intra-Zone Freight NSTR distribution for South macrozone (only inland traffic included)**

Distribution of freight ton-km 2005 according to NSTR 1digit classification for South Europe, including inland traffic (road, rail, and IWW).

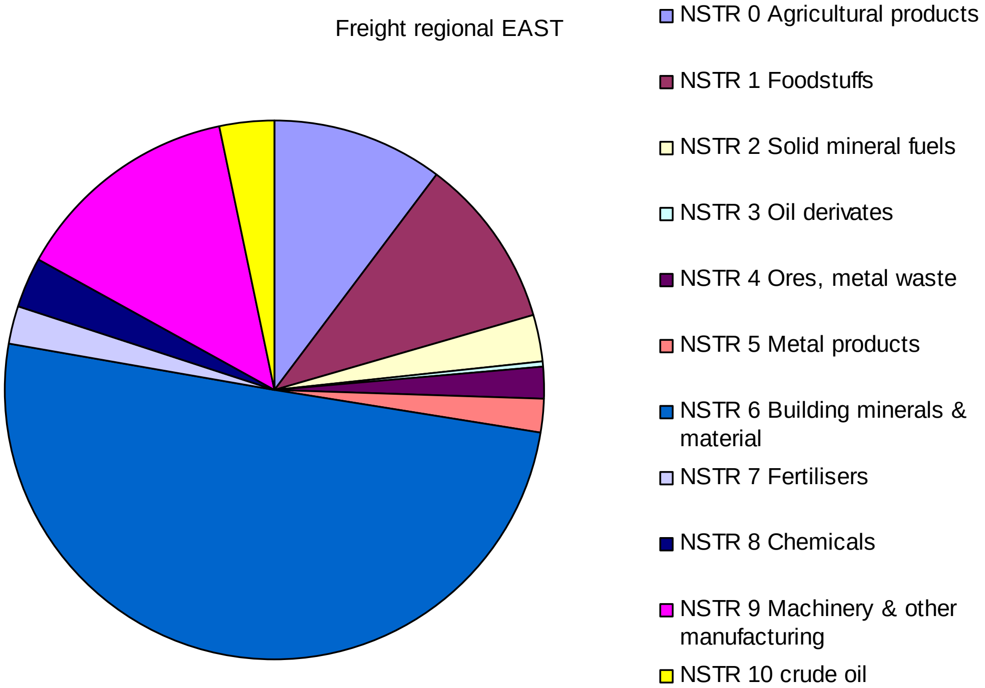



**Figure 155: TRANS-TOOLS 2005 Regional Freight NSTR distribution for East macrozone (only inland traffic included)**

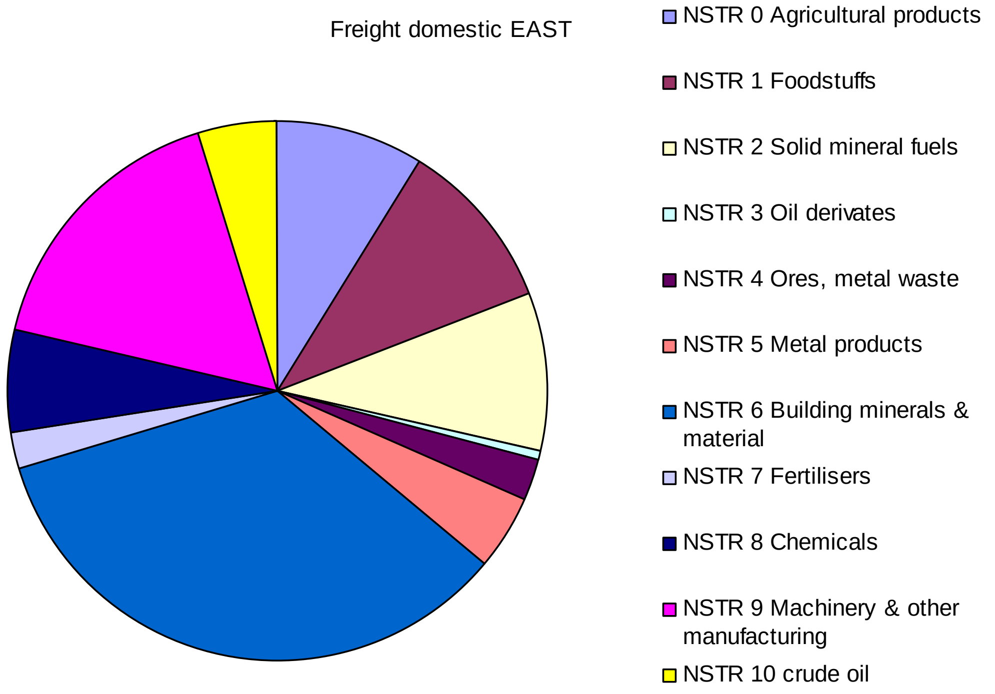



**Figure 156: TRANS-TOOLS 2005 Domestic Freight NSTR distribution for East macrozone (only inland traffic included)**

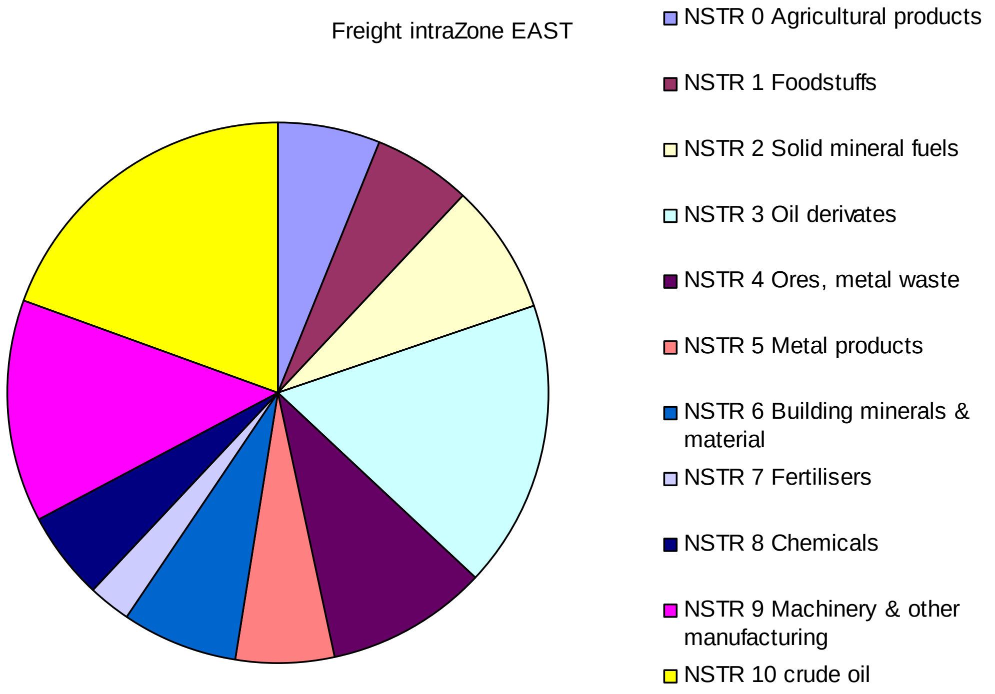



**Figure 157: TRANS-TOOLS 2005 Intra-Zone Freight NSTR distribution for East macrozone (only inland traffic included)**

Distribution of freight ton-km 2005 according to NSTR 1digit classification for East Europe, including inland traffic (road, rail, and IWW).

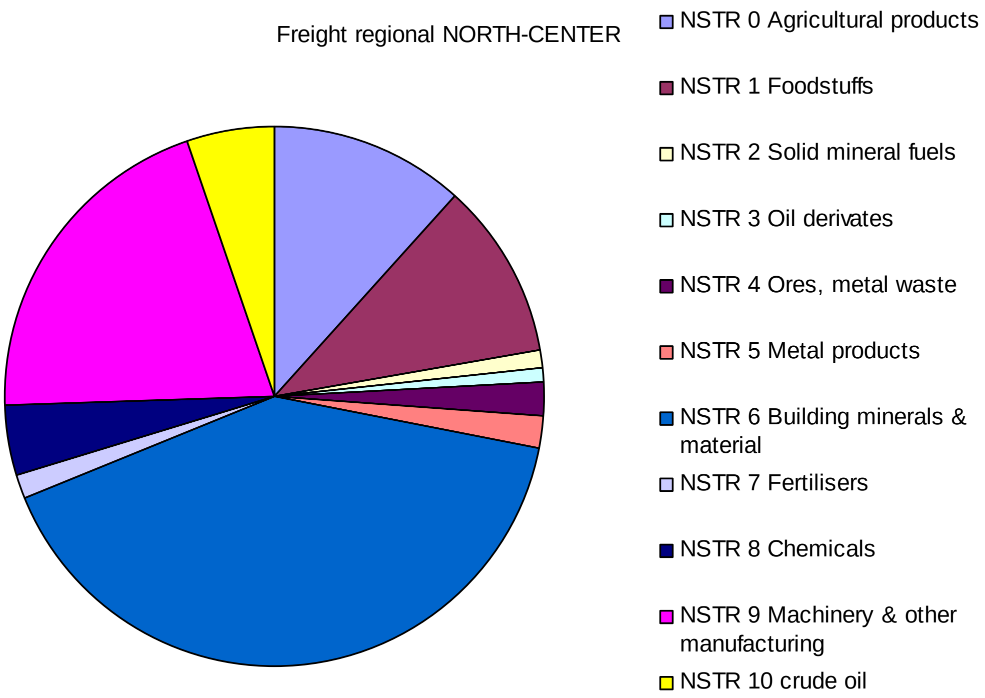



**Figure 158: TRANS-TOOLS 2005 Regional Freight NSTR distribution for North/Centre macrozone (only inland traffic included)**

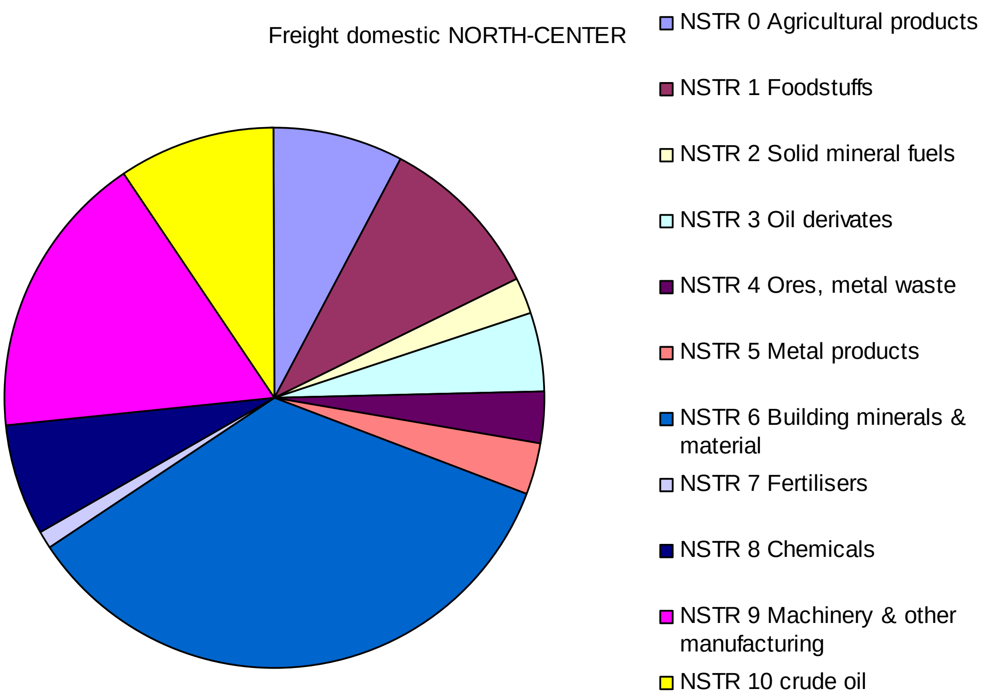



**Figure 159: TRANS-TOOLS 2005 Domestic Freight NSTR distribution for North/Centre macrozone (only inland traffic included)**

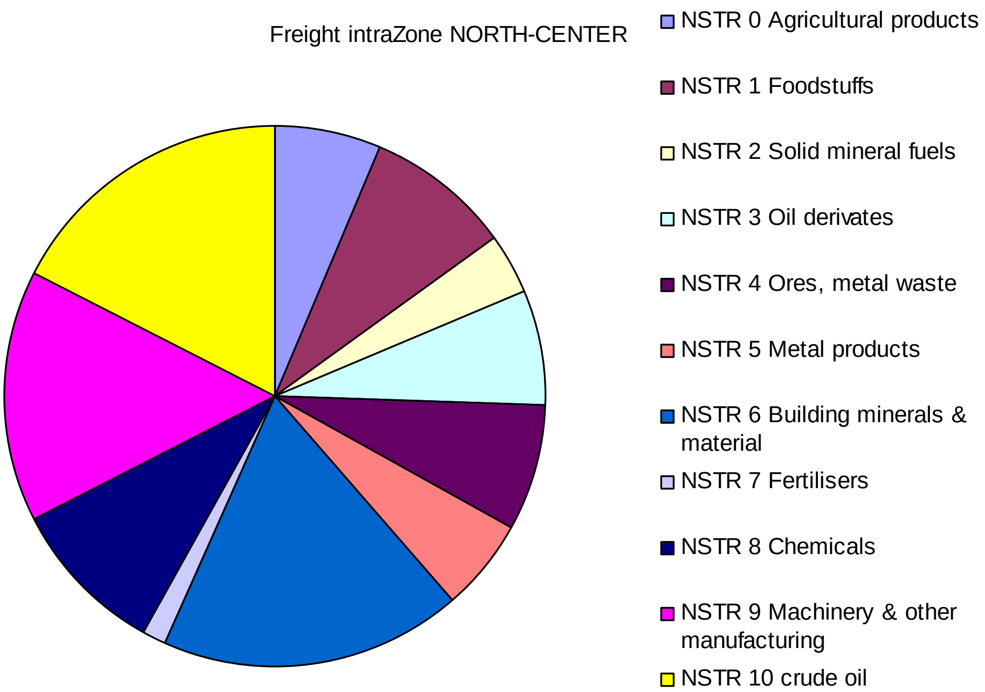



**Figure 160: TRANS-TOOLS 2005 Intra-Zone Freight NSTR distribution for North/Centre macrozone (only inland traffic included)**

Distribution of freight ton-km 2005 according to NSTR 1digit classification for North/Centre Europe, including inland traffic (road, rail, and IWW).

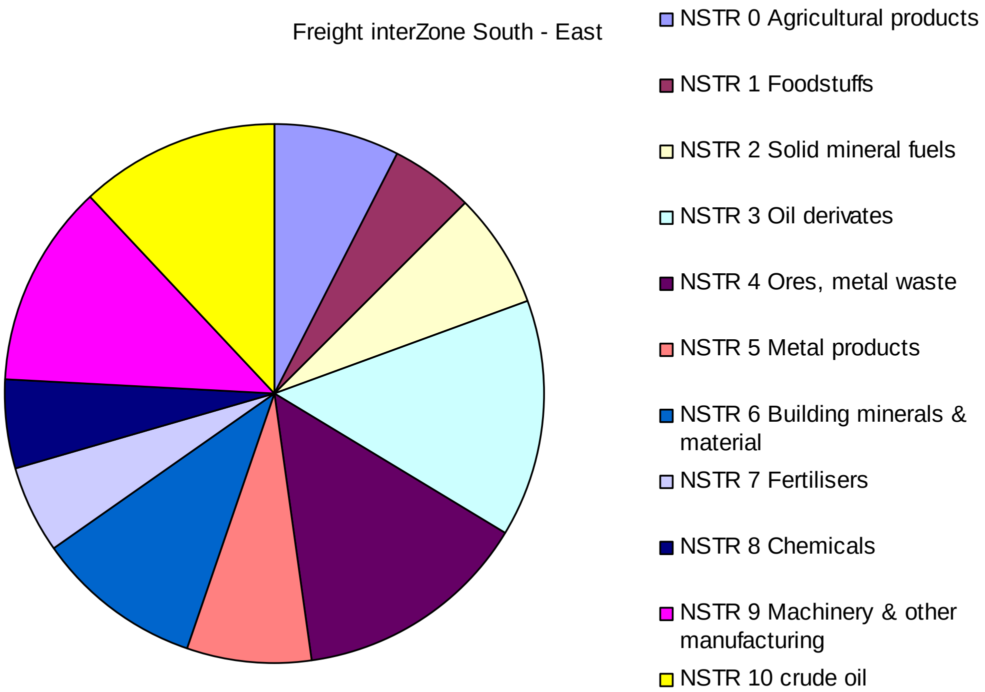



**Figure 161: TRANS-TOOLS 2005 Inter-zone Freight NSTR distribution for South / East relations (only inland traffic included)**

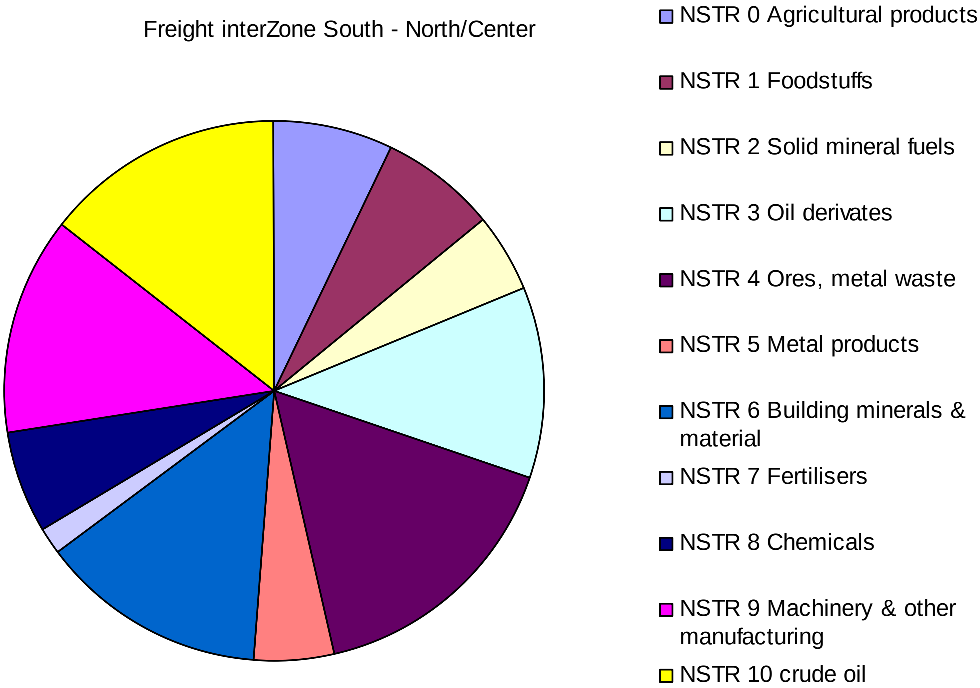



**Figure 162: TRANS-TOOLS 2005 Inter-zone Freight NSTR distribution for South / North/Centre relations (only inland traffic included)**

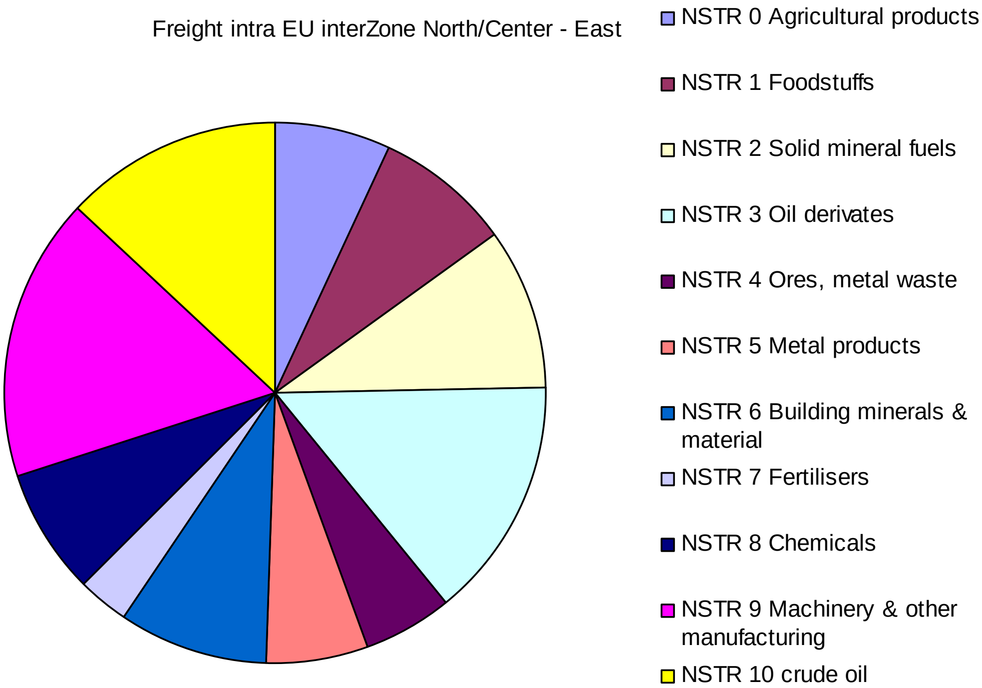



**Figure 163: TRANS-TOOLS 2005 Inter-zone Freight NSTR distribution for East / North/Centre relations (only inland traffic included)**

Distribution of freight ton-km 2005 according to NSTR 1digit classification for traffic among European macrozones, including inland traffic (road, rail, and IWW).

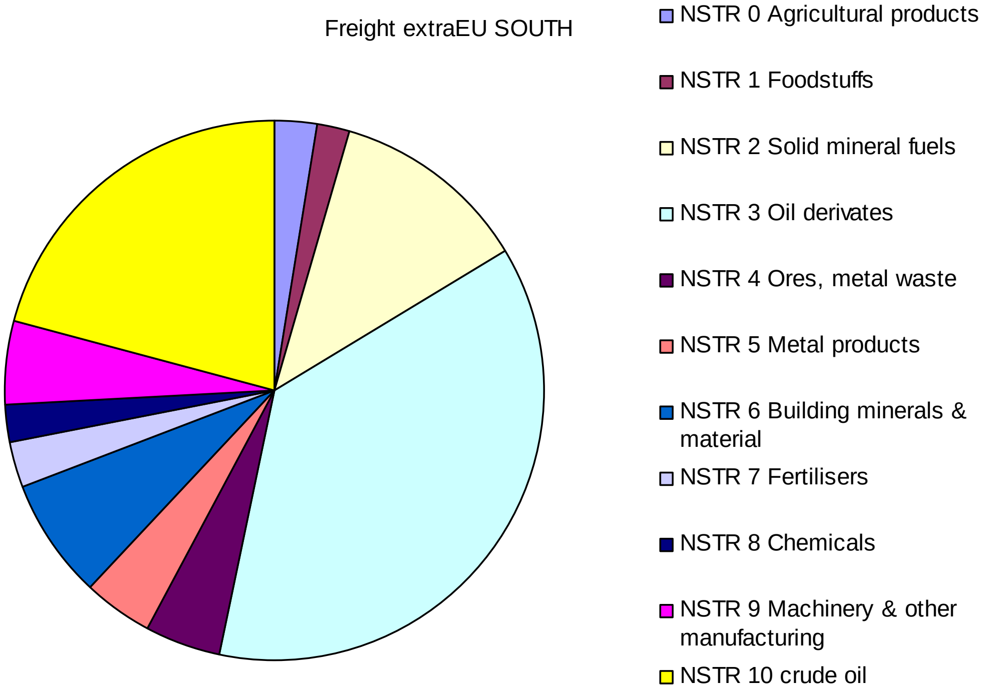



**Figure 164: TRANS-TOOLS 2005 Extra-EU Freight NSTR distribution for South macrozone (only inland traffic included)**

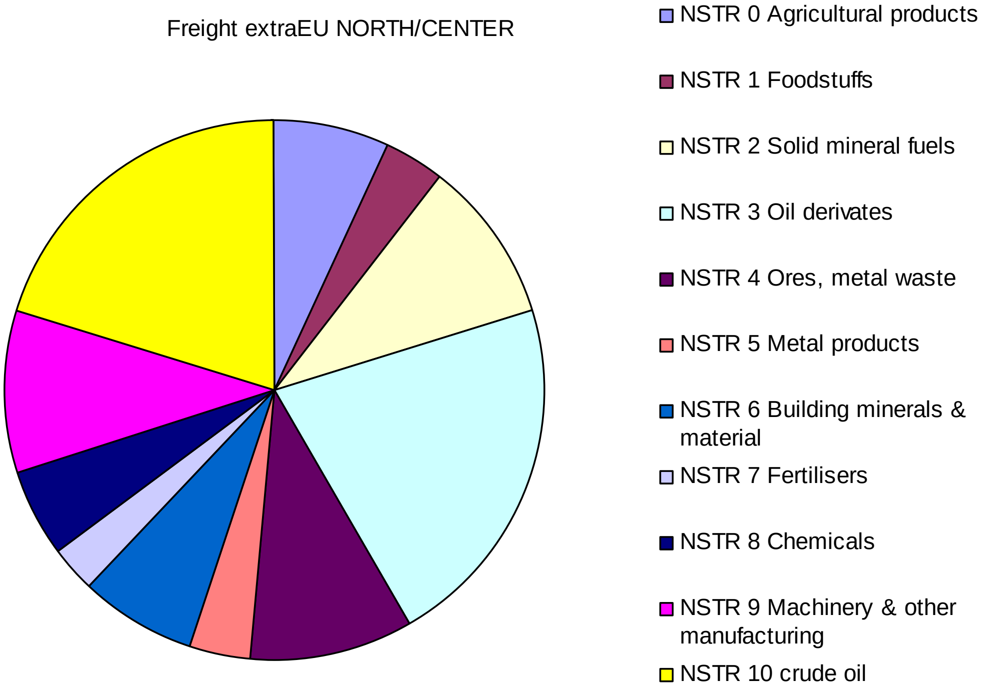



**Figure 165: TRANS-TOOLS 2005 Extra-EU Freight NSTR distribution for North/Centre macrozone (only inland traffic included)**

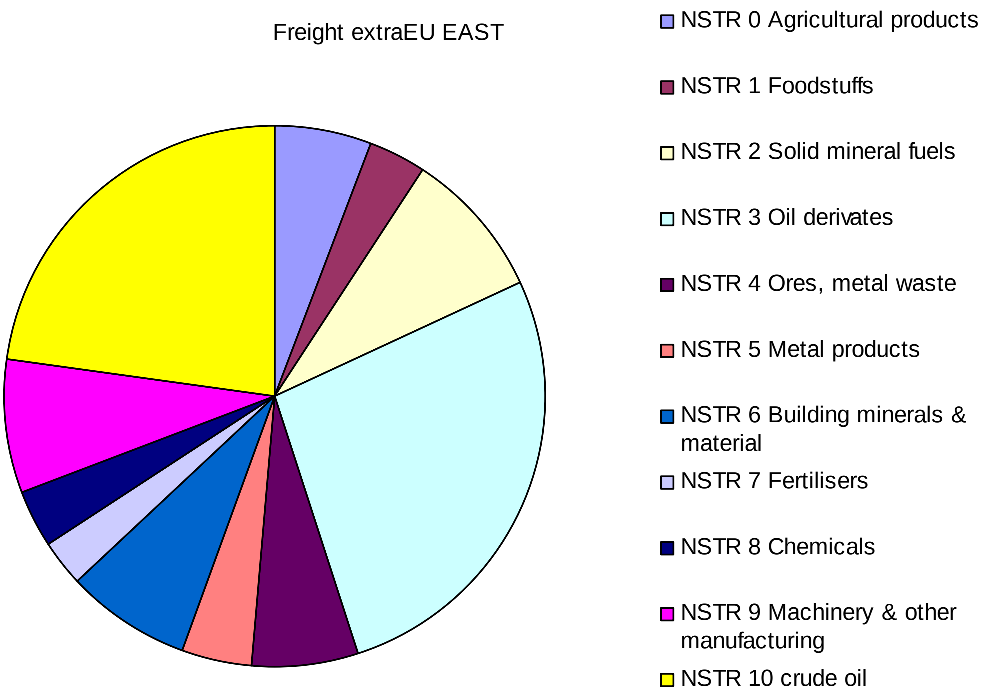



**Figure 166: TRANS-TOOLS 2005 Extra-EU Freight NSTR distribution for East macrozone (only inland traffic included)**

Distribution of freight ton-km 2005 according to NSTR 1digit classification for traffic with non-EU-27 countries, including inland traffic (road, rail, and IWW).

## 9.4. *Analysis of freight (only inland traffic included) for baseline in 2030*


**Figure 167: TRANS-TOOLS 2030 Baseline Freight Ton-km geographic distribution according to distance of trip (only inland traffic included)**

Geographic distribution of EU-27 ton-km from TRANS-TOOLS 2030 baseline, including inland traffic (road, rail, and IWW). Excluding maritime mode results in a reduction of the share of extra-EU traffic.

Extra-EU traffic includes freight imported from overseas moving within EU-27, from main ports to final destinations by road or rail or IWW. Pipelines are not included, but road and rail traffic from Russia, Belarus, Ukraine, Turkey are included. Rail traffic between Russia and the Baltic countries are relatively high in tn-km, even if the distances are not so large.

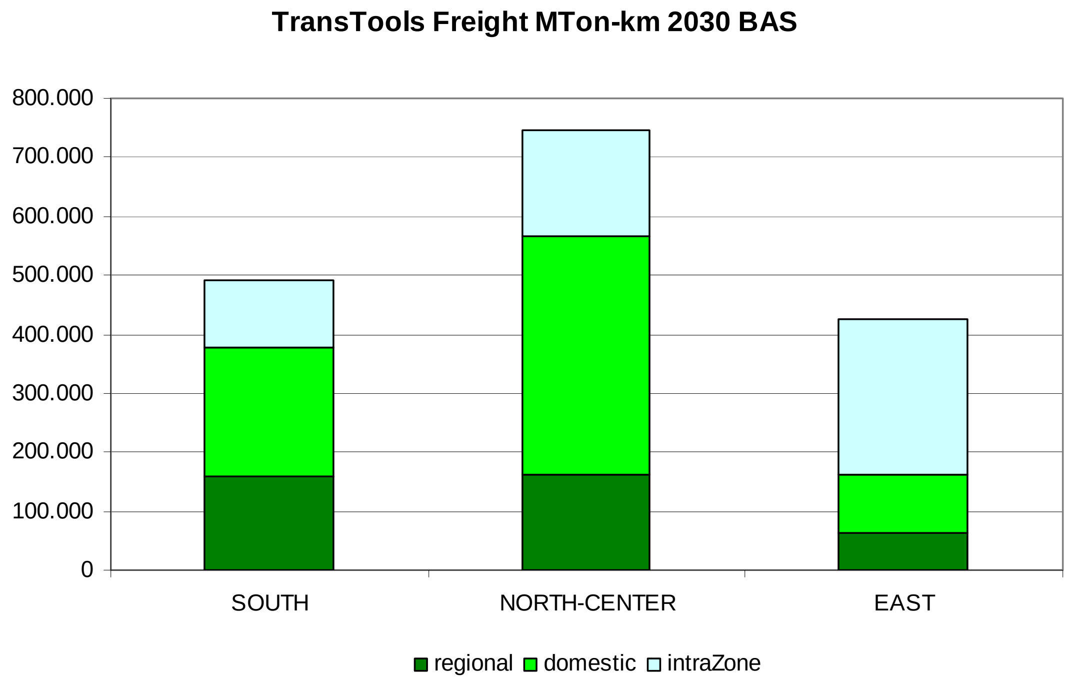



**Figure 168: TRANS-TOOLS 2030 Baseline Freight Ton-km volume of short and mid-distance trips according to European macrozone (only inland traffic included)**

Share of freight volumes according to length of trip in ton-km from TRANS-TOOLS 2030 baseline, including inland traffic (road, rail, and IWW), divided by European macrozones.

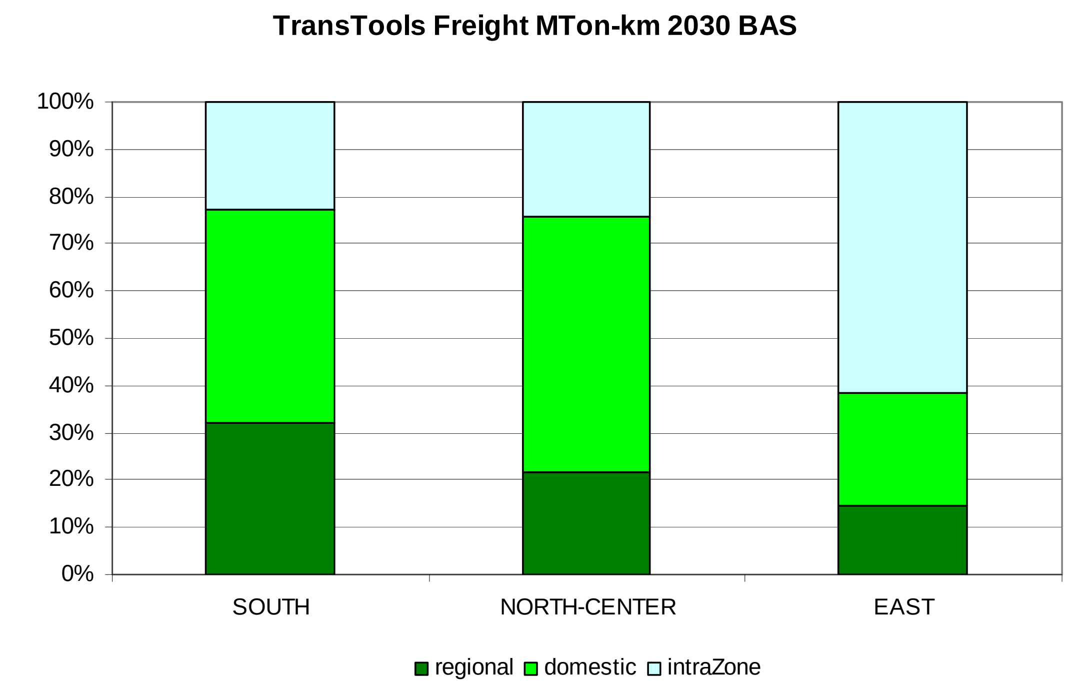



**Figure 169: TRANS-TOOLS 2030 Baseline Freight Ton-km distribution of short and mid-distance trips according to European macrozone (only inland traffic included)**

Share of freight volumes according to length of trip in ton-km from TRANS-TOOLS 2030 baseline, including inland traffic (road, rail, and IWW), divided by European macrozones.

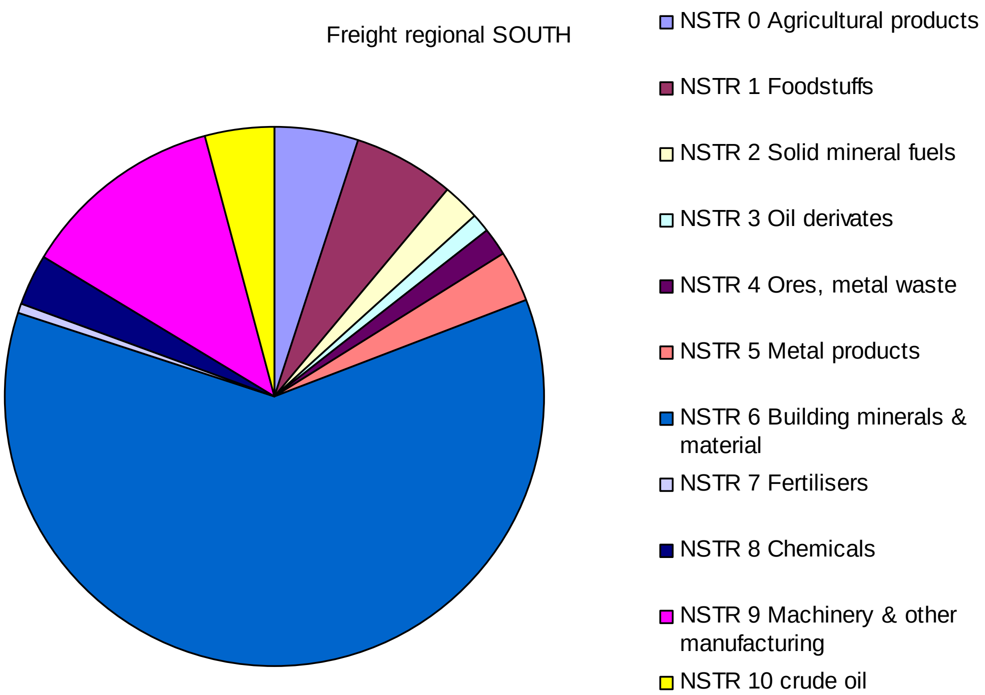



**Figure 170: TRANS-TOOLS 2030 Baseline Regional Freight NSTR distribution for South macrozone (only inland traffic included)**

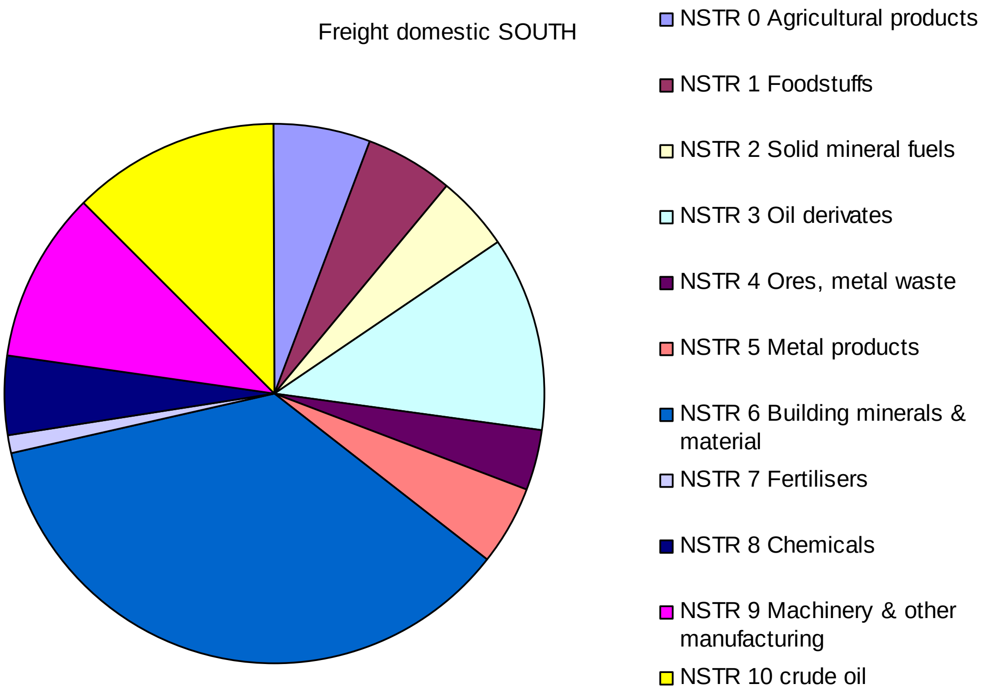



**Figure 171: TRANS-TOOLS 2030 Baseline Domestic Freight NSTR distribution for South macrozone (only inland traffic included)**

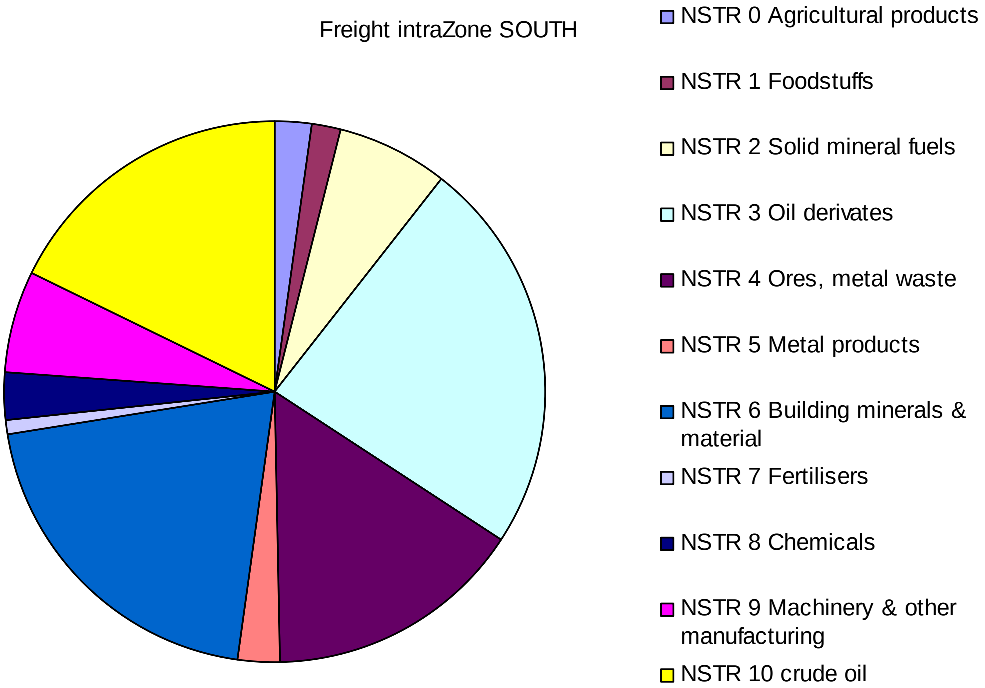



**Figure 172: TRANS-TOOLS 2030 Baseline Intra-Zone Freight NSTR distribution for South macrozone (only inland traffic included)**

Distribution of freight ton-km 2030 baseline according to NSTR 1digit classification for South Europe, including inland traffic (road, rail, and IWW).

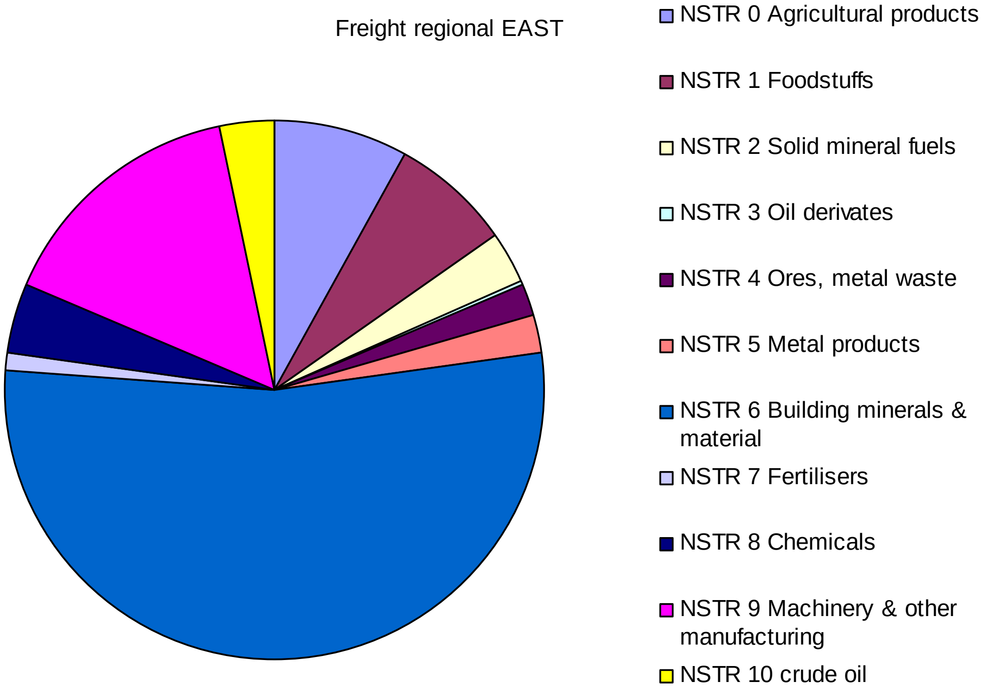



**Figure 173: TRANS-TOOLS 2030 Baseline Regional Freight NSTR distribution for East macrozone (only inland traffic included)**

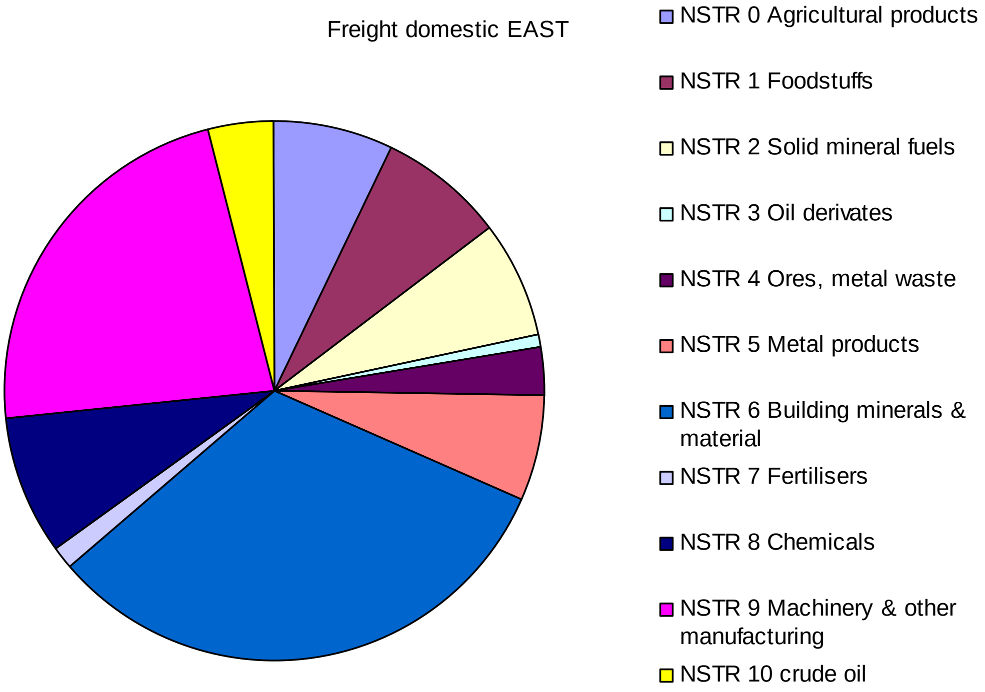



**Figure 174: TRANS-TOOLS 2030 Baseline Domestic Freight NSTR distribution for East macrozone (only inland traffic included)**

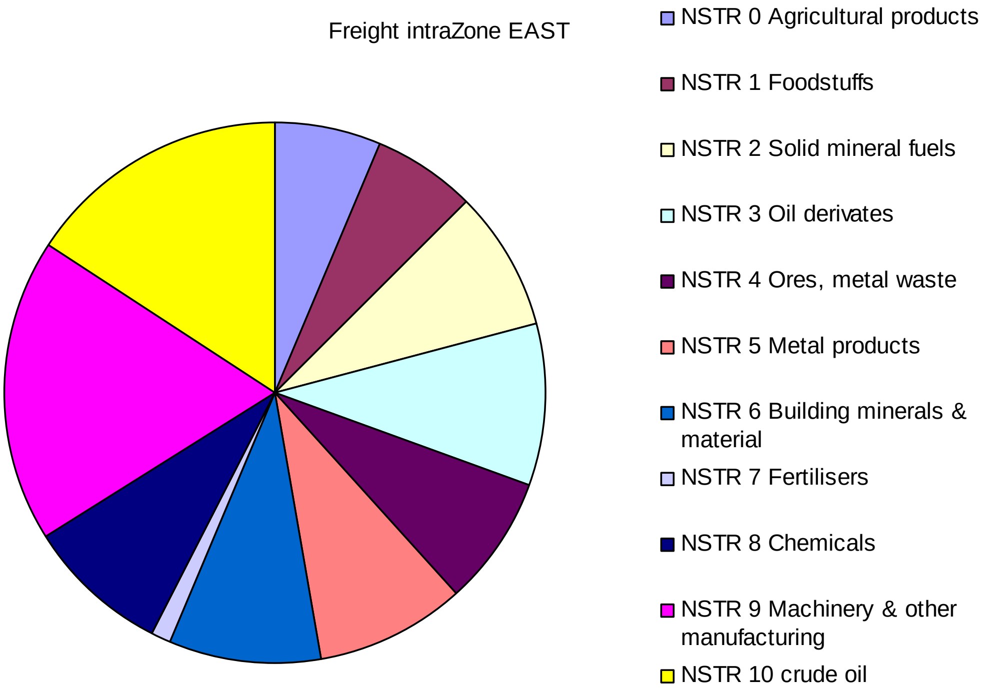



**Figure 175: TRANS-TOOLS 2030 Baseline Intra-Zone Freight NSTR distribution for East macrozone (only inland traffic included)**

Distribution of freight ton-km 2030 baseline according to NSTR 1digit classification for North/Centre Europe, including inland traffic (road, rail, and IWW).

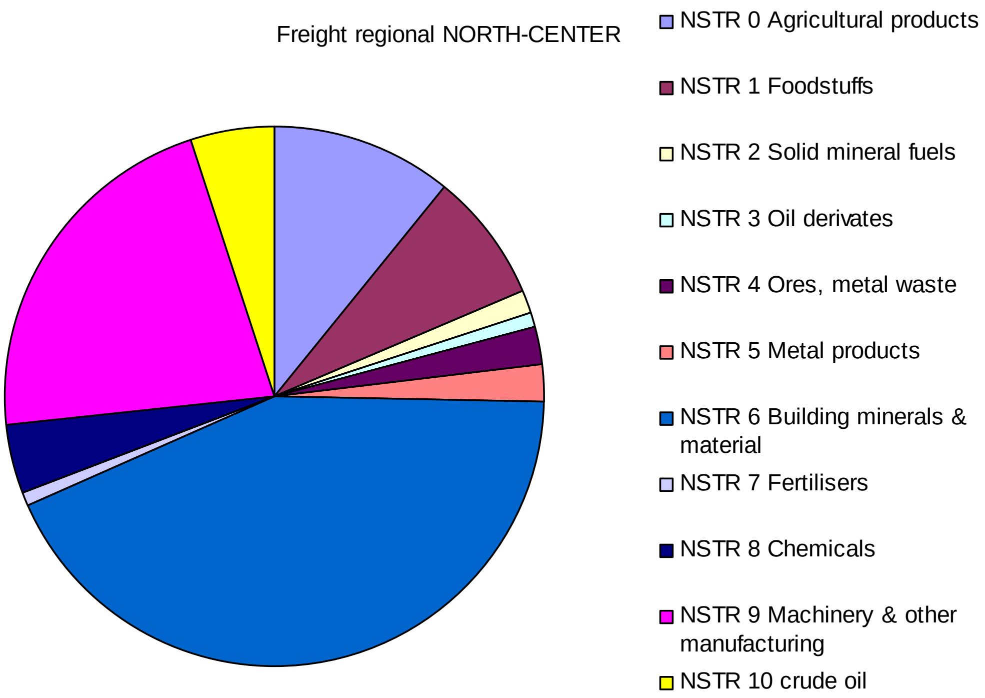



**Figure 176: TRANS-TOOLS 2030 Baseline Regional Freight NSTR distribution for North/Centre macrozone (only inland traffic included)**

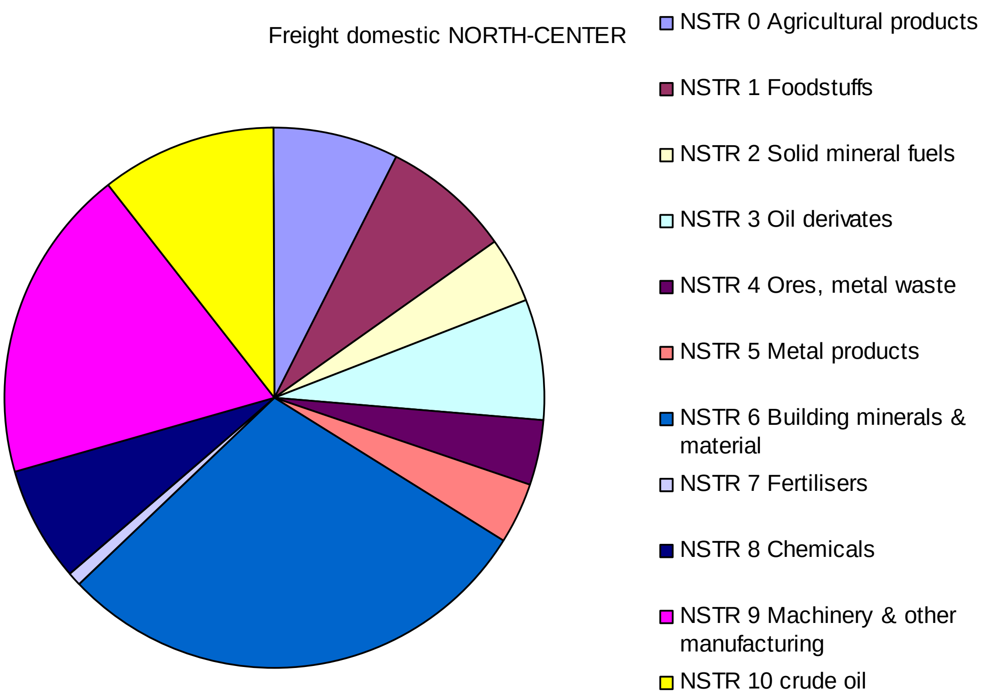



**Figure 177: TRANS-TOOLS 2030 Baseline Domestic Freight NSTR distribution for North/Centre macrozone (only inland traffic included)**

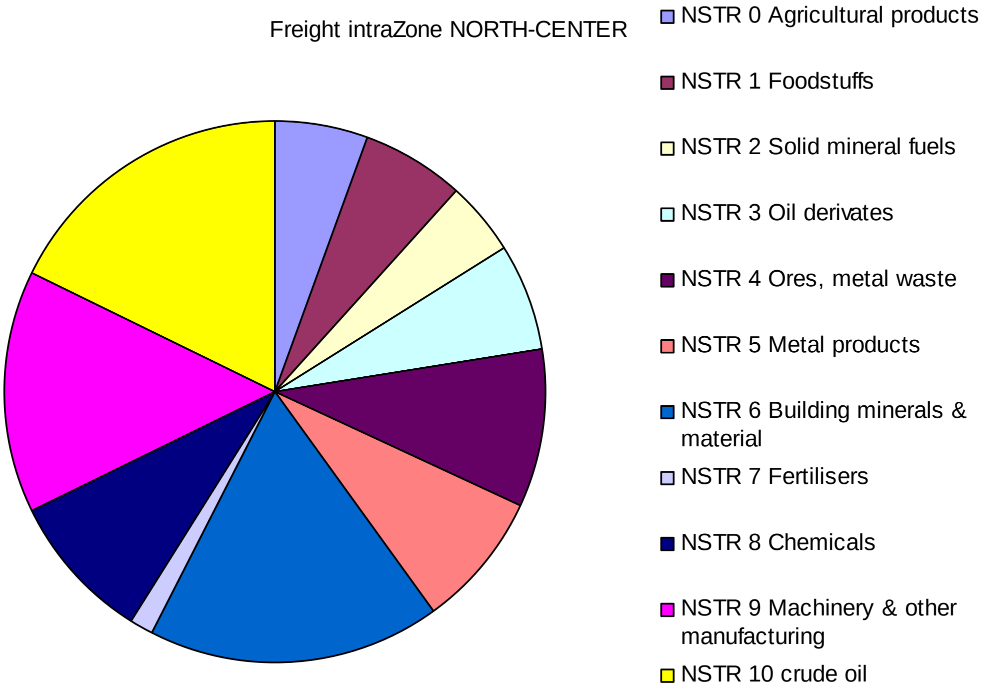



**Figure 178: TRANS-TOOLS 2030 Baseline Intra-Zone Freight NSTR distribution for North/Centre macrozone (only inland traffic included)**

Distribution of freight ton-km 2030 baseline according to NSTR 1digit classification for East Europe, including inland traffic (road, rail, and IWW).

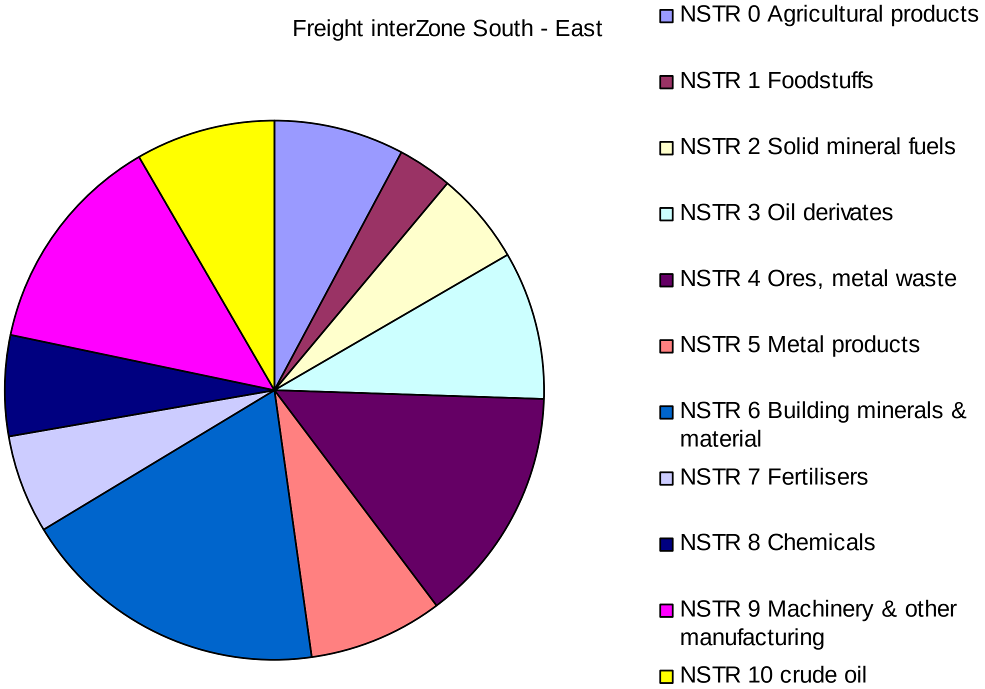



**Figure 179: TRANS-TOOLS 2030 Baseline Inter-zone Freight NSTR distribution for South / East relations (only inland traffic included)**

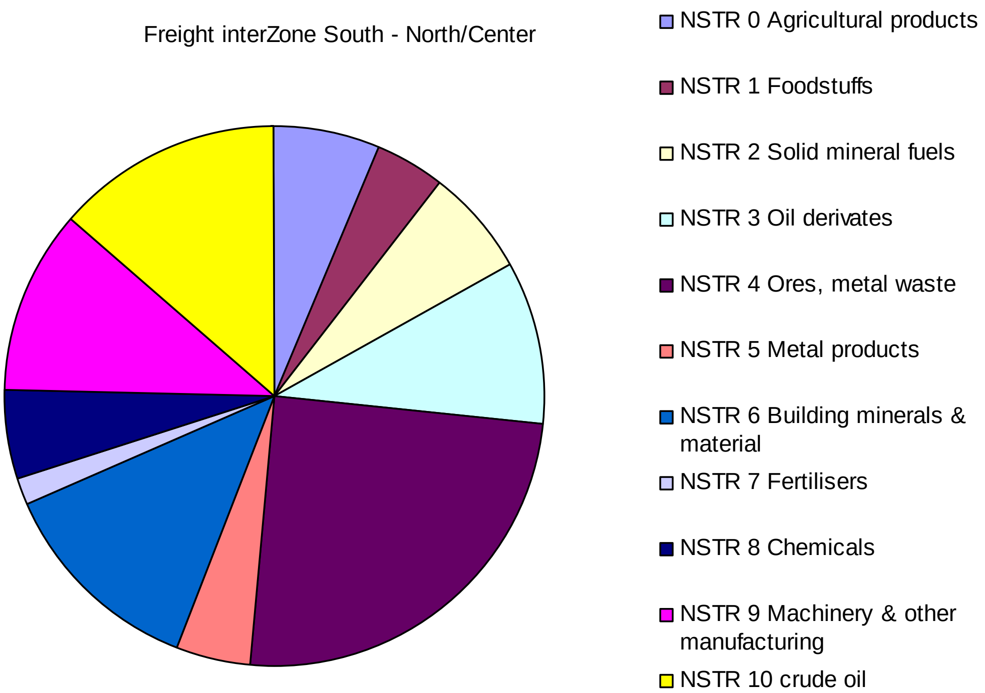



**Figure 180: TRANS-TOOLS 2030 Baseline Inter-zone Freight NSTR distribution for South / North/Centre relations (only inland traffic included)**

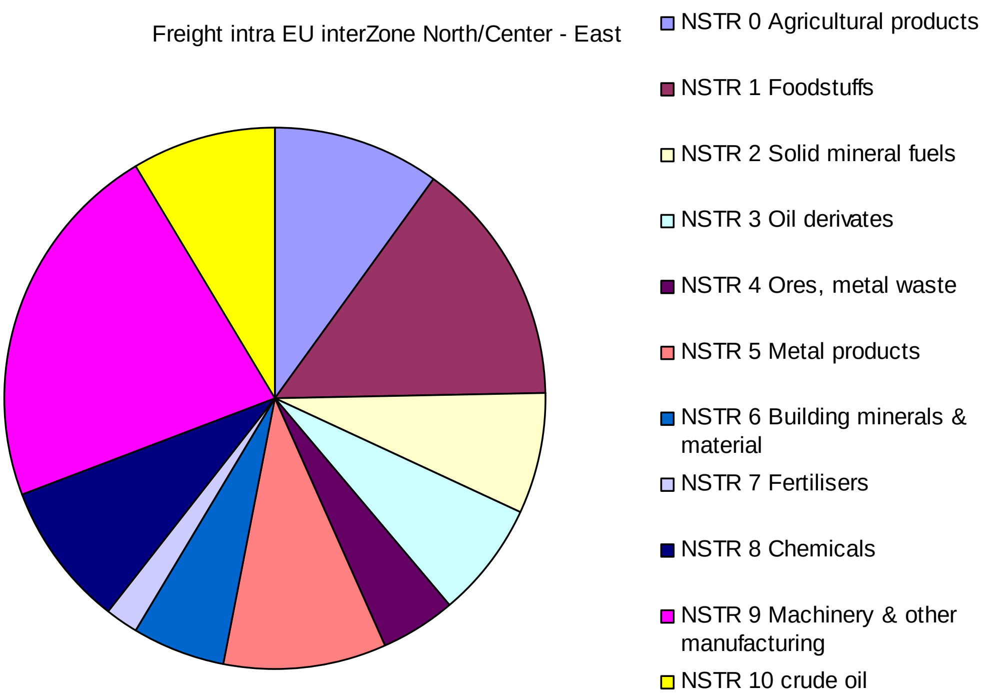



**Figure 181: TRANS-TOOLS 2030 Baseline Inter-zone Freight NSTR distribution for East / North/Centre relations (only inland traffic included)**

Distribution of freight ton-km 2030 baseline according to NSTR 1digit classification for traffic among European macrozones, including inland traffic (road, rail, and IWW).

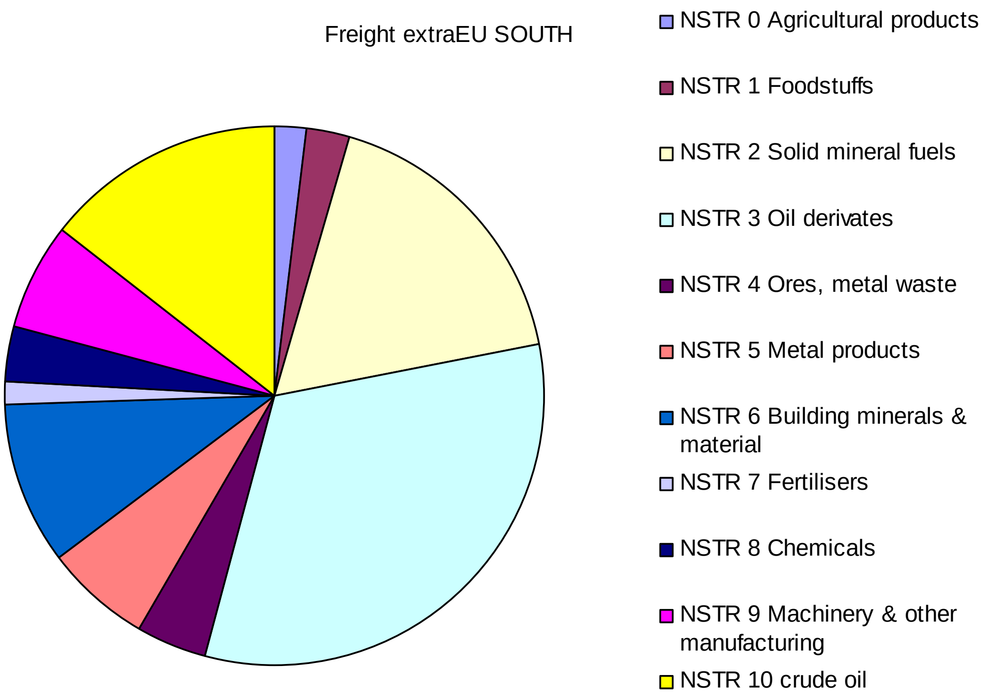



**Figure 182: TRANS-TOOLS 2030 Baseline Extra-EU Freight NSTR distribution for South macrozone (only inland traffic included)**

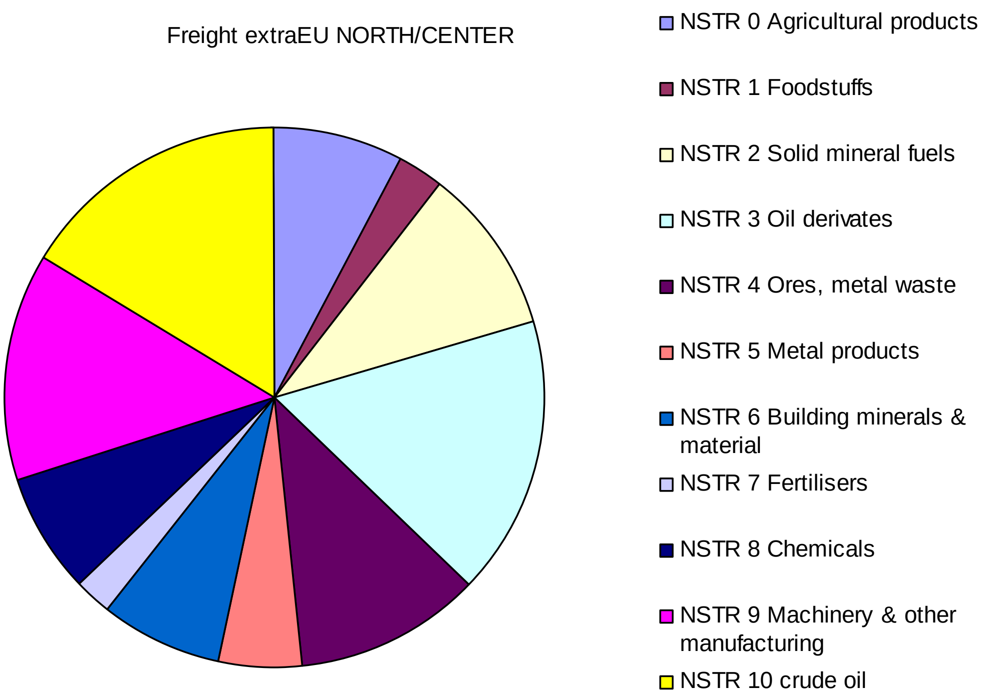



**Figure 183: TRANS-TOOLS 2030 Baseline Extra-EU Freight NSTR distribution for North/Centre macrozone (only inland traffic included)**

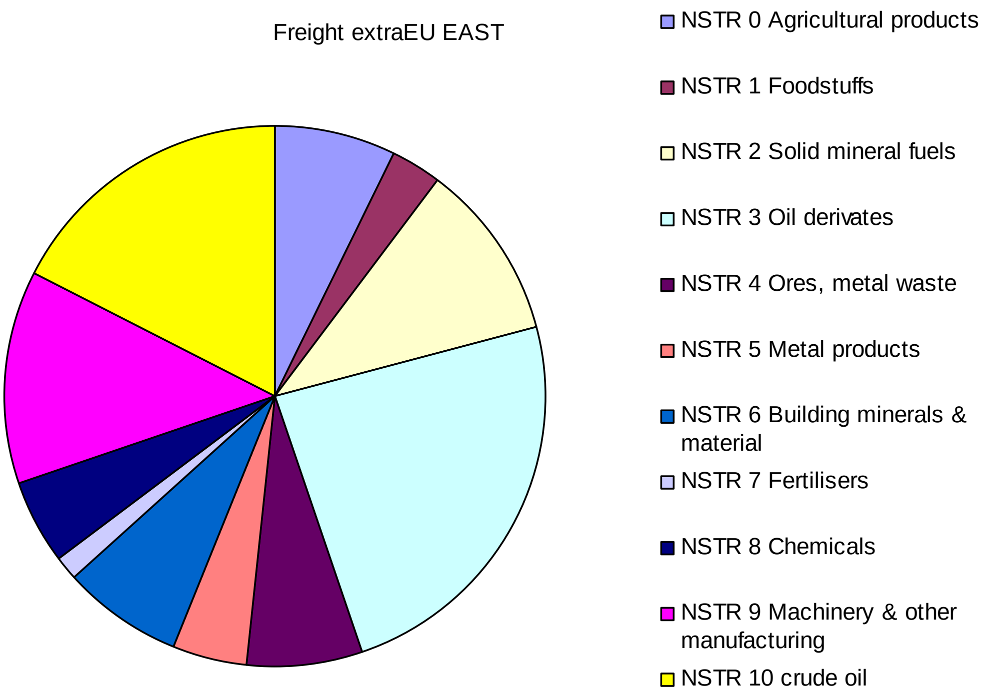



**Figure 184: TRANS-TOOLS 2030 Baseline Extra-EU Freight NSTR distribution for East macrozone (only inland traffic included)**

Distribution of freight ton-km 2030 baseline according to NSTR 1digit classification for traffic with non-EU-27 countries, including inland traffic (road, rail, and IWW).

# 10. Appendix III: Results of predictive scenarios for passenger transport.

Five different types of trips are considered:

- Regional: intra-NUTS2 trips.
- Domestic: rest of trips with origin and destination inside the same country.
- Intra-Zone: trips with origin and destination inside the same macrozone, South (Portugal, Italy, Greece, Spain), North/Centre (rest of the EU-15), East (rest of the EU-27).
- Inter-Zone: trips with origin and destination in different macrozones.
- Extra-EU: trips with origin or destination outside the EU-27, in one of the neighbouring countries.

Given that TRANS-TOOLS does not include air traffic to overseas (although it is added externally in the Meta-models), the following figures only include the intra-european air traffic and the trips to neighbouring countries. Overflights in European airspace are also excluded, as they are out of the scope of either TRANS-TOOLS and Meta-models, although these flights generate emissions and congestion over Europe.

## 10.1. *Analysis of passenger traffic in 2005 (all modes included)*

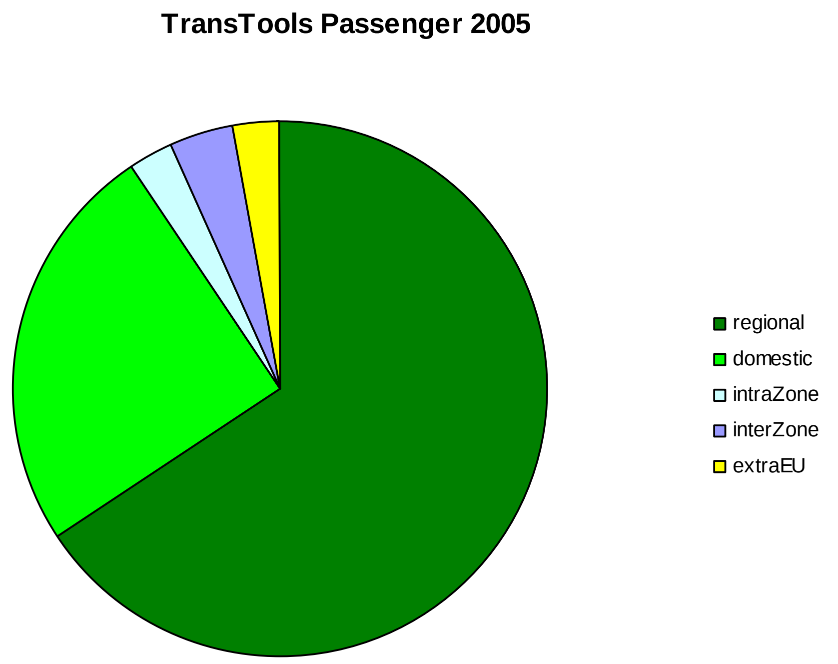



**Figure 185: TRANS-TOOLS 2005 Passenger Pax-km geographic distribution according to distance of trip (all modes included)**

Geographic distribution of EU-27 passenger-km from TRANS-TOOLS 2005, including road, rail, and air.

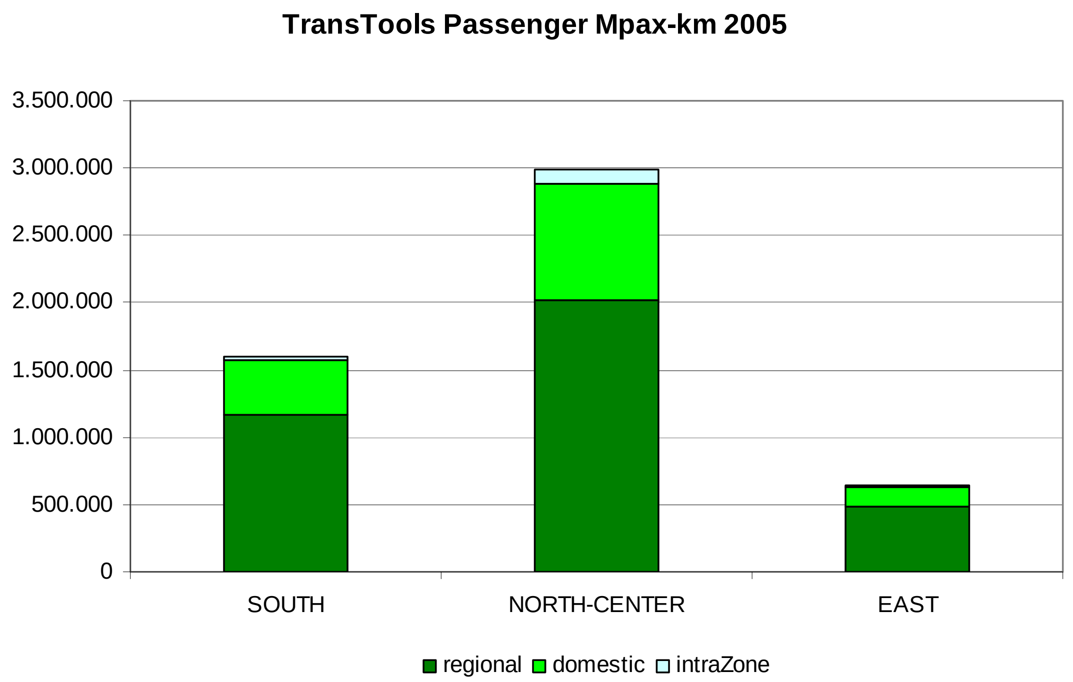



**Figure 186: TRANS-TOOLS 2005 Passenger Pax-km volume of short and mid-distance trips according to European macrozone (all modes included)**

Passenger volumes in pax-km from TRANS-TOOLS 2005, including road, rail, and air, according to European macrozone.

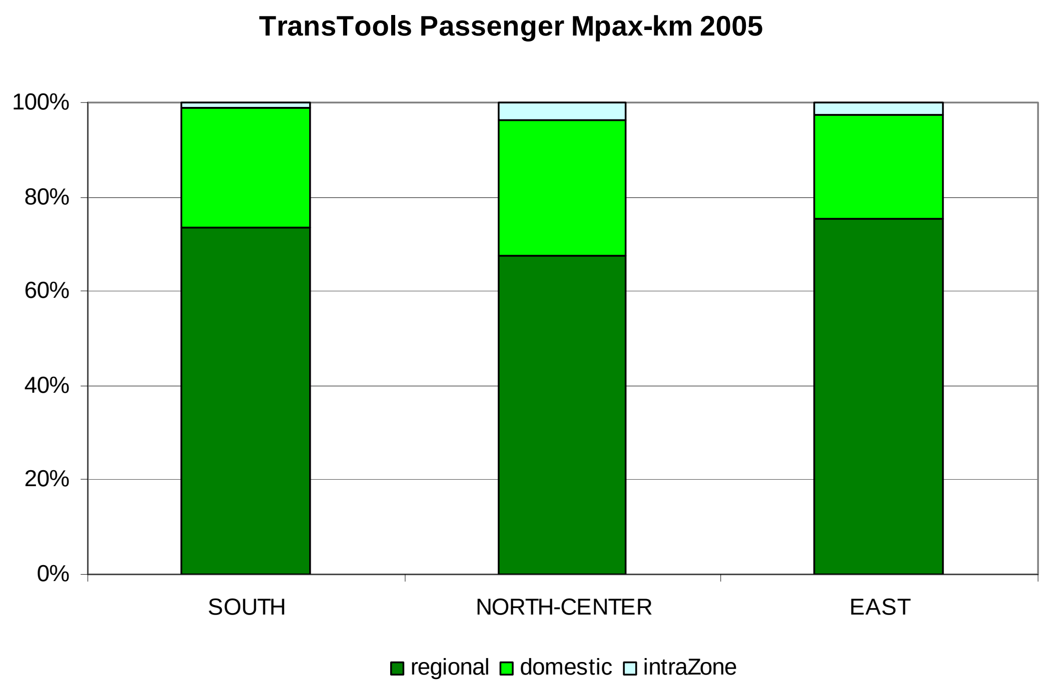



**Figure 187: TRANS-TOOLS 2005 Passenger Pax-km distribution of short and mid-distance trips according to European macrozone (only inland traffic included)**

Share of passenger volumes according to length of trip in pax-km from TRANS-TOOLS 2005, including road, rail and air, divided by European macrozones.

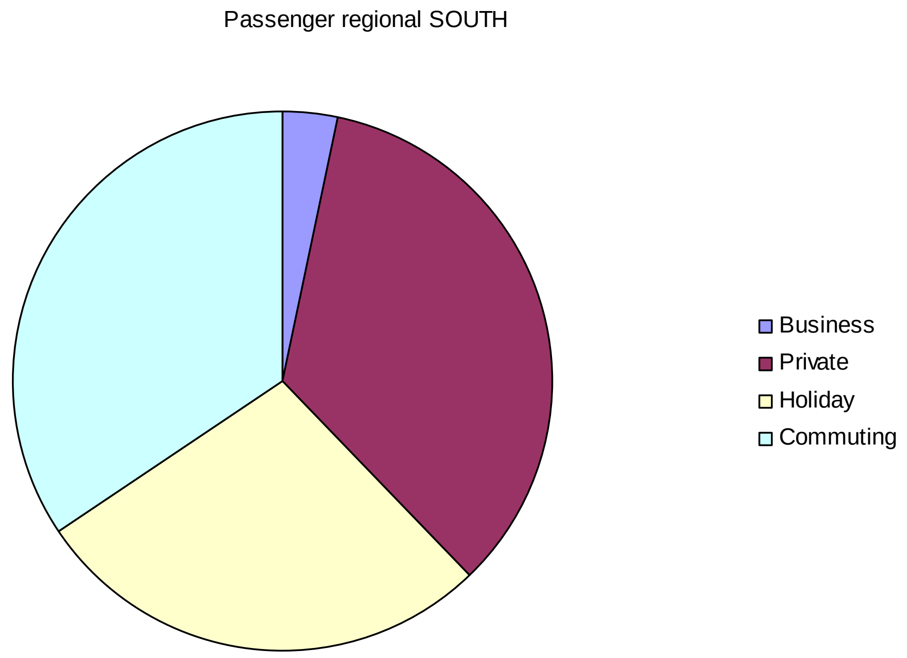



**Figure 188: TRANS-TOOLS 2005 Regional Passenger trip purpose distribution for South macrozone (all modes included)**

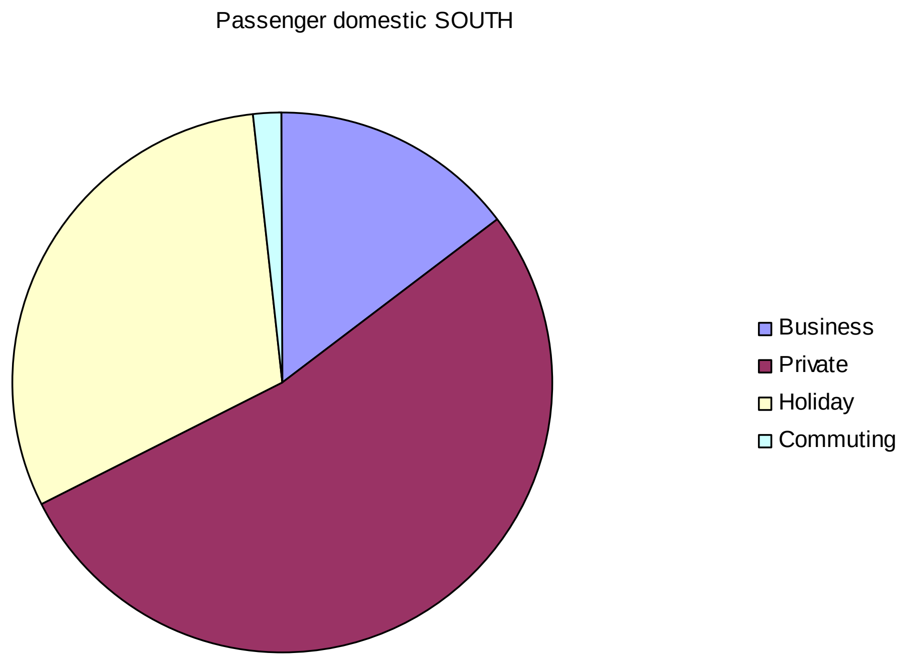



**Figure 189: TRANS-TOOLS 2005 Domestic Passenger trip purpose distribution for South macrozone (all modes included)**

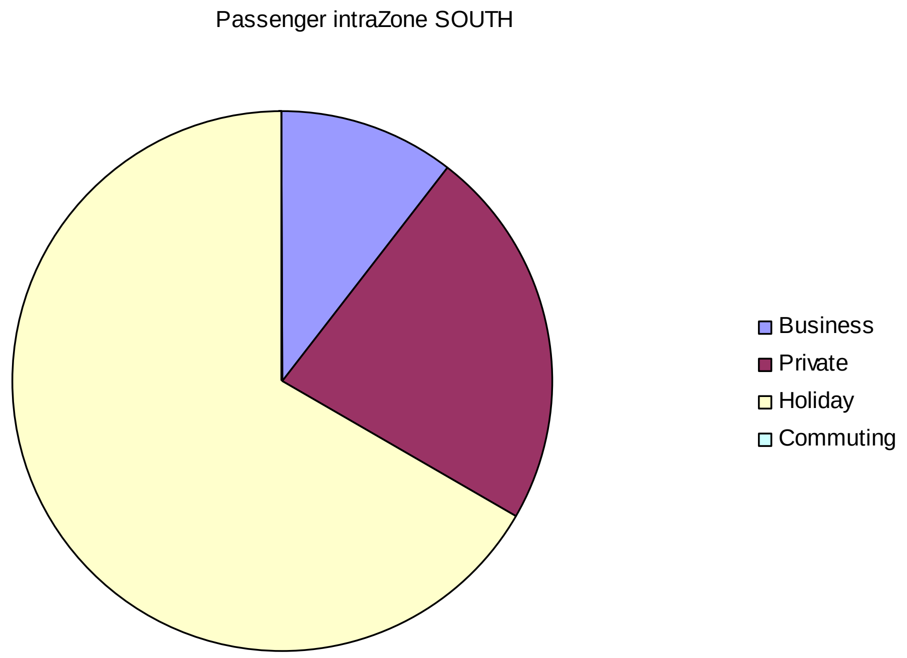



**Figure 190: TRANS-TOOLS 2005 Intra-Zone Passenger trip purpose distribution for South macrozone (all modes included)**

Distribution of passenger pax-km 2005 according to trip purpose for South Europe, including road, rail and air.

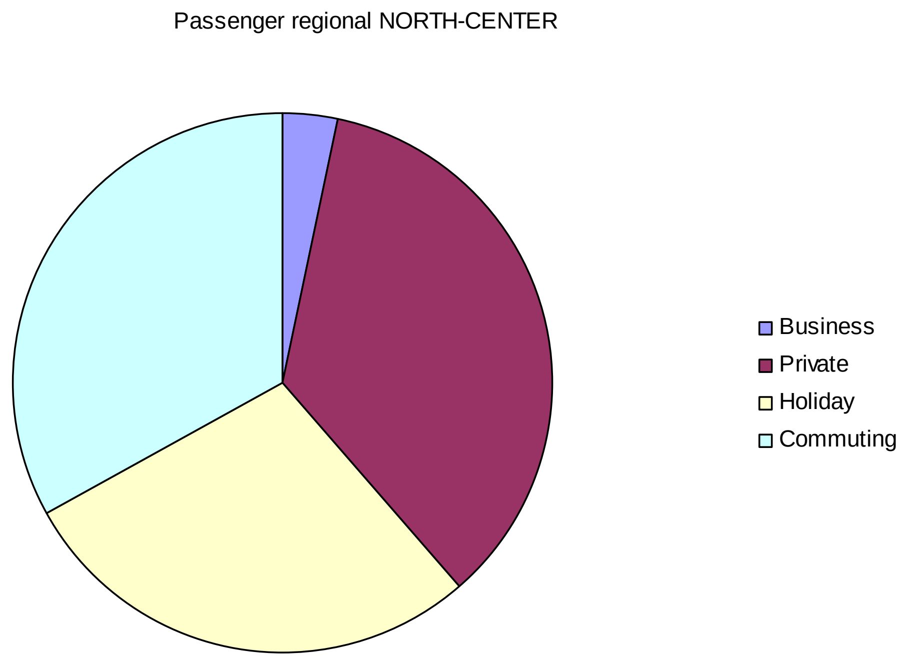



**Figure 191: TRANS-TOOLS 2005 Regional Passenger trip purpose distribution for North/Centre macrozone (all modes included)**

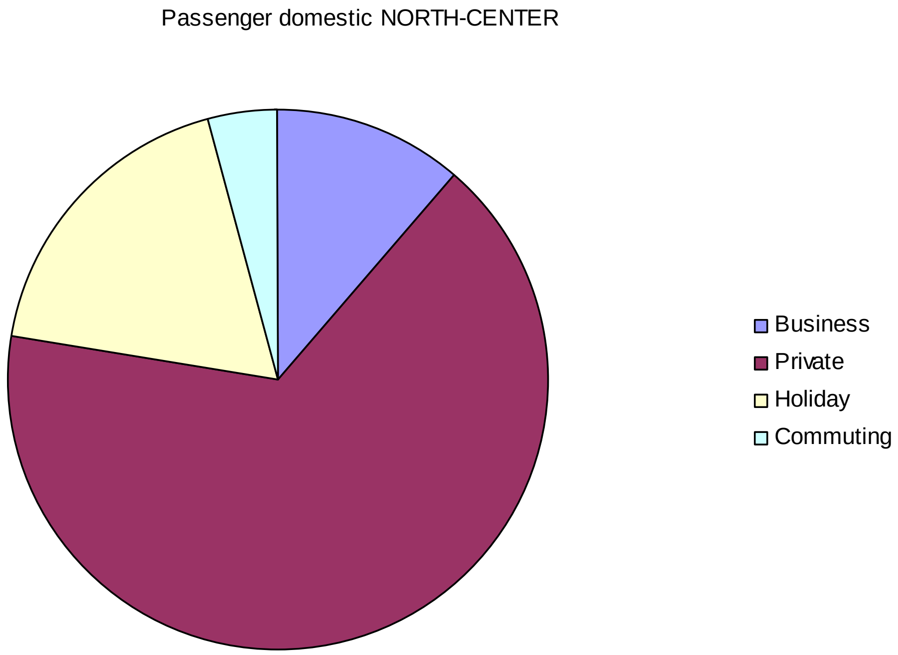



**Figure 192: TRANS-TOOLS 2005 Domestic Passenger trip purpose distribution for North/Centre macrozone (all modes included)**

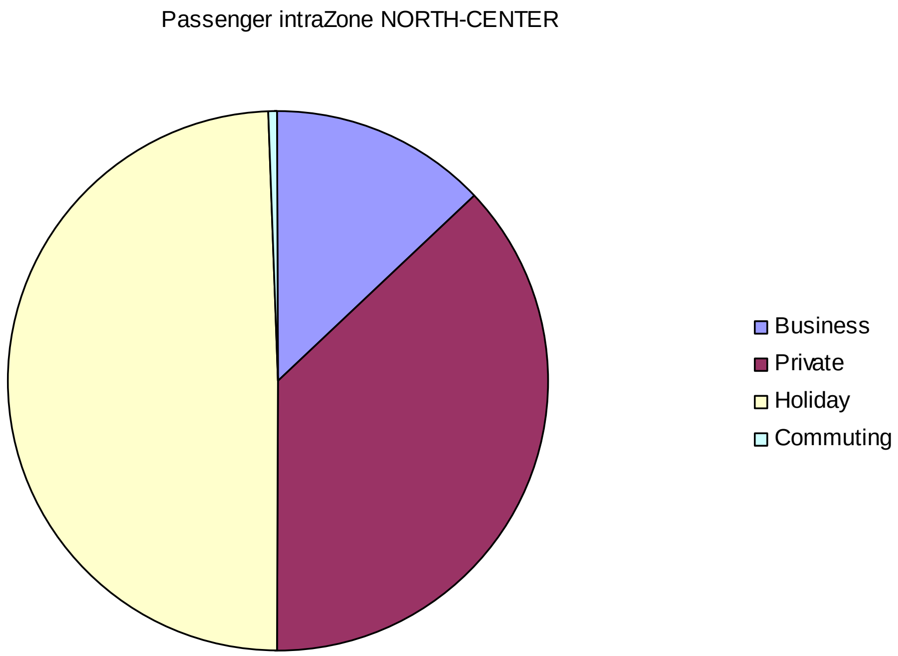



**Figure 193: TRANS-TOOLS 2005 Intra-Zone Passenger trip purpose distribution for North/Centre macrozone (all modes included)**

Distribution of passenger pax-km 2005 according to trip purpose for North/Centre Europe, including road, rail and air.

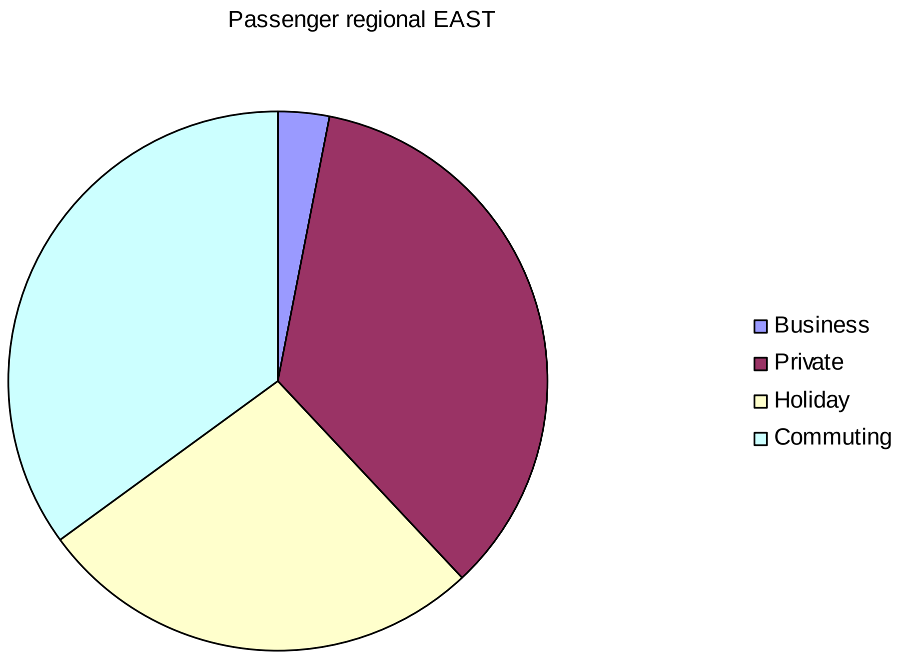



**Figure 194: TRANS-TOOLS 2005 Regional Passenger trip purpose distribution for East macrozone (all modes included)**

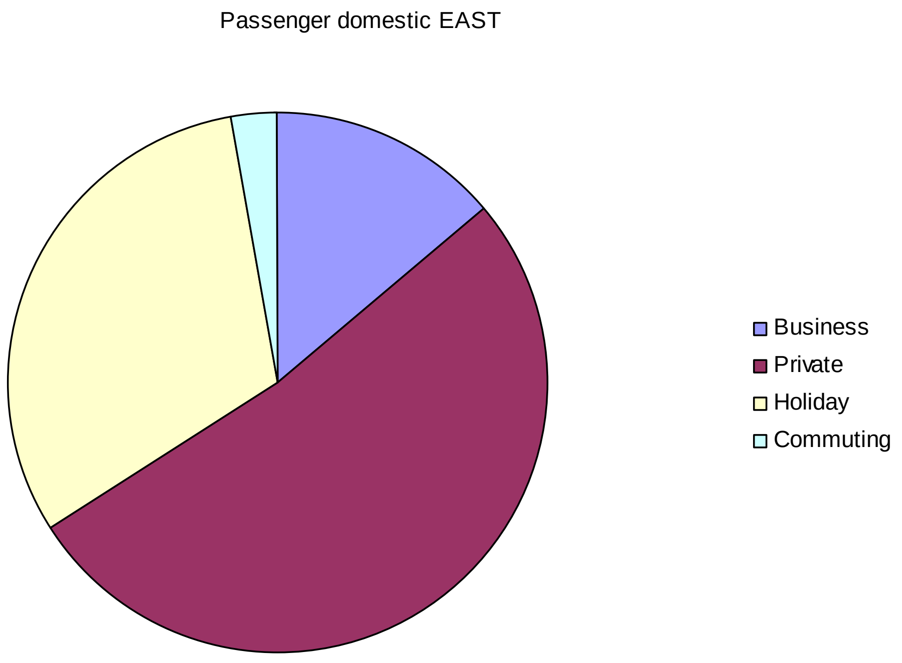



**Figure 195: TRANS-TOOLS 2005 Domestic Passenger trip purpose distribution for East macrozone (all modes included)**

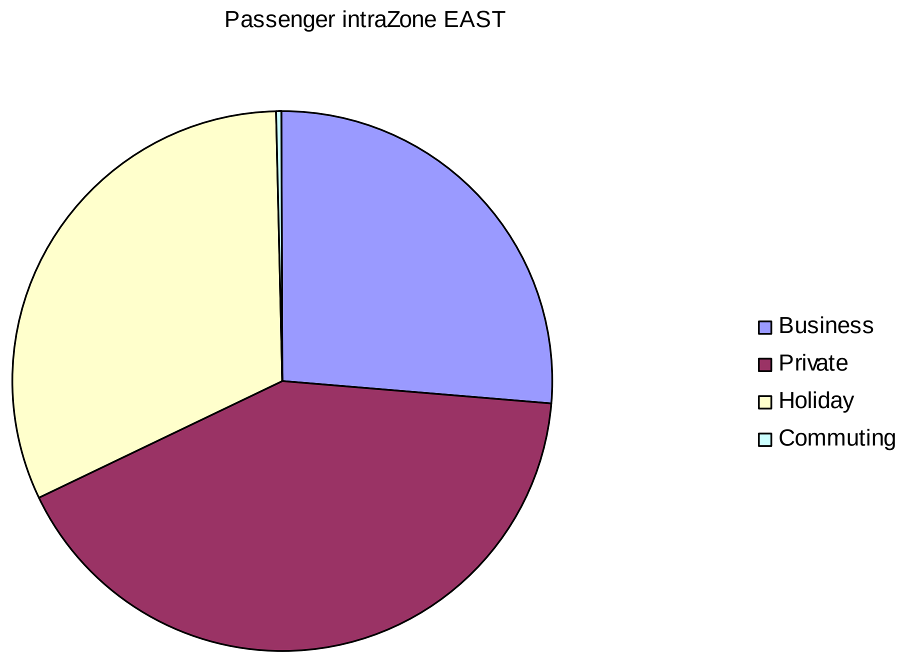



**Figure 196: TRANS-TOOLS 2005 Intra-Zone Passenger trip purpose distribution for East macrozone (all modes included)**

Distribution of passenger pax-km 2005 according to trip purpose for East Europe, including road, rail and air.

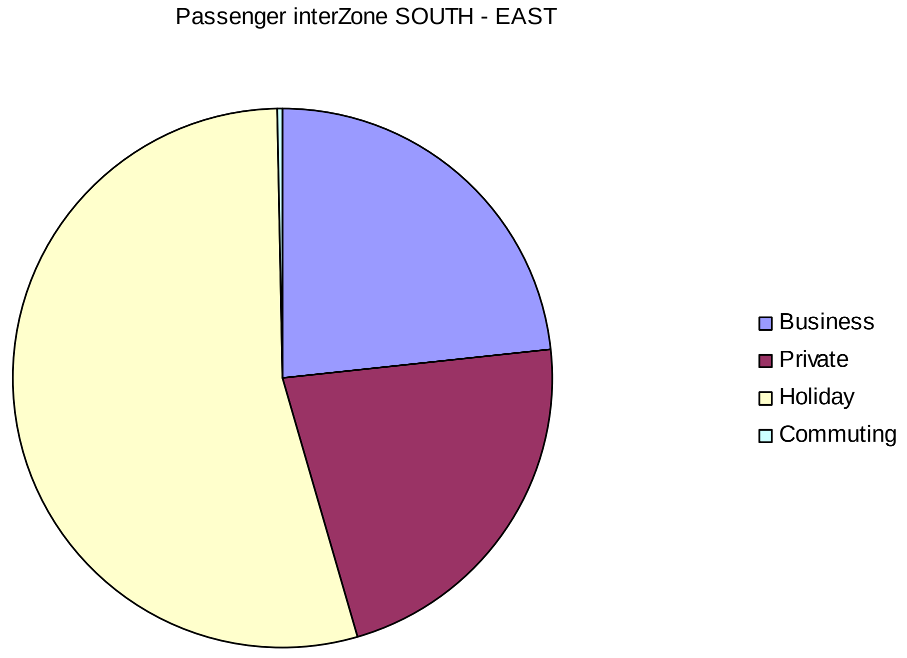



**Figure 197: TRANS-TOOLS 2005 Inter-Zone Passenger trip purpose distribution for South / East relations (all modes included)**

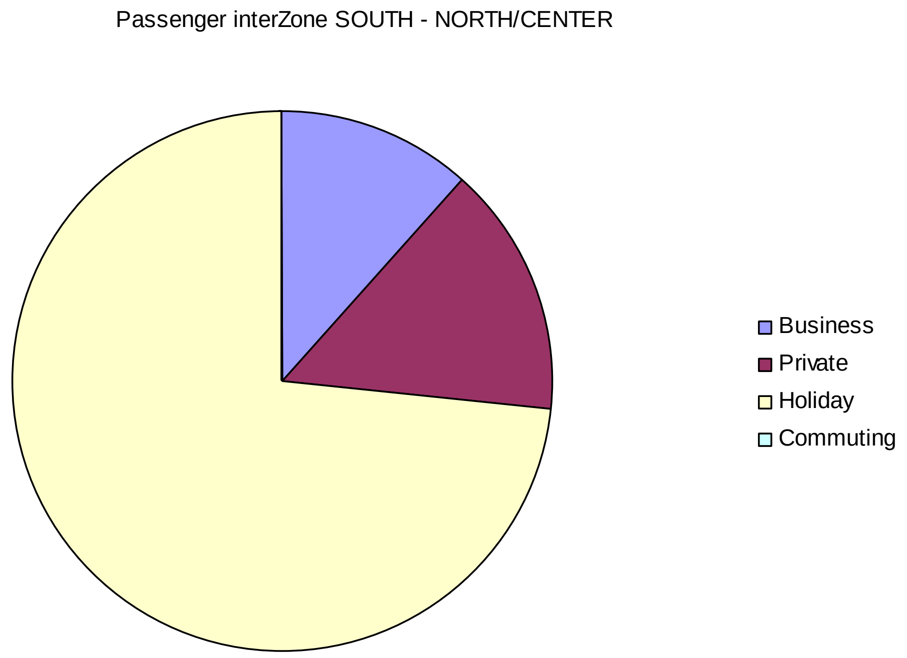



**Figure 198: TRANS-TOOLS 2005 Inter-Zone Passenger trip purpose distribution for South / North/Centre relations (all modes included)**

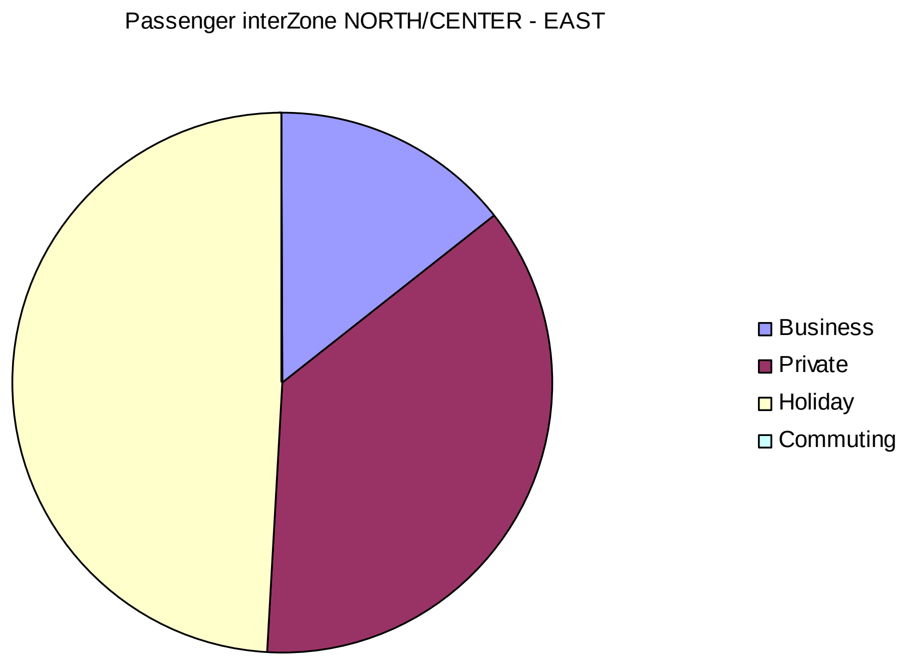



**Figure 199: TRANS-TOOLS 2005 Inter-Zone Passenger trip purpose distribution for East / North/Centre relations (all modes included)**

Distribution of passenger pax-km 2005 according to trip purpose among European macrozones, including road, rail and air.

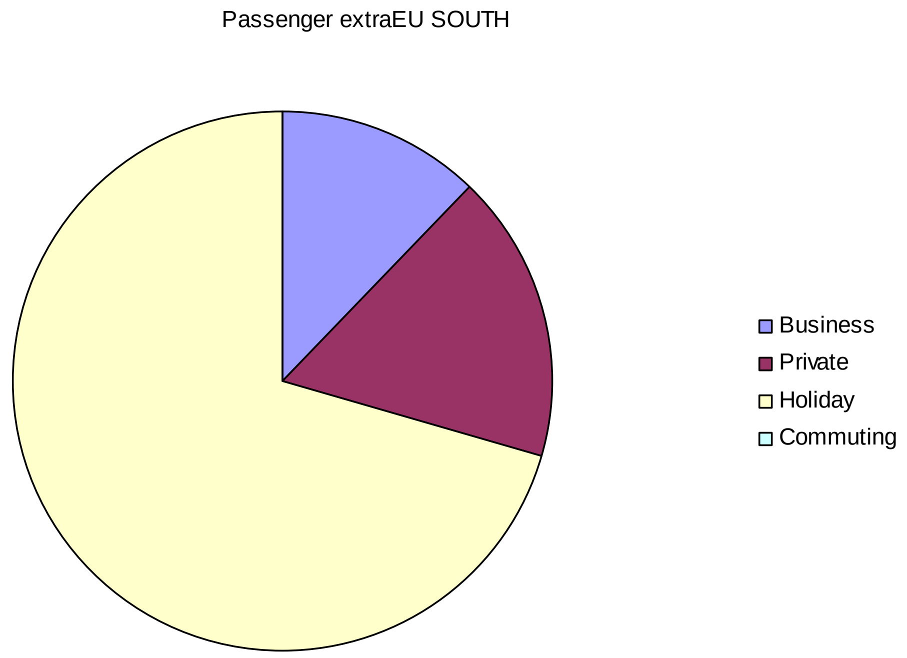



**Figure 200: TRANS-TOOLS 2005 Extra-EU Passenger trip purpose distribution for South macrozone (all modes included)**

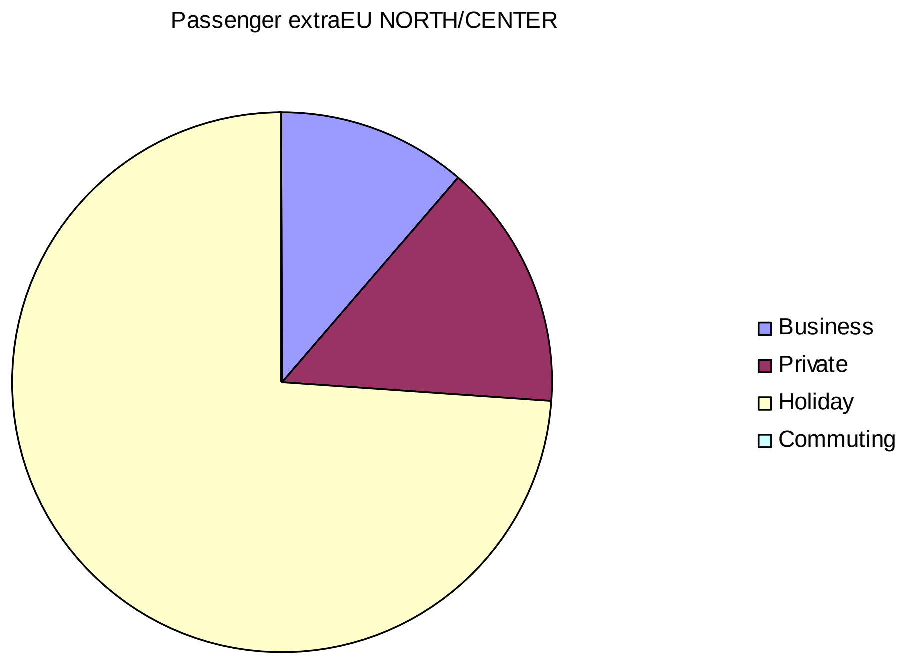



**Figure 201: TRANS-TOOLS 2005 Extra-EU Passenger trip purpose distribution for North/Centre macrozone (all modes included)**

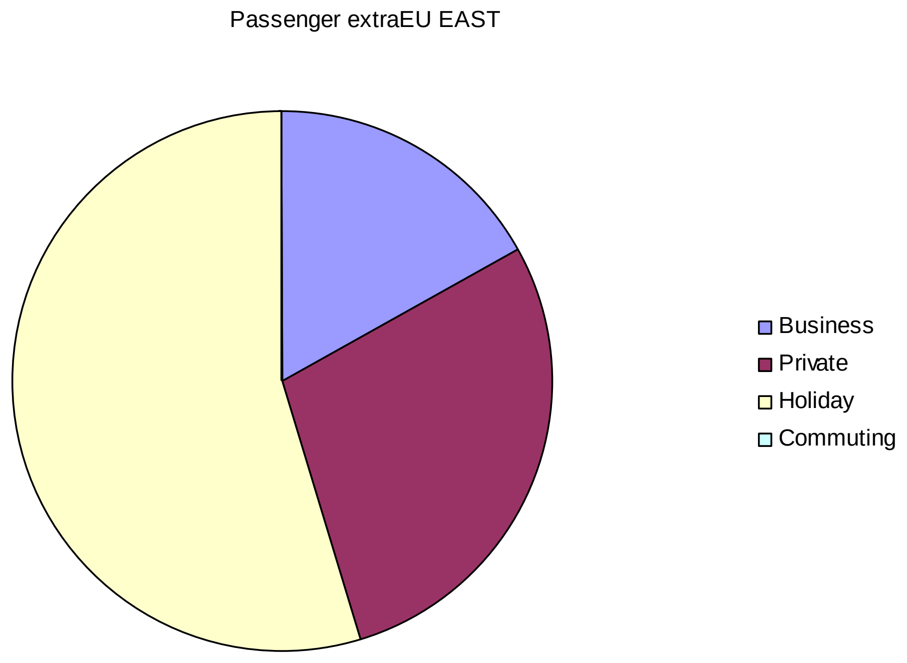



**Figure 202: TRANS-TOOLS 2005 Extra-EU Passenger trip purpose distribution for East macrozone (all modes included)**

Distribution of passenger pax-km 2005 according to trip purpose for trips with origin or destination outside THE EU-27, including road, rail and air.

## 10.2. *Analysis of passenger traffic (all modes included) for the baseline in 2030*

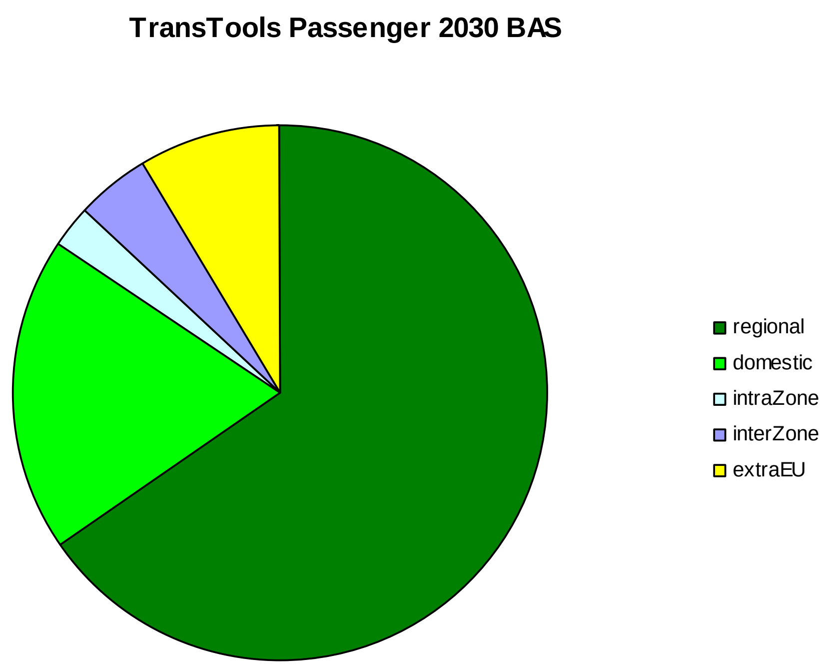



**Figure 203: TRANS-TOOLS 2030 Baseline Passenger Pax-km geographic distribution according to distance of trip (all modes included)**

Geographic distribution of EU-27 passenger-km from TRANS-TOOLS 2030 baseline, including road, rail, and air.

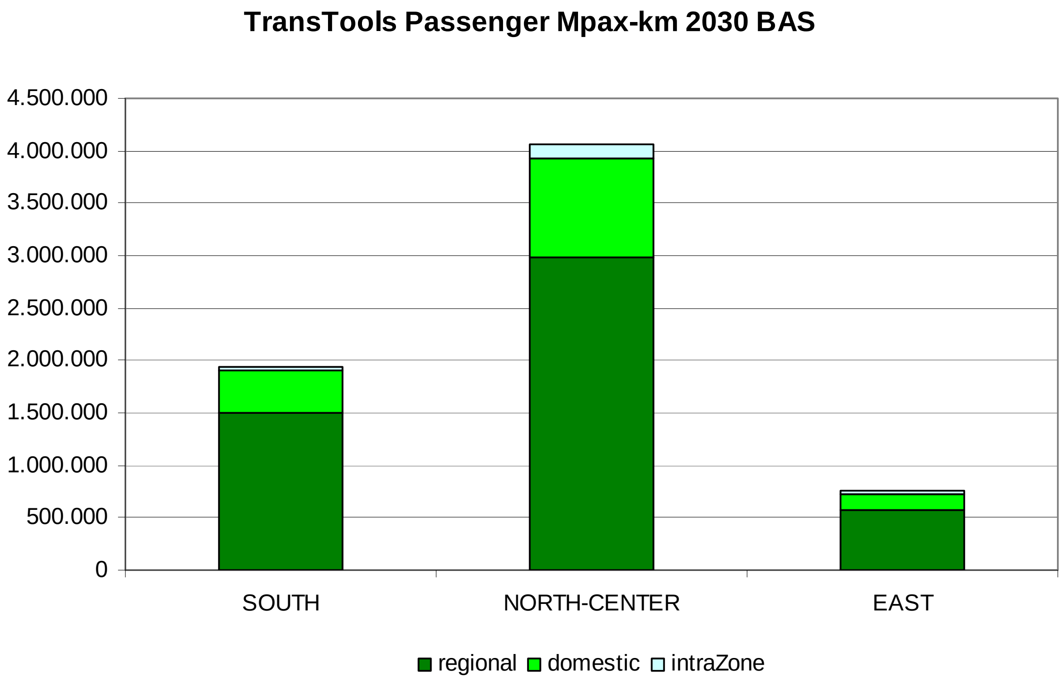



**Figure 204: TRANS-TOOLS 2030 Baseline Passenger Pax-km volume of short and mid-distance trips according to European macrozone (all modes included)**

Passenger volumes in pax-km from TRANS-TOOLS 2030 baseline, including road, rail, and air, according to European macrozone.

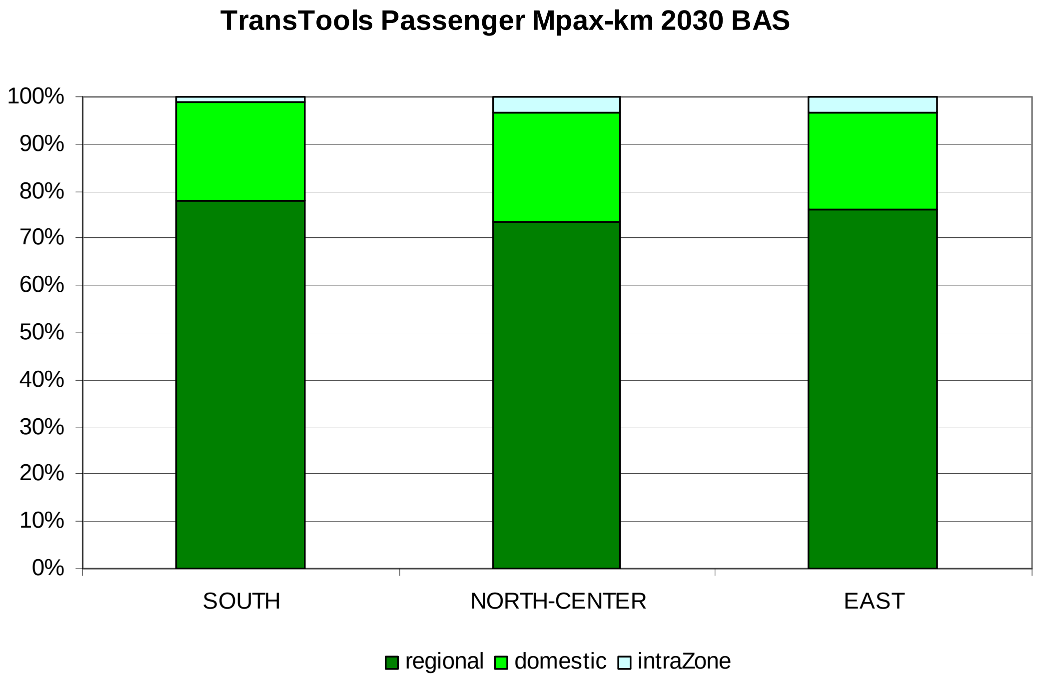



**Figure 205: TRANS-TOOLS 2030 Baseline Passenger Pax-km distribution of short and mid-distance trips according to European macrozone (only inland traffic included)**

Share of passenger volumes according to length of trip in pax-km from TRANS-TOOLS 2030 baseline, including road, rail and air, divided by European macrozones.

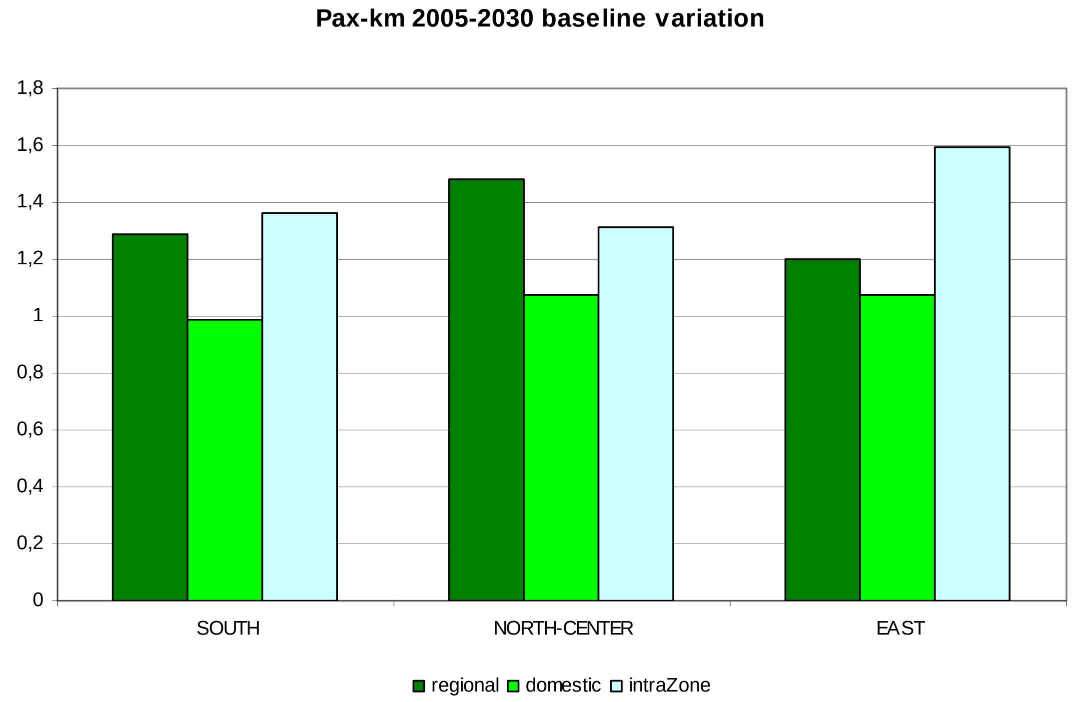



**Figure 206: TRANS-TOOLS Pax-km 2005-2030 Baseline variation according to macrozone**

Passenger traffic growth is of similar magnitude in the three considered macrozones. Because the absolute volume of traffic in the Eastern macro-zone is smaller, the absolute growth is also small.

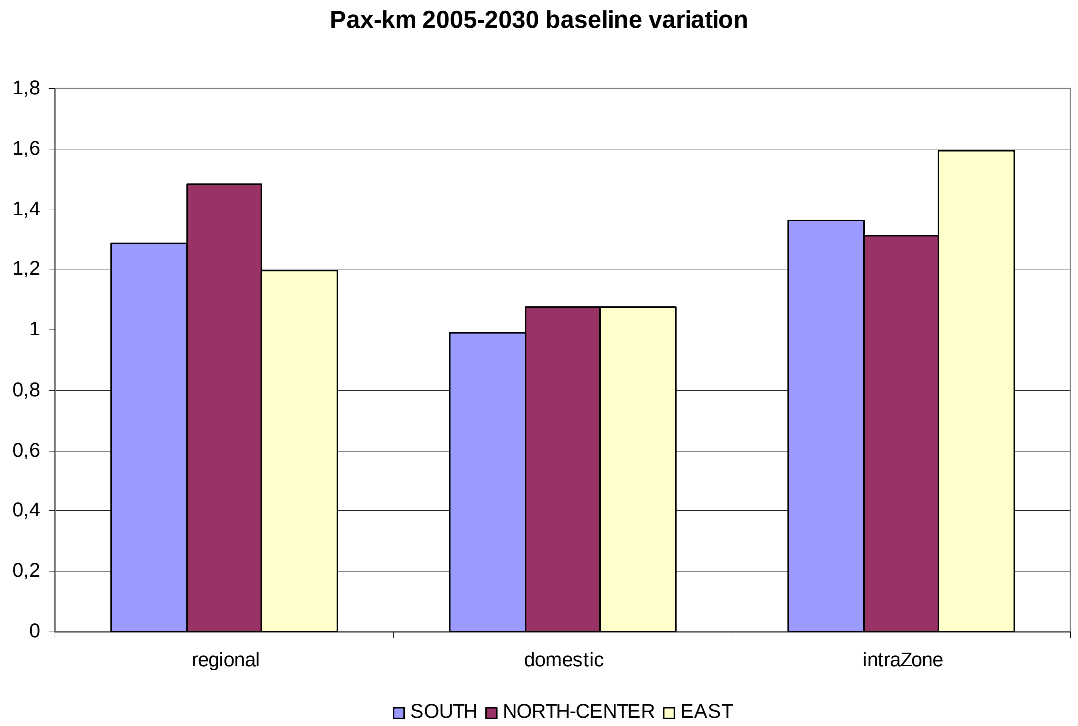



**Figure 207: TRANS-TOOLS Pax-km 2005-2030 Baseline variation according length of trip**

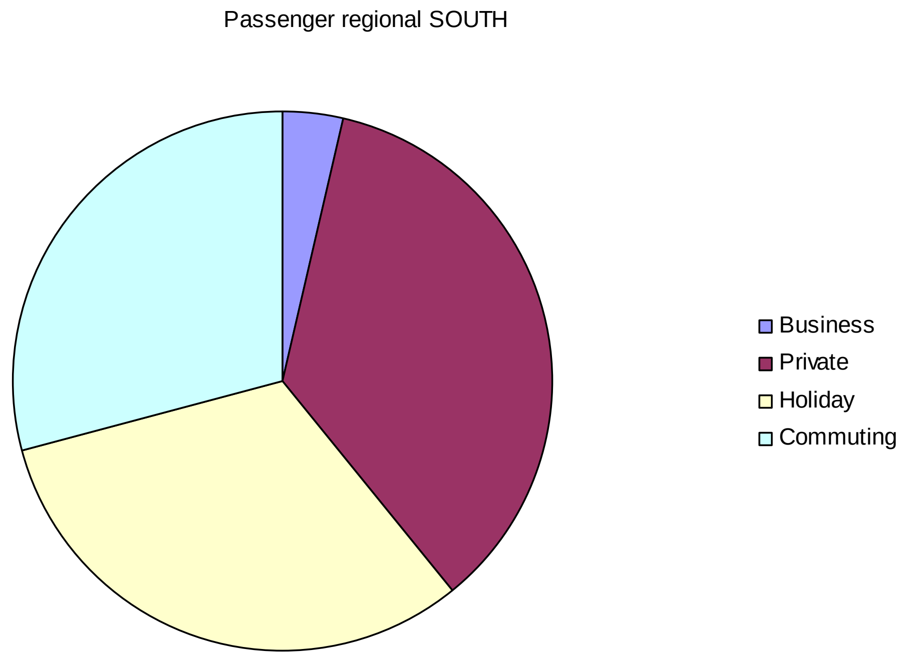



**Figure 208: TRANS-TOOLS 2030 Baseline Regional Passenger trip purpose distribution for South macrozone (all modes included)**

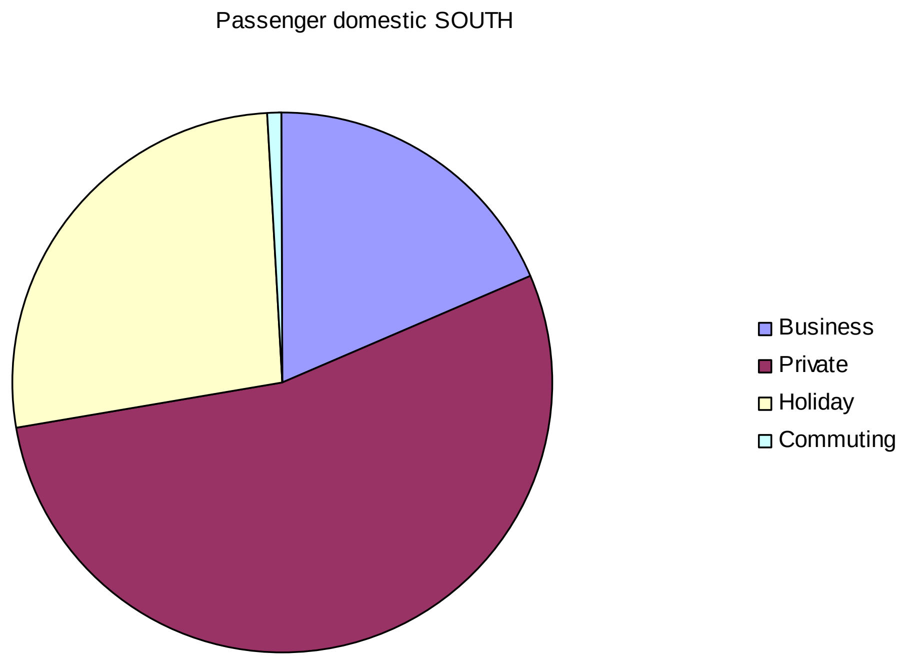



**Figure 209: TRANS-TOOLS 2030 Baseline Domestic Passenger trip purpose distribution for South macrozone (all modes included)**

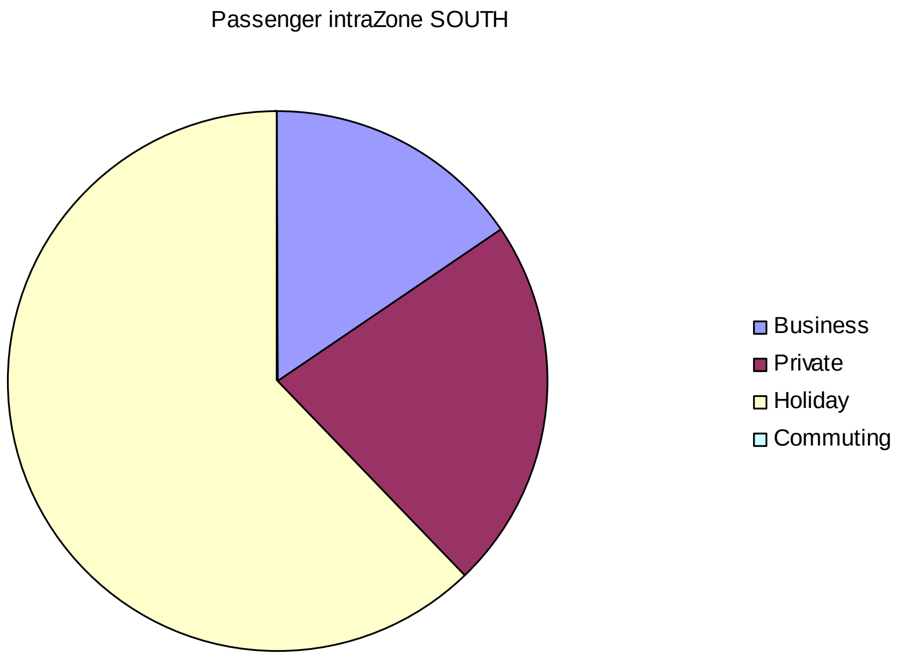



**Figure 210: TRANS-TOOLS 2030 Baseline Intra-Zone Passenger trip purpose distribution for South macrozone (all modes included)**

Distribution of passenger pax-km 2030 baseline according to trip purpose for South Europe, including road, rail and air.

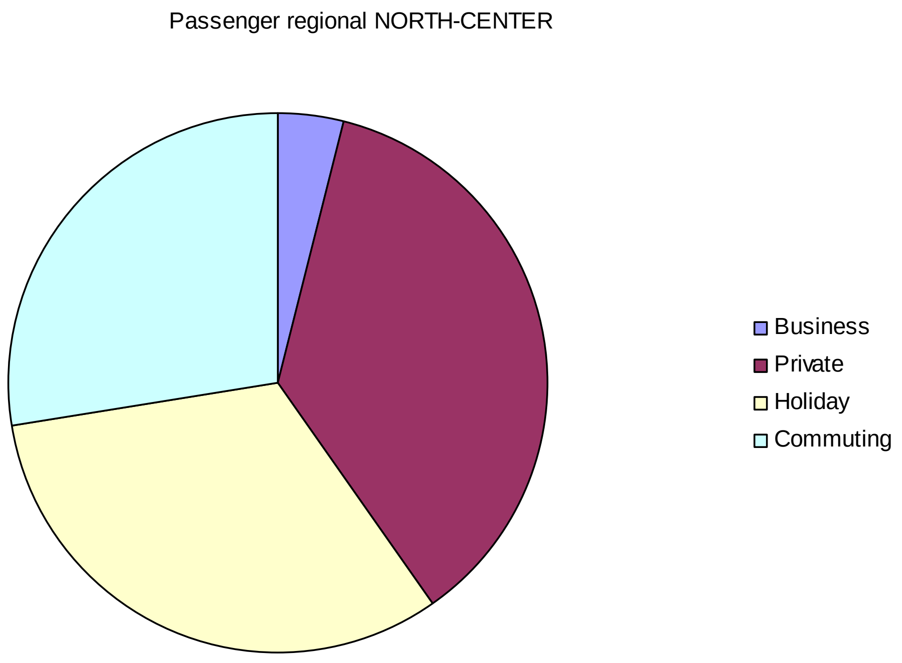



**Figure 211: TRANS-TOOLS 2005 Regional Passenger trip purpose distribution for North/Centre macrozone (all modes included)**

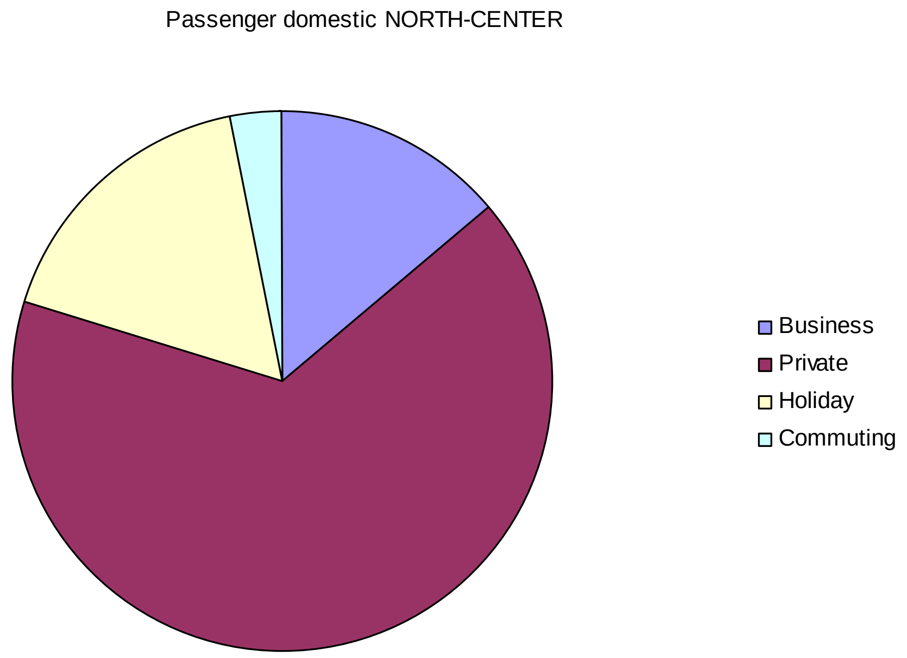



**Figure 212: TRANS-TOOLS 2030 Baseline Domestic Passenger trip purpose distribution for North/Centre macrozone (all modes included)**

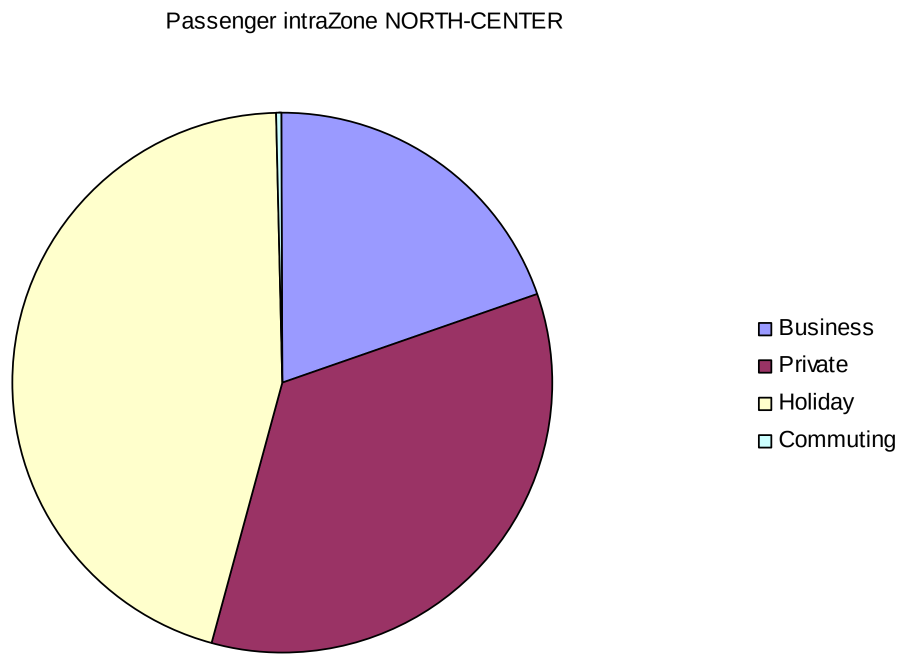



**Figure 213: TRANS-TOOLS 2030 Baseline Intra-Zone Passenger trip purpose distribution for North/Centre macrozone (all modes included)**

Distribution of passenger pax-km 2030 baseline according to trip purpose for North/Centre Europe, including road, rail and air.

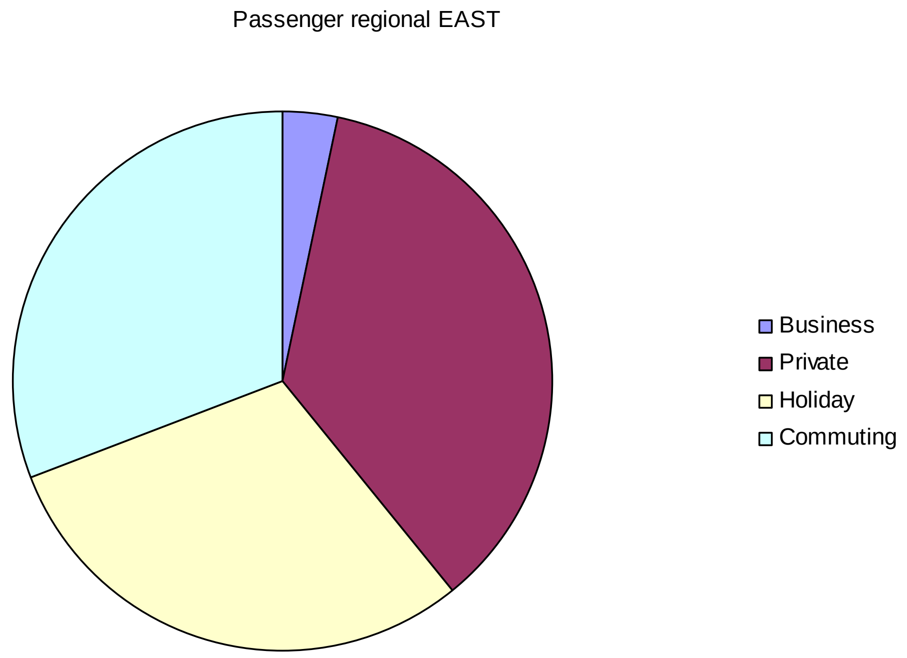



**Figure 214: TRANS-TOOLS 2030 Baseline Regional Passenger trip purpose distribution for East macrozone (all modes included)**

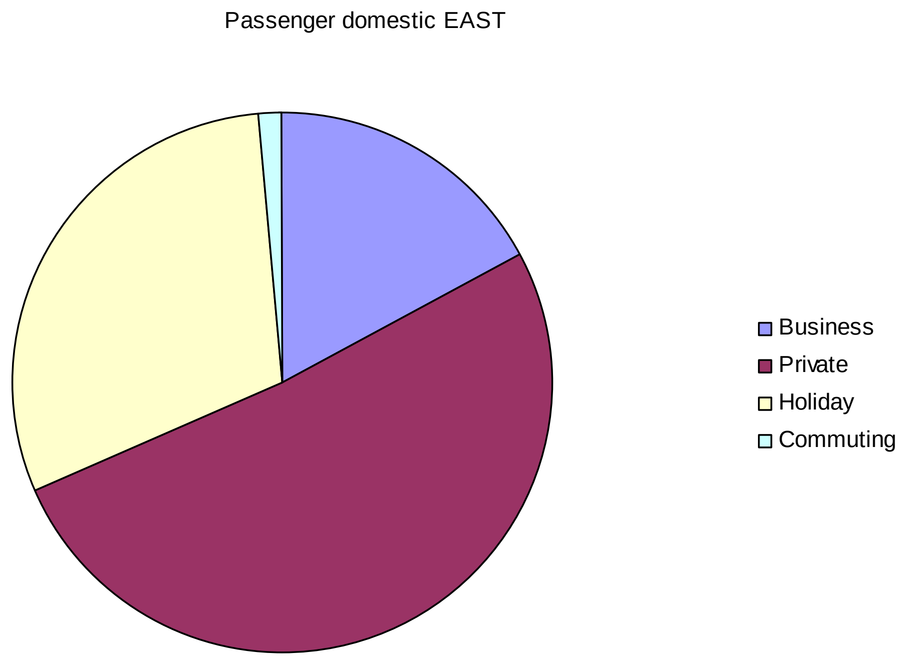



**Figure 215: TRANS-TOOLS 2030 Baseline Domestic Passenger trip purpose distribution for East macrozone (all modes included)**

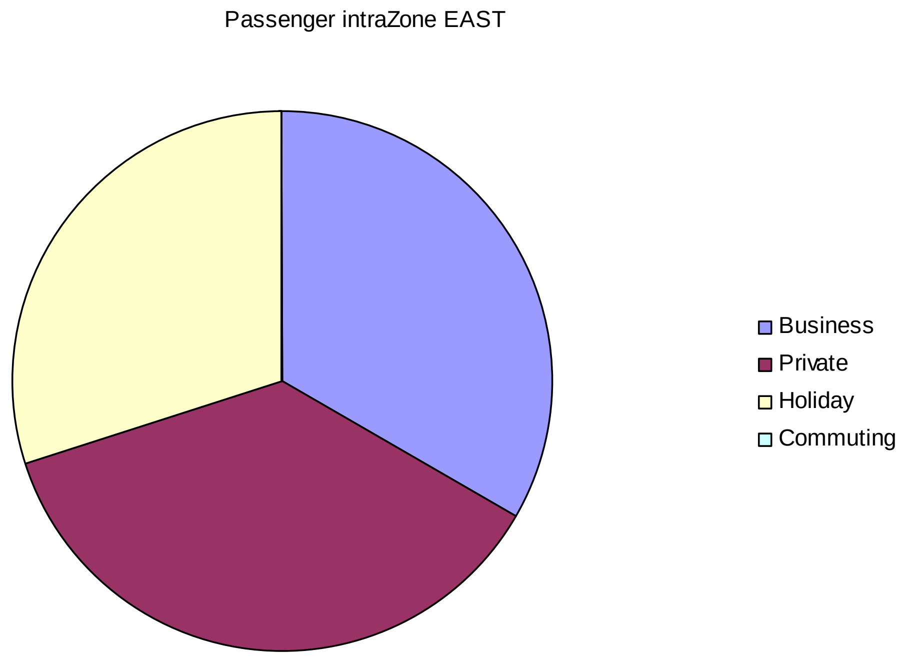



**Figure 216: TRANS-TOOLS 2030 Baseline Intra-Zone Passenger trip purpose distribution for East macrozone (all modes included)**

Distribution of passenger pax-km 2030 baseline according to trip purpose for East Europe, including road, rail and air.

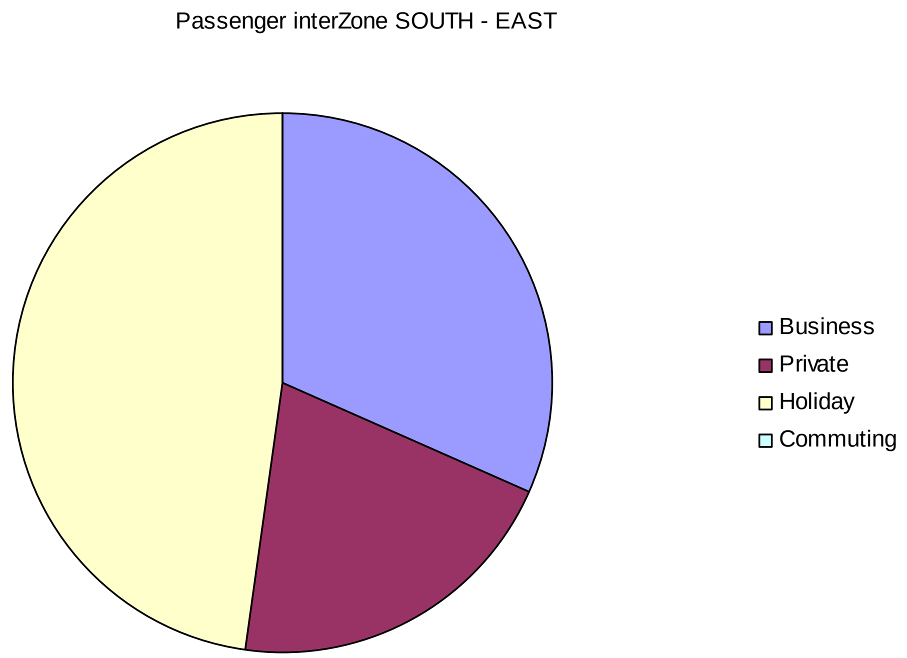



**Figure 217: TRANS-TOOLS 2030 Baselione Inter-Zone Passenger trip purpose distribution for South / East relations (all modes included)**

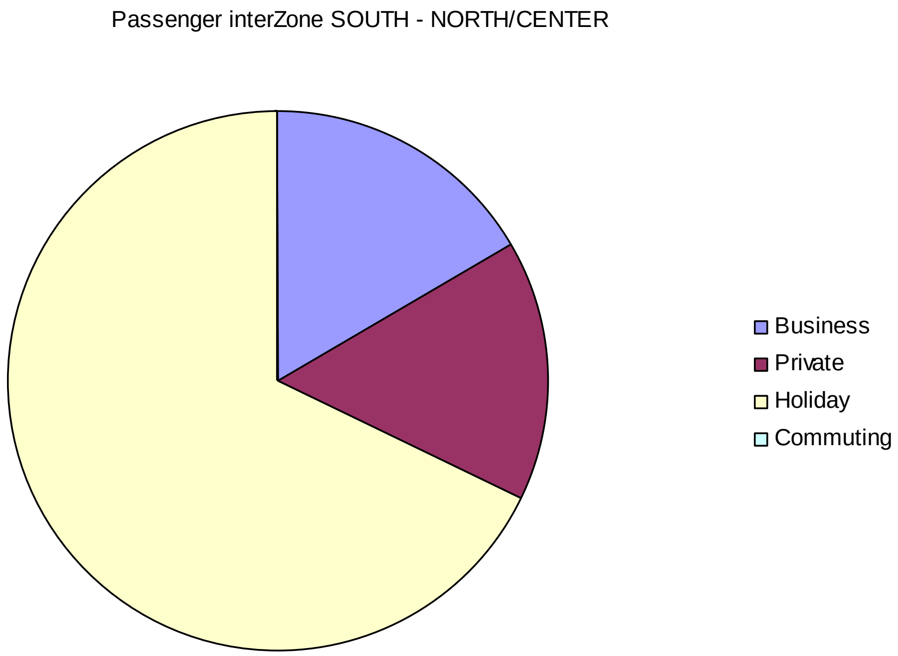



**Figure 218: TRANS-TOOLS 2030 Baseline Inter-Zone Passenger trip purpose distribution for South / North/Centre relations (all modes included)**

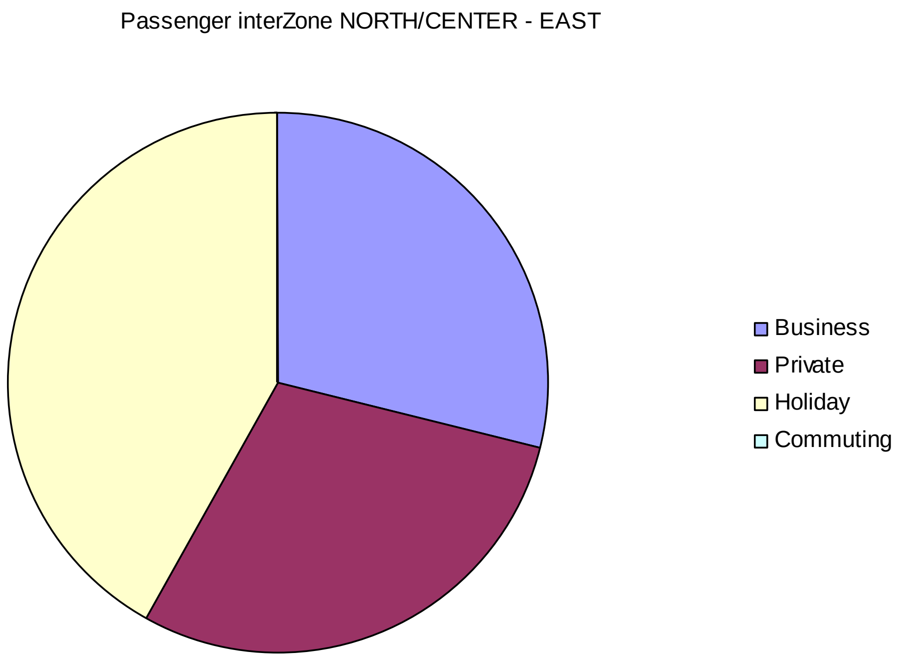



**Figure 219: TRANS-TOOLS 2030 Baseline Inter-Zone Passenger trip purpose distribution for East / North/Centre relations (all modes included)**

Distribution of passenger pax-km 2030 baseline according to trip purpose among European macrozones, including road, rail and air.

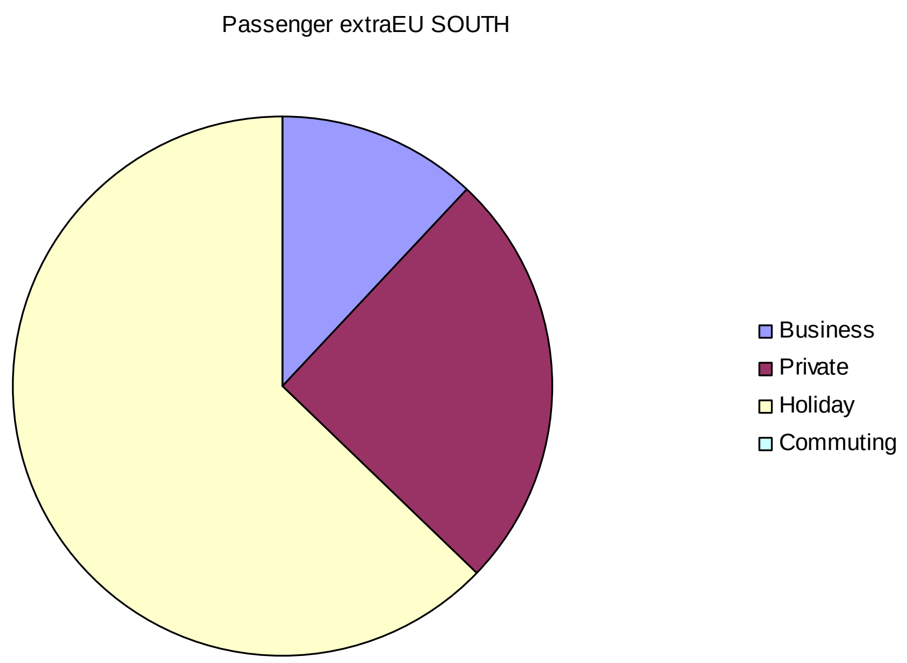



**Figure 220: TRANS-TOOLS 2030 Baseline Extra-EU Passenger trip purpose distribution for South macrozone (all modes included)**

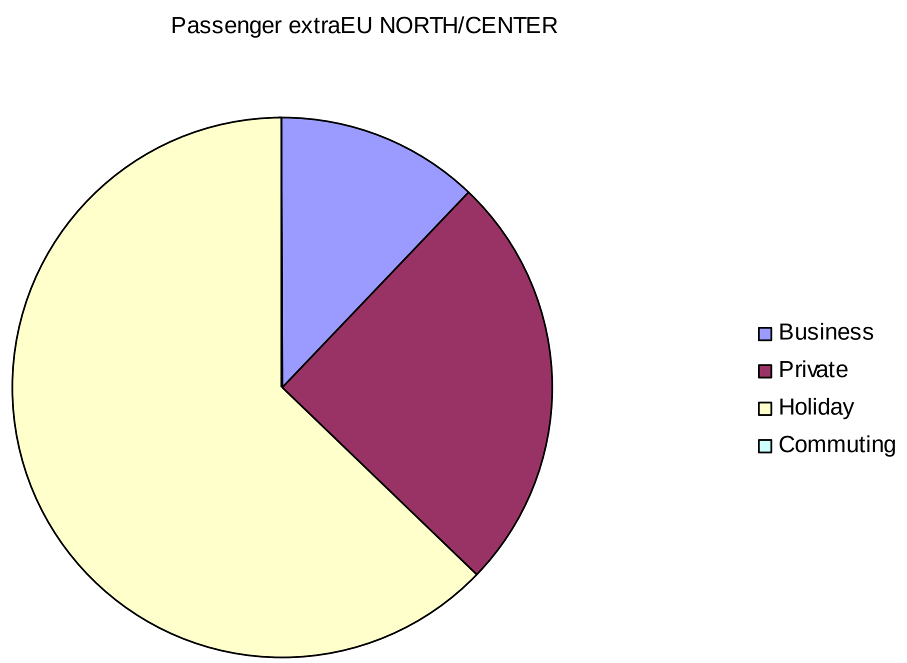



**Figure 221: TRANS-TOOLS 2030 Baseline Extra-EU Passenger trip purpose distribution for North/Centre macrozone (all modes included)**

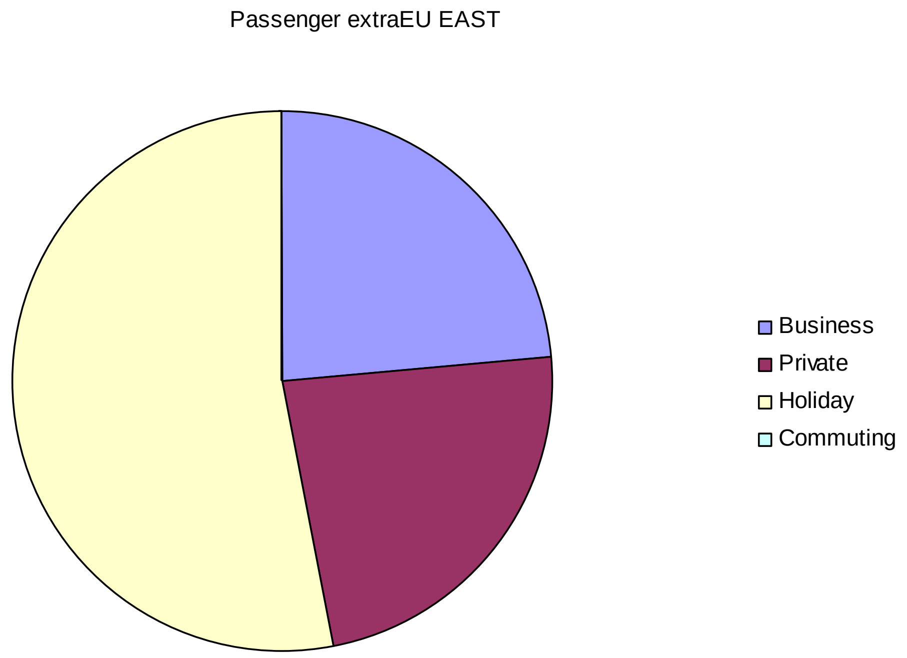



**Figure 222: TRANS-TOOLS 2030 Baseline Extra-EU Passenger trip purpose distribution for East macrozone (all modes included)**

Distribution of passenger pax-km 2030 baseline according to trip purpose for trips with origin or destination outside the EU-27, including road, rail and air.

# 11. Appendix IV: Case Studies.

## 11.1. *Introduction*

The Case studies in the TRANSvisions project have been developed in order to indicate different types of projects for the future already now being pursued. These projects can provide insight into the future development of transport policies. The TRANSvisions study has defined five different groups of policy instrument. The groups were:

- **Infrastructure** development of new infrastructure in order to improve cohesion, accessibility and reduce congestion. However, it should be acknowledged that the majority of large infrastructure is already in place today. If a new type of vehicle is invented, new infrastructure can be established relatively fast, as was demonstrated with the European High Speed Train system. The EU has the possibility to influence infrastructure development.

- **Technology**; development of new or improved technology in the transport field. This includes development and improvement of vehicles using other types of fuel than fossil, but it also includes development of automotive technology, less fuel-consuming technology, and integration and application of IT. EU has limited possibilities for influencing this policy area (such as support for Research and Development, and framework conditions for introduction and use of new technology).

- **Economic**; this is an area where a number of transport policy initiatives are being carried out, including infrastructure charging and internalising external costs.

- **Regulatory**; development of legislation and regulations monitoring traffic, vehicle performance, working hours, and land use and planning regulations.

- **Participatory**; instruments concerned with citizen involvement, for example in the planning of new infrastructure.

Particularly in the group of technology, a number of future-oriented projects are being carried out. In the other groups it has also been possible to identify initiatives pointing to the future.

## 11.2. *Infrastructure*

Much of planned infrastructure for the future is rail infrastructure. Development of rail infrastructure is being pursued by the European Union through its policies on Trans-European Networks, ERTMS and research and development in the rail sector. Of particular interest is the Betuwe line, which is a dedicated freight railway line connecting the port of Rotterdam with the Ruhr area. A future infrastructure policy could be development of a specific freight railway infrastructure system.

Some of the important pieces of infrastructure development in Europe have been construction of bridges and tunnels linking previously separated areas with each other. A very successful development has been the Öresund fixed link connecting Denmark and Sweden. This link has been successful not only because it connects two major urban areas in the region and an important airport, but also because a number of other aspects favoured a strong traffic development, such as high employment in Denmark, unemployment in south Sweden, expensive housing in Denmark and many cheap dwellings in southern Sweden.

Two sectors with strong development potential are the seaport and the airport sectors. Both sectors react to market conditions and development of seaports and airports are therefore first initiated when the need is obvious. However, the development of the low cost airlines has resulted in a number of major airports loosing traffic to smaller, cheaper airports. Therefore, new ways of designing airports have been initiated.

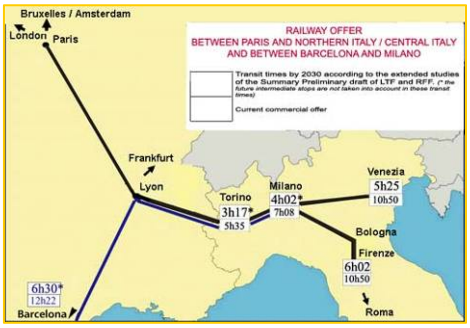
### 11.2.1. Ferrmed Great Rail Freight Axis Scandinavia-Rhine-Rhone-Western Mediterranean

Source: Ferrmed website http://www.ferrmed.com


FERRMED is a multi-sector association that came from private sector initiative in order to enhance European competitiveness by promoting the so-called “FERRMED Standards”, the improvement of Ports and Airports connections with their respective hinterlands. The result was the conception of Great Rail Freight Axis Scandinavia-Rhine-Rhone-Western Mediterranean, a more sustainable development because of its reduction of pollution and climate-changing emissions. The **“concept of Great Axis Network”** incorporates areas going from Saint Petersburg in Russia through the south of Finland, almost all Estonia, the majority of Latvia, the western part of Lithuania, the town of Kaliningrad in Russia, the southern half of Sweden, the area of Oslo in Norway, Denmark, the majority of Germany, the North-West corner of Poland, the Netherlands, Belgium, Luxemburg, the South-East part of Great Britain, the majority of France, Switzerland, Lichtenstein, the western corner of Austria, the northwest of Italy, Andorra, the eastern and southern part of Spain and finally northern Morocco and Algeria.

## 11.2.2. Lyon-Turin rail link: From 6 to 40 million tonnes per year by 2030.

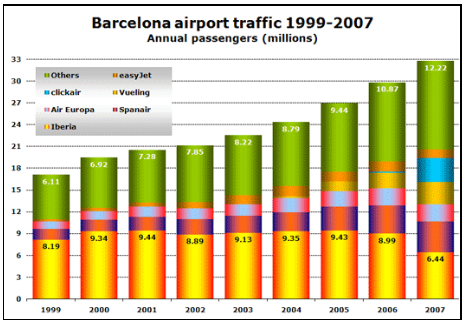
Source: LTP- Lyon Turin Ferroviaire: http://www.ltf-sas.com

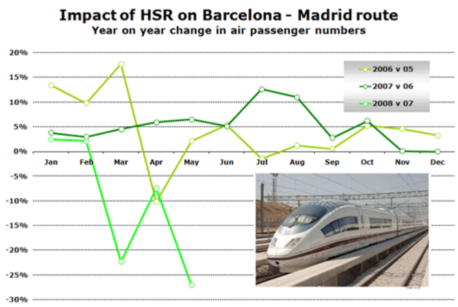



Every year, more than 150 million tonnes of freight cross the Alps. In the course of the next 15 years, economic growth and the development of trade should see this figure rise by up to 75%.Today, less than a third of this traffic is carried by train. The result: on some weekdays, up to 3,500 trucks pass through the Maurienne valley in Savoie and the Susa Valley in the Piedmont, with serious consequences for the environment and the local population. The objective of the new Lyon-Turin rail link is to transport over 40 million tonnes by rail per year by 2030, compared with the little over 6 million tonnes currently transported. The new line will be able to handle three types of rail transport: High-speed passenger traffic, connected to the French and Italian rail networks, traditional freight transportation, and "The Rail Motorway". This will allow the transfer of over a million trucks per year by train, reducing road traffic across the Franco-Italian Alps by almost a third, and improving passenger traffic. Passengers will be able to go from Milan to Paris in about 4 hours (today it takes 7), and from Barcelona to Milan in 7 hours (today, it takes more than 12). Travelling from Lyon to Turin will take only 1 hour and 45 minutes as opposed to over 4 hours currently. The existing line will be mainly devoted to regional use with an improved quality of service. Three stretches of line are planned: a French section (entrusted to RFF); a joint Franco-Italian section (under the responsibility of LTF) and an Italian section (entrusted to RFI). **The costs involved for the Lyon-Turin programme are both dedicated to investment (the main part) and to; the operation of the system.** The investment cost has been estimated at approximately **7.600M€.** Italy will assume 63% of the investment and France 37% (in complement to the financing expected from the European Union for the cross-border section). Operating costs have been estimated at **34 million Euros per year** and include the renewal of equipment, **8.3 million/year for operation** (on the basis of a staff of 130 persons) and finally **22 million euros/year** dedicated to maintenance.

### 11.2.3. Barcelona: “New Vueling” dominates but rail taking 25% of Madrid traffic

Anna-aero, airline network news and analysis (jul’08):
http://www.anna.aero/2008/07/11/new-vueling-dominates-but-rail-takes-25-of-traffic-of-biggest-route-madrid/




Barcelona has long been the second busiest airport in Spain after Madrid and in recent times, it has become a battleground for low-cost carriers attempting to establish themselves in the Spanish market. Spain’s two soon-to-merge home-grown low-cost carriers (LCCs) Clickair and Vueling both began their feverish growth from Barcelona’s El Prat airport as a response to the ‘invasion’ by foreign LCCs such as EasyJet and Virgin Express, and Ryanair which set up a base at Girona some 90 kilometres north of El Prat. Passenger growth has accelerated in recent years with the completion of various infrastructure projects. Domestic services represent around 47% of scheduled flights and 45% of seat capacity at present. Spanair, which SAS has now reluctantly decided to hang on to after being unable to find a buyer, has the biggest market share and offers 20 routes. Iberia, thanks primarily to its 209 weekly departures to Madrid still ranks second ahead of Clickair, Air Europa and Vueling. Apart from Iberia, Spanair also operates 100 weekly departures to Madrid, Air Europa 39 and Vueling 22. However, capacity on this route has been cut since the start of the year due to the launch of high-speed rail (HSR) services. In 2007, around five million passengers flew the almost 500 kilometres between Barcelona and Madrid, making it Europe’s busiest airport-pair route by some margin. On 20 February of 2008, after much delay, high-speed rail services were finally introduced between the two cities, reducing city centre to city centre rail journey times from three hours 55 minutes to two hours 38 minutes. As a result of this competition, total airport traffic at Barcelona was down 4.7% in May and year-to-date total passenger demand is down 0.8%. This compares with 6% growth at Madrid, 14% growth at Alicante and 8% growth at Bilbao and Seville.

## 11.2.4. Betuweroute, a 160Km double-track freight rail line opened in June 2007

Source: Railway Technology website: http://www.railway-technology.com/projects/betuweroute/


The Betuweroute is a 160km, €4.7bn, double-track freight rail line stretching from the port of Rotterdam, Europe's largest, to the German border at Zevenaar-Emmerich. The project fits in well with the deregulation of Europe's freight railway network, furthering the aim of seamless transfers across national frontiers and different railway systems. The eventual opening in June 2007 was a year behind schedule and under diesel power only. The new line is unusual for modern railway in a densely populated region in being built specifically for freight traffic. It will provide greater continuity of power supply for up to 150 freight trains per day, as its 25kV AC supply, different from the systems of the host country or the destination, allows for heavier trains and better acceleration under larger loads. The objective of the new line is to allow uninterrupted journeys through the Netherlands, with more and faster carriage of loads between the port area and central Europe. It is a key part of the Trans-European Network's (TEN) Trans-European Freight Rail Network (TEFRN). The Betuweroute has ERTMS/ETCS LEVEL 2, which uses GSMR for communications between train and traffic control, allowing travel at up to a speed of 120km/h. In 2006, at 42 million tonnes carried, Dutch rail freight grew by 9% over the previous year. Growth of up to 90 million tonnes by 2020 is forecast. Following a European competition attracting five bids, in October 2007 Keyrail and Strukton Railinfra signed a contract for the entire Betuweroute maintenance and management from 1 January 2008 until 1 January 2011.

### 11.2.5. Dedicated roadways for trucks: South Boston Bypass Road.

Source: By Walter D. Herrick, Boston Central Artery, Massachusetts. May 2002: http://www.pbworld.com/news_events/publications/network/issue_52/52_18_HerricW_SouthBostonHaul.asp


The South Boston Haul Road (SBHR) project moved beyond the traditional definition of intermodal to include a shared infrastructure rather than movement of passengers from one mode to another. The concept of the SBHR was to use an existing transportation corridor for both railroad freight and commercial highway vehicles. The positive benefits projected for various stakeholders included: The Community: Reduced truck traffic volume (which was as high as 14% of average daily traffic) in the residential neighbourhoods of South Boston with corresponding enhanced safety, reduced noise and improved air quality; Highway Users: Significantly reduced trip times; Railroads: Land sale income and new railroad tracks; Public Agencies: Reduced commercial traffic (trucks, busses, taxis, etc.) on roadways being reconstructed as part of the CA/T project; Commercial Users: A direct, non-stop route through the South Boston community for commercial traffic and CA/T construction vehicles. The actual final design of the SBHR consisted of three main parts: highway, railroad and drainage. The SBHR is essentially an urban two-lane limited access highway more than 1-mile long. As such, the SBHR has future potential for use as a very long ramp for all highway vehicles to and from Interstate 93 and Interstate 90. Additionally, a large convention centre complex is under construction adjacent to the SBHR. The potential exists for the SBHR to provide substantial traffic relief before and after convention centre events.

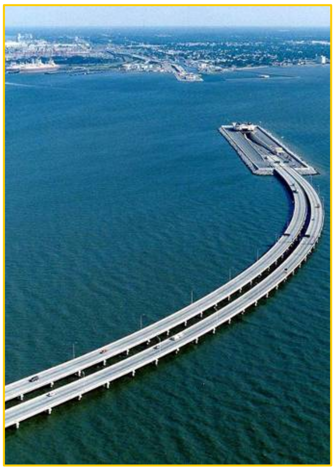
### 11.2.6. L9 Barcelona: the largest metro line under construction in Europe: 46 new stations in 45.5 km under construction. More than 120 new km in 2010.

Source: Gregory Qushair, City Mayors website: http://www.citymayors.com/transport/barcelona_metro.html


In 2001, the Barcelona Metropolitan Transport Authority (ATM) laid out its plans (*Pla Director d'Infraestructures 2001-2010*) for expanding and upgrading city transit service over the following decade. The flagship of the PDI is the new metro line (L9). Currently under construction, it will be the longest and most advanced metro line operating in Europe upon its planned inauguration along 2009. In designing L9 (in orange in the map) from the airport up to the north through the whole city, the TMB sought to create a seamless link from the airport in the southeast, through underserved neighbourhoods in the east, and finally into northern suburbs such as Badalona. The L9 will also connect to the future TGV/metro hub being constructed at the *Sagrera* station, and is expected to transport 90 million passengers annually. Line 9 will comprise 46 stations serviced by a long central line that branches north and south at both ends. The TMB has used the world's largest Earth pressure balance shield borer, featuring a drill diameter of 12 m, to create portions of the path of L9. By 2010, the Barcelona Metro will include seven lines servicing 150 stations (not counting the FGC), and will span over 120 km. The TMB has also planned upgrades for carriages and stations, including driverless operation for all lines and total accessibility for all passengers at all stations. The cost has increased significantly since the first estimates (4,340 M€), because the construction has been much more difficult than expected. To finance and manage it, public-private partnerships have been established.

## 11.2.7. The Öresund Fixed Link Rail and road project opened in June 2000: With imports between Denmark and Sweden amounting to 10% of each country's foreign trade

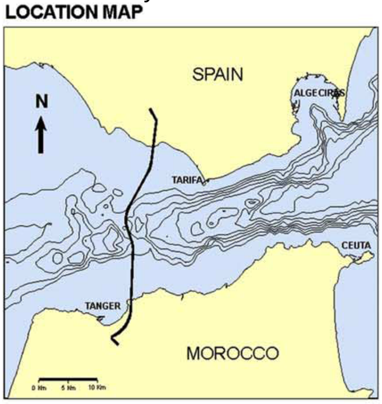
Source: Railway Industry website: http://www.railway-technology.com/projects/denmark/



The Öresund Fixed Link rail and road project, which provides the first physical link between Denmark and Sweden, is among the largest ever undertaken in Scandinavia. The crossing straddles an 18km-wide waterway, and the effect on the region's communications is illustrated by the fact that a crossing which formerly had to be undertaken by water in one hour, is now achieved in just seven minutes. This remarkable achievement had come about at a cost of Danish Kroner (DDK) 14.75 billion, which paid for two crossings, a four-lane motorway, and a double-track railway bridge, running from Lernacken on the Swedish side, to Kastrup in Denmark. Financing and overseeing of the project's implementation has been the responsibility of Oresundkonsortiet, which obtained international capital market loans with guarantees from the Swedish and Danish governments. The Öresund Fixed Link project comprises two separate water crossings; one bridge and one tunnel interlinked by an artificial island constructed as part of the project. The railway line is electrified. However, different voltage systems exist in Denmark and Sweden. Therefore, trains using the link have to be dual-voltage. The line is equipped with automatic train control (ATC), which provides drivers with information on an in-cab video display. Lineside signals are also provided for conventional operation in the event of a failure of the ATC system. DSB has increased its market share to 27%, boosted by the opening of the railway link to Copenhagen's International Airport on 28 September 1998. In 2007, a total of 9.7m passengers crossed the Öresund with the Rail Service and 14.8m passengers used cars.

## 11.2.8. Gibraltar Tunnel

Source: swissinfo
http://www.swissinfo.org/eng/front/detail/Swiss_plan_tunnel_under_Strait_of_Gibraltar.html?siteSect=105&sid=7118024&cKey=1159613846000




A Spanish-Moroccan committee has been considering various options since 1980, not surprising since the difficulties faced by potential builders are a huge challenge. It was only in 2004 that the two countries' governments decided to go ahead. A bridge was ruled out because of the depth of the strait. It would be impossible to build supporting pillars in 300 metres of water. A floating bridge was also not an option because of the number of ships passing through the Gibraltar bottleneck. An underwater tunnel made out of prefabricated elements was considered unfeasible as well as the sea bottom is unstable and currents too strong. If the project goes ahead, it will be a close cousin of the Eurotunnel that runs under the Channel between France and Britain. Running at depths of up to 600 metres, it will connect Tarifa in Spain to Tangiers in Morocco. Two publicly owned companies in Spain and Morocco are financing the project. Lombardi reckons it will cost up to €5 billion (SFr7.9 billion) to complete it, but cannot be more precise at this stage. Preliminary studies should be finished by 2008. A 4.8-metre-wide service tunnel will be built first. Aside from the actual tunnel itself, it is likely that a branch from the Madrid-Seville AVE line will connect to the tunnel at the north end. There are also proposals to develop a high-speed network in Morocco. Similarly, terminals will have to be constructed for trans-shipment of road vehicles like those at Cheriton and Frethun.

## 11.2.9. The Strait of Messina Bridge: World's longest single-span suspension bridge

Source: Bridges e-newsletter. February 2005: http://www.gobridges.com/article.asp?id=452.


The Strait of Messina, which separates the island of Sicily from the Italian mainland, has long been viewed by many engineers as the ultimate challenge of bridge engineering and construction prowess. Since the late 1960s, the Italian government has considered spanning the two-mile-wide strait. For years discussion and planning for the bridge have been taking place; under Romano Prodi in 2006 the project was cancelled, however since winning the elections in 2008 Silvio Berlusconi has announced that the plans will be quickly restarted. Construction was to begin in 2006 and was expected to be completed in 2012. Further, there were questions of funding, water depth, and wind. To avoid the problem of deep water, the design solution was to build the world's longest suspension bridge. It will have a two-mile main span and 590-foot side spans, with an overall length of 2.5 miles. The main piers will be founded under 400 feet of water. The proposed bridge also would feature two pillars higher than the Eiffel Tower supporting the central span, which would be three times the length of the Golden Gate Bridge in San Francisco. To deal with aerodynamic and seismic concerns, the bridge will be fitted with a new, patented, lighter deck design that engineers say will help the structure withstand 134-mph winds and endure a M7.1 earthquake. The money for the project, which currently is estimated to cost $5.5 billion, will come from shareholders (about 40 percent of project costs), with the remainder to be financed through the debt markets. An environmental impact study found that the bridge is preferable to upgrading the ferry system because it would result in reduced emissions, significantly shorter travel times, and socioeconomic integration among the local economies of Messina and Reggio Calabria, and the regions of Calabria and Sicily.When it is finally constructed, the Strait of Messina Bridge certainly will stand as one of the most spectacular bridges of our time, perhaps of all time.

### 11.2.10. 2,000 ha of expansion in Port of Rotterdam between 2013 and 2033.

Source: Maasvalakte website: http://www.maasvlakte2.com


The realisation of Maasvlakte 2, a part of the Rotterdam Mainport Development Project (PMR), entails the creation of a new world-class port and industrial area with 2.000 ha. The port will allow the largest ships to put in here 24 hours a day. No other port in Europe can match this. This project also includes compensation to the natural world, the creation of a 750 ha area for nature and recreation and improvements to the Existing Rotterdam Area. Maasvlakte 2 will be situated directly adjacent to the existing Maasvlakte, and will not only benefit the port of Rotterdam, but the entire Dutch economy. The area will be built by first constructing a seawall in the sea, after which sand will be sprayed on within this perimeter, creating new land. Maasvlakte 2 will be completed in phases, avoiding unnecessary vacant sites. The first container terminal at Maasvlakte 2 will be taken into use in 2013. Expectations are that Maasvlakte 2 will reach full occupation as late as 2033. Maasvlakte 2 will primarily accommodate growth sectors: container terminals, distribution activities and the chemical industry.

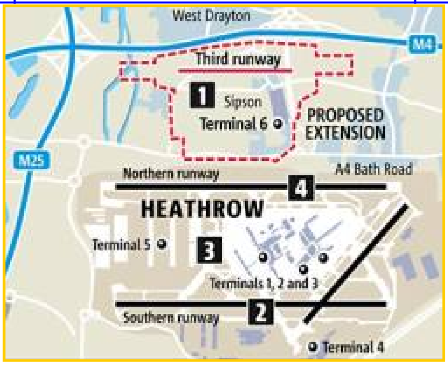
### 11.2.11. The new Tanger Med port:

Source: Port Strategy online edition. September 2008: http://www.portstrategy.com/archive101/2008/september/in_focus_tanger_med/opinion_piece_impact_of_tanger_med_on_spain

Spain's two south coast ports of Málaga and Algeciras Bay face new competition. The former reported a 28.3% drop in traffic in the first five months of this year, while the latter saw a decline of 2.04%. Both are transhipment hubs, whose longer-term viability has been put into doubt through the opening of Tanger-Med, where rock-bottom labour rates are proving highly tempting to shipping lines. In contrast, the two main Spanish import-export hubs of Valencia and Barcelona continue to report growth. While the latter reported a modest 3.26% increase in the year to the end of May, the former boosted traffic by 8.23% to 1.34m teu. Astonishingly, this is just 50,000 teu fewer than Algeciras handled. APM Terminals shows absolutely no signs of pulling out of the concession it operates at Algeciras. Having noted in which direction the wind was blowing some years ago, Algeciras adopted a strategy of diversifying traffic and it is now looking at further diversification through the arrival of Hanjin as terminal operator in 2010. Up to now, APM was solely dedicated to handling Maersk traffic, but now it appears to be looking at attracting other third-party business.

## 11.2.12. Heathrow expansion: the busiest airport in Europe.

Source: Jane Wardell. December 2007:
http://www.aviation.com/travel/071214-ap-heathrow-expansion-begins.html




Outdated and overcrowded, Heathrow Airport began a long-awaited makeover in 2008 that will radically transform the busy transit hub. Heathrow, designed to serve about 45 million passengers a year, now handles around 68 million. To deal with the existing crush and an anticipated further increase, BAA plans to rebuild, refurbish or redesign all airport buildings and facilities over the next five years - meaning that most passengers arriving for the 2012 Olympic Games will be travelling through terminals that do not currently exist. The first step is the opening of the £4.3 billion (US$8.8 billion; € 6 billion) Terminal 5, which will have capacity for 30 million passengers annually. Expanding further will depend on whether the government decides to press on with plans to build a third runway and a sixth terminal by 2020, which would allow Heathrow to handle 702,000 takeoffs and landings each year by 2030, compared to the current limit of 480,000. The government, aware of Heathrow's importance for the health of the British economy, has already indicated tacit approval. Compared to Heathrow's two runways, Schiphol in Amsterdam has five, Charles De Gaulle in Paris four and Frankfurt three. Building the new facilities would involve destroying 700 homes, including an entire small village, and significantly increase noise levels for 2 million local residents.

## 11.2.13. Madrid: Europe's first airport by 2016?

Anna.aero, airline network news and analysis (nov'07)
http://www.anna.aero/2007/11/23/madrid-europes-no1-airport-by-2016/


The development of the main operational base of Iberia at Madrid Barajas airport appears to be quite certain. Thanks to the opening of two new runways and its Stirling Prize winning Terminal 4 in February 2006, Madrid now has plenty of room for expansion. In 2006, passenger numbers passed 45 million, making it Europe's fifth largest airport. It looks likely to overtake Amsterdam this year (2007) and possibly pass Frankfurt in 2008. According to OAG data this winter Madrid has scheduled links with 161 destinations, about the same as London Heathrow but well behind Frankfurt which offers consumers over 230 routes. Using simple forecasting techniques for Europe's five major hubs suggests that Madrid could become Europe's leading airport within 9 years and the first to break the 100 million passenger mark, possibly as soon as 2021. This year the airport is on course to break through the 50 million-passenger barrier thanks to growth of over 14% during the first nine months. Major contributing factors include the start of Ryanair services to 15 destinations last November and the opening of an easyJet base in February 2007 which now serves 19 destinations. Not surprisingly Iberia is the dominant airline at Madrid though in 2006 it carried well under half of all passenger traffic. All of the top four airlines are Spanish reflecting the vibrant domestic market and a healthy level of competition. Spanish domestic traffic accounts for around 45% of all Madrid airport passengers. Leading international country destinations are Italy and France, followed by the UK and Germany. The Madrid to Barcelona route is currently Europe's busiest airport-pair with over four and a half million passengers in 2006. However, the AVE high-speed rail link between the two cities, has significantly reduced rail journey times, and has affected air travel demand.

## 11.2.14. A new generation of more space-efficient airports

Source: Innovations Report website. June 2008
http://www.innovations-report.com/html/reports/logistics/report-111678.html


The new JetBlue terminal at New York's JFK Airport will serve twice the number of passengers (20 million) as the recently built international terminal, using just half the space. The new building will cost about the same as Delta's new terminal at Logan Airport (roughly half a billion $), but it will serve four times as many passengers. The actual level of air traffic in five, 10 or 20 years and the types of traffic occurring are routinely very far off from original predictions. Leading low-cost airlines with a preference for small, inexpensive airports are now the largest airlines in the United States and Europe, according to an MIT expert on airport design and operations, who said that airport planners in major metropolitan areas need to accept this paradigm shift and build flexibility into airport design. Low-cost airlines require terminals about half the size of those of the legacy airlines, because they use space more intensively. De Neufville recommends flexible design that encourages airport planners to recognize that major airlines may go out of business, air traffic patterns and distribution may change or move to another airport, and incoming airlines may well reject the facility vacated by a previous customer. The solution is to think through the likely possible scenarios, anticipate responses to those, and incorporate manoeuvrability into design and operations.

## *11.2.15.* Zaragoza PLAZA: the new biggest non-maritime logistic area in Europe 1.300ha developed from 2002

Source: Zaragoza City Council website: http://www.zaragoza.es/ciudad/dossier/en/plaza_en.htm

The Logistic Platform **PLAZA** is one of the areas of reference in the industrial, economic and commercial activity of Zaragoza, the best example of the specialisation of the city in key sectors such as logistics. With almost 1,300 hectares, Zaragoza Logistics Platform (PLAZA) is the biggest logistics area of the European Union. Its management, execution and promotion mainly depend on the Government of Aragon, the City of Zaragoza and the two main banks of the Autonomous Community. PLAZA has been the place chosen by more than 300 national and international leading companies in their sectors -INDITEX, Imaginarium, Memory Seth, Porcelanosa, TDN, DHL Express, Barclays Bank, Mann Filter...-, due to its extension and location in the diagonal of the European Southwest, and also to its intermodal capacity. The strategic value of PLAZA, where around 11,000 people is working, lies in the strength of its communications network. The global project of PLAZA includes different areas with no relation with logistics that will enrich and complement the project. Once PLAZA had consolidated its activity and working in full, nearly 13,000 people, taking into account direct and indirect jobs, will be working there.

## 11.3. *Urban infrastructural development for soft traffic*

### 11.3.1. New bicycle boulevard: A near continuous network of bicycle boulevards in Berkeley, California (USA)

Source: http://www.livablestreets.com/streetswiki/bicycle-boulevard ; August 2008


Bicycle boulevards are lightly trafficked streets that prioritize bicycles. Although many routes have no bike lanes, bicyclists are free to use the middle of the street, sharing road space with cars. Motorists on these routes therefore travel with caution because they expect to see bicyclists. These designated streets should be distinguished with uniformly coloured signs and bold pavement markings. For novices or younger riders, bicycle boulevards provide a transition between bike paths and high-traffic shared roads. However, they are also quite useful for experienced riders because of their reduced traffic and connectivity. The cost of implementing a bicycle boulevard network is significantly less than constructing bike paths or trails. Traffic calming measures are often employed to limit bicycle boulevards to local vehicles only. The City of Berkeley has created a near continuous network of bicycle boulevards that is considered one of the best in the nation. Because Berkeley has a traditional urban street grid, most roads stretch long distances, often from one end of the city to the other. In fact, Berkeley's long, narrow side streets are ideal for the concept (it likely would not work on wide suburban arterials). Four north-south and three east-west residential streets have been set aside for bicycles. These streets were chosen because they are near larger roads, so that most traffic can be diverted there rather than into residential neighborhoods. Other examples in North America are in Palo Alto, Portland, Eugene, and Vancouver.

### 11.3.2. Paris and Bordeaux now have shared lane networks of 118 and 40km respectively

Source: Andy Hamilton. August 2008: http://www.livablestreets.com/streetswiki/bike-bus-lanes


Bike-bus lanes are travel lanes restricted to buses, bicycles, and (usually) vehicles turning right. The lane is separated from general-purpose lanes by a solid white line, and designated by signs and painted legends. This configuration requires bicyclists and buses to pass one another in "leapfrog" fashion. Cities employing shared bike-bus lanes include Tucson, AZ; Madison, WI; Toronto, Ontario; Vancouver, BC; and Philadelphia, PA. In some cities, bicycle lanes are provided to the left of dedicated bus lanes. A reportedly suppressed study by Transport for London leaked to the London Telegraph indicates that on two corridors where bicycles and motorized cycles were allowed in bus lanes, bicyclist crashes were reduced 44%. Bike-bus lanes have been used in French and German cities. Paris and Bordeaux have shared lane networks of 118 and 40km, respectively. According to the German Cycling Federation, the Federal Ministry of Transportation reports cyclists are safer using bus lanes, and bus operations are not negatively affected by this arrangement. The Ministry states that, where traffic speeds exceed 30 mph, the width of the lane should be at least 4 meters to allow bicyclists to overtake a bus without entering an adjacent lane. Narrower widths, typically 3.0 meters (10.5 - 11.5 feet) are acceptable in lower speed environments (20mph or less). By contrast, the City of Madison, Wisconsin, prefers a width of 16 feet, but may allow widths of 14 feet or even less when necessary.

### 11.3.3. Bike Boxes

Source: Ben Fried. July 2008: http://www.livablestreets.com/streetswiki/bike-boxes


A bike box is a coloured area at a signalized intersection that allows bicyclists to pull in front of waiting traffic. Designed to be used only at red lights, the box is intended to reduce car-bike conflicts, increase cyclist visibility and provide bicyclists with a head start when the light turns green. In most cases, the bike box is a 14-foot wide rectangle marked in front of the stop line for motorists, but behind the pedestrian crosswalk. The box typically extends the width of one or more travel lanes and provides room for several bicyclists. Bike boxes are also often used in conjunction with bike lanes, from which bicyclists pedal directly into the box. The boxes have no intended function when traffic is already in motion. Bike boxes work best at intersections with a high volume of bicyclists. They improve cyclists' visibility. They reduce delay for cyclists by providing space for "jumping the queue" of waiting vehicles. They allow a left-turning bicyclist to reach a better position for making a safe turn. They allow bicyclists to reduce exposure to vehicle tailpipe emissions, and are also thought to elevate the "status" of bicyclists relative to motor vehicles.

### 11.3.4. Pedestrian Scramble

Source: Andy Hamilton. September 2008: http://www.livablestreets.com/streetswiki/pedestrian-scramble

The Pedestrian Scramble is a traffic signal phasing scheme in which pedestrians are given their own signal phase to cross in any direction, including diagonally through the intersection. It is an example of a pedestrian signal innovation, which in this case has two objectives: first, to reduce or eliminate conflicts between vehicles and pedestrians; second, to allow intersections to operate more efficiently when large pedestrian volumes prevent vehicles from being able to make turns. The Pedestrian Scramble is not used widely in North America, but has made a comeback as traffic innovations to increase pedestrian safety have been pursued more consistently since the mid-1990s. Early studies showed the Pedestrian Scramble can reduce pedestrian crashes by 50% at intersections with high pedestrian volumes and low vehicle speeds and volume. Another significant benefit is that the Scramble can greatly enhance the efficiency of the intersection, in effect adding capacity without the need for road-widening, new signals, or other expensive and disruptive treatments.

## 11.4. *Economic policies and market development*

Economic aspects of transport policy are related to charges for using infrastructure, internalisation of external costs, congestion charging etc. However, these charges are mainly established in order to prepare a level playing field for all transport users.

There are examples of congestion charging in London and Stockholm, but the system is used in a number of cities all over Europe. Charges related to the use of infrastructure have been known for a long time. This is not detailed further in the case studies.

Competition between transport modes and market penetration has been particularly visible in the area of high-speed trains, airports and ports. In the following, a few examples are provided of development traits, which may develop much more in the future. This also applies to urban transport where the development of the bicycle mode is penetrating in some areas.

### 11.4.1. London new urban road pricing: Cordon Tolling since April 2003 (30% traffic decline, 60.000 less cars per day, - greater than expected)

Sources: Transport for London: http://www.tfl.gov.uk/roadusers/congestioncharging/6722.aspx
International Urban Road Pricing. Final Report. Work Ortder 05-002: Ossues and Options for Increasing the Use of Tolling and Pricing to FinanceTransportation Improvements. U.S Department of Transportation. Federal Highway Administration June 2006


London implemented a central area congestion-pricing scheme in February 2003 that required the payment of a daily £5 (about $9) fee to travel within central London between 7:00 am and 6:30 pm, Monday through Friday. The daily rate was increased to £8 (about $14) per vehicle in July 2005. The fee is enforced by cameras at entry points to the central city, which record the license plate numbers of every vehicle entering the central city and match the license plate numbers to payments made. The technology selected to administer and enforce the congestion charging scheme is a video-based license plate recognition system. This system requires the installation of cameras at entry points and software to accurately read license plate numbers as they enter the zone at speed and link those license plate numbers to a payment. The primary disadvantage of the system is that it charges the same fee regardless of the amount of travel made by a vehicle in the city centre on a given week day. Another system drawback is the inability to catch more than 80 percent of the violators due to issues with the cameras or the license plate reading software .The Central London congestion pricing scheme has been particularly successful in reducing congestion within the charging area but less successful in generating revenues for transportation improvements. Automobile movements have decreased by 60,000 vehicles daily since the congestion pricing scheme was implemented in 2003. After the first year of the initiative, the amount of traffic entering the cordon zone declined by 18% while the extent of traffic congestion within the cordon zone declined by 30%. In comparison, there was a 30% rise in taxi use and a 20% increase in bus movements in the zone, both modes being exempt from paying the congestion charge.

### 11.4.2. Stockholm's urban road pricing

25% traffic reduction, 40.000 less cars per day
Source: IBM website. April 2007
http://www.ibm.com/podcasts/howitworks/040207/images/HIW_tr_04022007.pdf

Traffic congestion has been a growing aggravation in Stockholm for years, with over half a million cars travelling into the city every weekday. And it's not going to get any better on its own. The population of Stockholm County is growing at a rate of around 20,000 people a year, which inevitably means more traffic and an even greater burden on city streets. The solution they came up with was a high-tech traffic charging system that directly charges drivers who use city centre roads during peak business hours. The hope was that this pilot project, which launched in January 2006, would encourage more people to leave their cars behind and use public transportation instead. The charge was also intended to bring about an overall improvement in the urban environment in Stockholm, particularly in air quality.

Drivers can install simple transponder tags that communicate with receivers at the control points and trigger automatic payment of road use fees. Once a vehicle passes a roadside control point during designated congestion hours, it is recognized by the transponder that is read by sensors. In addition, cars passing through these control points are photographed, and the license plate numbers are used to identify those vehicles without tags and to provide evidence to support the enforcement of non-payers. The information is sent to a computer system that matches the vehicle with its registration data, and a fee is charged to the owner. Drivers can pay their bills at local banks, over the Internet and at area convenience stores, like 7-Eleven. The technologies at work here include RFID tags, which use radio waves to automatically identify objects, and wireless sensors, which are little devices that can detect and measure real-world conditions and convert them into signals that are sent to computers. Another emerging technology—optical character recognition software—is used to identify license plates from any angle. The road charging system had an immediate impact on congestion and overall quality of life for the citizens of Stockholm. By the end of the trial, traffic was down nearly 25 percent and train and transit passengers increased by 40,000 a day.

## 11.4.3. Benefits to Airlines from Using High-Speed Train Services

Source: Aerlines Magazine e-zine edition, Issue 34; January 2007: http://www.aerlines.nl/issue_34/34_Givoni_Benefits_HST_hub.pdf

In general, the air transport industry does not seem to promote the idea of aircraft/train substitution. Airlines in particular do not do so, despite the fact that when rail infrastructure is provided at airports, airlines make use of that infrastructure. This is understandable considering the market share high-speed train services (HST) gain on routes where they compete directly with the airlines. London Heathrow (LHR) is estimated to contribute a substantial part of the benefits the air transport industry provides the UK with (estimated at 1.4% of GDP and 480,000 jobs in total). This economic argument dominated the public inquiry that recommended the construction of a fifth terminal (T5) at LHR. Airlines are expected to incur operating costs following mode substitution, but this is expected to be more than compensated for by benefits of freed runway capacity and network economics. It is an opportunity to ensure that the development of the rail network includes the airports. For example, the European HST network must include stops at the major European airports if the EU goals of (beneficial) mode substitution and integration between the transport modes are to be achieved. Given the nature of the planning system and the nature of planning and developing the rail network, the air transport industry (airlines and airports) must act now to promote the inclusion of the airports in the rail network. Once the rail network is constructed, it would (almost) be impossible to turn back time.

### 11.4.4. Annual growth of 7% for Asia Pacific Ports will continue beyond 2010

Source: Port Technology website: www.porttechnology.org

With 39% share of the global market, the Asia Pacific maritime industry has been booming and is forecast to grow at a CAGR of 7% between 2006 and 2010. Maritime services, offshore and freight forwarding are slated to be the fastest growing areas. The Port of Singapore Authority for instance, already operates 26 ports in 15 countries. Growth for port operations and services is expected to be widespread in the Asia Pacific region as well. Asia Pacific accounts for 42% of the global value market of port operations and is expected to grow share further to 44% or US $54 billion by 2010. The main areas of growth in ports and terminals are expected in China, India and Korea. By 2011, Asia is expected to handle 206 million TEU including 64 million TEU in transshipment. Asia Pacific's US$43billion ship building industry enjoys a 66% global market share and is currently seeing a boom in demand. This is being led by three factors; the phasing out of single hull tankers by 2010 that is driving ship owners to build new ships, an upswing in trade between China and the US that is leading to demand for super sized ships, an increase in oil demand by India and China which have prompted a rise in the use of LNG and hence new LNG carriers and the global hunt for oil which has led to the development of new offshore oil production facilities. The key beneficiary has been South Korea (with over 40% global market share), which had orders worth over US$12billion placed in Q12007 alone and is booked with orders until 2010. However China (15% share) is fast catching up with Korea and has secured 56.6% of the total contracts in Q12007 for bulk carriers and smaller tankers to be delivered by 2009.

### 11.4.5. Glasgow or Edinburgh face sell-off in airport competition crackdown

Source: Alastair Dalton. August 2008:
http://news.scotsman.com/latestnews/Glasgow-or-Edinburgh--face.4383568.jp


Competition watchdogs are poised to order BAA to sell off one of Scotland's two main airports. Speculation has increased that Glasgow or Edinburgh will be put up for grabs after the Competition Commission said common ownership "adversely affects competition between them". Other airport owners and investment groups are expected to compete for the airport, which analysts said could be worth up to £1 billion. Glasgow is seen as the more likely Scottish target for a sale because its core charter traffic is declining, but BAA may be given the option of selling booming Edinburgh Airport instead. However, opinion over a sell-off is divided in Scotland, with several major business groups opposed and many airlines welcoming it, while the jury is still out over whether a change of ownership would make a difference to passengers. Many airports are suffering a slump in passenger numbers because of high fuel prices and the economic slowdown, but analysts predict they will remain attractive purchases for investors.

### 11.4.6. Bicycle rental as emerging public-individual transport in European cities

Source: Sebastian Bühramann; European Conference on Bicycle Transport and Networking –MEETBIKE; Dresden. April 2008

Innovative schemes of rental or free bicycles in urban areas can be used for daily mobility as one-way use is possible. They are part of the public transport system. They differ from traditional, mostly leisure-oriented bicycle rental services as they provide fast and easy access. They also have a diversified in organisational layout, the business models and the applied technology towards “smart bikes” (automated rental process via smart card or mobile phone). There are many different applications in European cities: Lyon– “Vélo’v”, Barcelona– “Bicing” (since March 2007); Paris – “Velib’” (since July 2007). Other cities beyond Europe: Buenos Aires, Bejing, San Francisco, Tel Aviv, Brasil, Montreal, etc. Challenges. The challenges of this scheme: it is not easy to get it started, financing is a hurdle to overcome; achieving real long-term impact needs continuous development of overall urban transport strategies towards multi-modal travel behaviour.

## 11.5. *Technology*

Technology is a policy area where many new developments are being spotted. This is also an area where developments related to reducing $CO_2$ emissions, reducing noxious gases and improving engine and vehicle technology are taking place.

Many new seeds are related to development of individual passenger transport systems, but research is also being carried out in the field of new public transport technology.

### 11.5.1. Masdar City (Abu Dhabi) To Get Solar-Powered Personal Rapid Transit System

Source: Michael d'Estries. May 2008: http://www.groovygreen.com/groove/?p=3034

One of the more interesting technologies being put into action in Masdar City in Abu Dhabi is the PRT — or Rapid Transit System. Designed to hold six people, these pods, which are solar powered, will travel to more than 1,500 stations distributed throughout the city. Unlike other PRT systems in development, this one will be completely underground. They will essentially take you anywhere you want to go, with no fixed routes like a traditional metro system.

## 11.6. *Emerging technologies for road vehicles*

### 11.6.1. Zero VMT vehicle

Completely human-powered vehicles such as bicycles fit in this category as well as hybrid human-electric vehicles such as the Aerorider

Source: http://www.livablestreets.com/streetswiki/zero-vmt


One way to substantially reduce vehicle-miles travelled (VMT) is the broad implementation of vehicles that produce virtually no emissions and require minimal energy amounts both sufficiently far below averages for vehicles captured by the VMT metric to be considered negligible and allowing them to be called Zero VMT vehicles. Since it is *only* people that are being moved, using modular vehicles the size and weight of human beings, and optimally much smaller, is a much better, more agile and cost-effective way to move them. The inherent advantages of bicycles are that they only require human energy; they allow a person to travel *four times faster* than walking and that being low cost, very small, and light, have the extremely important transportation attributes of being readily *distributed* to provide immediate no-wait transportation *on-demand*; precisely the critical services required by fast-paced modern societies.

### 11.6.2. Plug-in Hybrids "Gas-optional" or “plug-in” hybrid (PHEV) yields dramatic gains in fuel economy.

Source: Hybrid cars website. April 2006: http://www.hybridcars.com/plug-in-hybrids/overview.html


With the plug-in hybrid, you still will not be required to plug the car in, but you will have the option. As a result, drivers will get all the benefits of an electric car, without the biggest drawback: limited range. You will be able to go all-electric for the vast majority of your driving that takes place close to home. When the electric charge runs out, a downsized gas engine kicks in and your car drives like a regular hybrid. Many hybrid car drivers enjoy keeping the car in all-electric “stealth” mode, when the car is in slow stop-and-go traffic. Plug-ins would extend the stealth mode for the lion’s share of our local driving. The potential advantages: A hybrid gets about twice the fuel economy as a conventional car of the same size and capacity A plug-in hybrid will get about twice the fuel economy of a hybrid A plug-in hybrid, running on biofuel (e.g., 85 percent ethanol) could almost entirely eliminate its use of petroleum. Plug-in Hybrids in the market: VentureOne, Fisker Karma, Chevrolet Volt and Saturn Vue Plug-in.

### 11.6.3. The new Insight Concept

A small, fuel efficient hybrid car that delivers big style and functionality

Source: Honda website. April 2008: http://corporate.honda.com/press/article.aspx?id=4722

Honda revealed a concept version of its new small hybrid vehicle, to be named Insight, at the 2008 Paris International Auto Show, October 2. The new Insight Concept shares styling cues with the Honda FCX Clarity fuel cell vehicle and will provide an early look at the highly-anticipated five-passenger hybrid vehicle. The Insight will advance the affordability and accessibility of hybrid technology to a new generation of buyers. The Insight Concept defines a new stage in the evolution of hybrid technology by utilizing a more cost-efficient version of Honda's Integrated Motor Assist™ (IMA™) hybrid technology, resulting in a new level of affordability for hybrid customers worldwide. The Insight Concept is designed with a low centre of gravity and a generous five-passenger cabin, offering the kind of driving pleasure and roomy interior that customers have come to expect from Honda The Insight is expected to have annual global sales of 200,000 units per year - approximately 100,000 in North America. Following the launch of the new Insight, Honda also plans to introduce another unique sporty hybrid vehicle based on the CR-Z, first shown at the 2007 Tokyo Motor Show. All together, Honda's global sales of hybrids should increase to approximately 500,000 units a year, or more than 10% of its total worldwide annual automobile sales. The original Honda Insight was introduced in December 1999 as America's first gas-electric hybrid car. The first vehicle to break the 70-mpg fuel economy barrier, Insight was designed from the ground up to demonstrate the ultimate potential for fuel-economy in a two-seater subcompact automobile.

## 11.6.4. Big 3 U.S. auto giants plug electric cars

Source: Martin LaMonica: http://news.cnet.com/8301-11128_3-10140131-54.html?part=rss&subj=news&tag=2547-1_3-0-5

General Motors, Ford, and Chrysler touted a coming generation of electric vehicles at this year's North American International Auto Show in Detroit. Ford on Sunday detailed a multi-prong electric car strategy, saying it will have an all-electric commercial van by 2010, an all-electric passenger car by 2011, and plug-in hybrid vehicles in 2012. General Motors showed of a concept Cadillac Converj that will be able to drive 64 kilometres off lithium-ion batteries. It will be outfitted with the same extended-range electric powertrain planned for the Chevy Volt. GM also introduced a four-door "mini car" called the Chevrolet Spark, originally a concept called the Chevy Beat, which will be available in Europe in 2010 and in the U.S. in 2011. Toyota at the auto show said that it will bring a small all-electric car to market in 2012 and test plug-in hybrid Priuses with lithium-ion batteries later this year. Chrysler, meanwhile, at the auto show showed a concept electric sedan called the 200C EV with a streamlined interior dashboard. The company also plans to have an electric edition of its Jeep Patriot as well.

## 11.6.5. Made in China: A plug-in hybrid for the masses

Source: Candace Lombardi. December 2008

http://news.cnet.com/8301-11128_3-10127029-54.html?tag=mncol;title

BYD Auto's plug-in hybrid electric vehicle, the F3DM, is now on sale in China. The F3DM, which will retail for 149,800 yuan ($21,200), can travel 100 km on its battery before needing to be recharged,and can be plugged in to any average Chinese 220-volt wall outlet to be recharged, according to BYD Auto. F3DM is the first one in China to be mass-produced and, therefore, widely available to the general public. Average Americans may also soon have a chance to buy a piece of BYD. The company also announced that it plans to begin exporting the F3DM to the U.S. in 2010. This year also ushered in the birth of the first chain of electric battery exchange stations. Better Place signed deals with Australia, the California Bay Area, Hawaii, and Japan to build stations where electric vehicles could stop to swap drained car batteries for fully charged ones.

## 11.6.6. Japan taps Better Place for electric car charging

Source: Martin LaMonica. December 2008: http://news.cnet.com/8301-11128_3-10119265-54.html


Japan's Ministry of the Environment announced a program on Tuesday to test electric vehicles and a network of charging stations, some sup The electric vehicle feasibility study will give local governments access to 50 electric cars for several months. Cars included are Mitsubishi Motors' iMiev, the Plug-in Stella from Subaru, the Honda Clarity fuel-cell vehicle, and the Erezo electric motorbike under development. Better Place will install battery exchange stations in the trial. The deal in Japan is similar to those made recently with several countries, the city of San Francisco, and the state of Hawaii that have signed on with Better Place, which has developed a system to accelerate electric car use through battery leasing and automated swapping. The trial is part of Japan's national goal of having electric cars make up half of all new vehicle sales by 2020. The program will also include a facility for rapid car battery charging. The first electric versions of familiar sedans from the likes of Nissan and others will start becoming available in 2010, but they will largely be used for testing. Broader availability of these cars will be in 2011 and 2012.

## 11.6.7. A visual tour of the GM Volt, electric cars

Source: Martin LaMonica. December 2008
http://news.cnet.com/8301-11128_3-10114274-54.html


Amid an uncertain future for the U.S. auto giants, one of the most exciting products is the Chevy Volt, one of dozens of electric cars under development. GM executives say that the project is still on track and getting all available resources despite the financial straits the company is in. The extended-range electric car, which uses batteries and a gas motor to supplement driving distance, is expected to serve as a platform for a whole line of cars. While the Volt and Fisker Karma have a gasoline engine that will let a driver go for hundreds of miles, the first iteration of all-electric town cars will be limited to about 100 miles. However, for daily commuting or for a second car, the range limit is not a serious barrier, say executives.

## 11.6.8. The future of the car industry

Source: Bill Vlasic. January 2009: http://www.nytimes.com/2009/01/11/business/11electric.html?ref=us

Inside the Ford Motor Company, it was called Project M - to build a prototype of a completely electric, battery-powered car in just six months. Certainly, Ford and other carmakers are betting billions of dollars on this new direction, at a time when they can ill-afford it and when Detroit is facing government scrutiny after the $17.4 billion bailout of G.M. and Chrysler. Throughout the cavernous Detroit auto show hall, typically the high temple of brute horsepower, auto companies will be competing this week to establish their green and electric credentials. On Sunday, when the show opens, Ford will announce plans for its electric vehicle, including a goal to start selling them by 2011. These are risky bets. There are no guarantees that consumers - for all their stated concerns about global warming, dependence on foreign oil and unpredictable gas prices - will buy enough of them. They may balk, for example, at the limits on how far they can drive on a single charge. Ford plans to make only 10,000 of the electric vehicles a year at first - very few by Detroit standards - to test the market cautiously. The surge toward electric vehicles also appears to be jump-starting investments in advanced-battery production in the United States. General Motors will announce plans at the auto show to build a factory in the United States to assemble advanced batteries for its Chevrolet Volt model, which it expects to start selling next year. American auto executives have warned that without home-grown suppliers, the country could potentially become as dependent on Asian-made batteries as it is on oil from the Middle East and elsewhere.

## 11.6.9. Hawaii Plans Electric Vehicle Charging Infrastructure

Source: Rex Roy

http://www.automobilemag.com/green/news/0901_hawaii_electric_vehicle_charging_infrastructure/index.html

While Hawaii has long welcomed eco-tourists to its shores, the state's motto "Ua mau ke ea o ka aina i ka pono," can now assume new meaning. The phrase translated means, "The Life of the Land is Perpetuated in Righteousness." Since so many environmental leaders view their role in this world as righteous, they should be applauding the state's recent move to allow a private company to begin installing an infrastructure to support EV-motoring. The state expects to have multiple battery charging and battery exchange stations in operation by 2012. The private company is called Better Place, and is venture-backed entity with funding from Israel Corp., Morgan Stanley, Ofer Group, VantagePoint Venture Partners, and private investors concerned about global climate change. Better Place installs charging stations all around the geographic areas they service-no mystery here. Better Place also erects fully-automated battery swapping stations that can replace a drained battery with a freshly-charged unit in under four minutes. Combined, these charging and swapping stations address the limited range of li-ion EVs.

## 11.6.10. Israel launches electric-car program

Source: Michael Kanello. January 2008: http://news.cnet.com/8301-11128_3-9854591-54.html

Renault-Nissan, the government of Israel, and an electric charging station start-up founded by Shai Agassi are mounting an effort to make electric cars part of ordinary life in Israel in the next decade. Project Better Place, Agassi's organization, will try to build 500,000 electric charging stations in the country, according to the organization. At some these stations, attendants will swap out depleted batteries and put in fully charged ones. This saves the several hours typically required to charge a lithium-ion battery pack made for cars. (You can also charge the batteries at home.) Renault-Nissan, meanwhile, will ship electric cars to the country in three years or so. Ultimately, the company hopes to ship 10,000 to 20,000 a year. Israel is also small, which makes it an easier market for electric cars as well as companies building electric charging stations. Electric cars can only go so far without a charge or a new battery. Ghosn said that the company's cars would go about 100 kilometres in the city and 160 kilometres on the highway on a charge.

## 11.6.11. Green Fuels, Cars Get Boost from Cow Pie Power, the Queen and New EV Charging Hub

Source: GreenBiz Staff. January 2009.http://www.greenbiz.com/news/2009/01/07/green-fuels-cars-get-boost


The drive to green mobility got a boost into the New Year with news of heightened efforts to produce fuels from a variety of waste products. Exploration of the power of poop, both bovine and human, made news in the U.S. and Japan. The energy chief for the state of Idaho, the third-largest milk-producer in the U.S., is looking to go big with the conversion of cow dung to natural gas that can power cars or homes, in addition to using the stuff to run turbines that would create electricity and recycling processed manure as plant bedding. In Japan, research from the Kajima Corporation and Tokyo University indicates that microbes from sewage could be a source of energy for hydrogen-powered cars. The idea of turning human waste into hydrogen fuel is also being pursued in California, where the Orange County Sanitation District and the University of California, Irvine, are working on an $8 million demonstration project of a conversion device that could begin operation this spring. In Britain, Queen Elizabeth is poised to use alternative, eco-friendly fuel made from plants. The Queen's two state Bentleys are to be converted to run on biofuel. The charging stations outside San Jose City Hall and at the Fourth Street garage in town are the first in the firm's planned ChargePoint network for electric cars and plug-in hybrid vehicles. Last fall, the cities of San Francisco, Oakland and San Jose teamed up with the Palo Alto firm Better Place to create an electric vehicle infrastructure throughout the greater Bay Area with EV charging outlets in parking lots, buildings and homes. Better Place has already established similar development arrangements in Australia, Israel and Denmark. In Japan, the race toward green mobility is focusing on development of mass-produced zero-emission cars.

## 11.6.12. Honda produces first commercial hydrogen cars

Source: Candace Lombardi. June 2008. http://news.cnet.com/8301-17912_3-9969263-72.html

The Japanese auto manufacturer Honda ceremoniously launched production of its first hydrogen-powered vehicles Japan, and announced its first customers. The four-door sedan, called the FCX Clarity, runs on electricity from a fuel cell battery that is powered by hydrogen fuel. Steam is the car's only by-product. The car can get a combined (city and highway driving) fuel efficiency of about 115 kilometres per kg of H2 which, according to Honda's own estimates, is the equivalent of getting about 74 mpg on a gas-powered car. The car can be driven for about 450 kilometres before needing to be refuelled. Honda claims it is the first company to have a hydrogen car certified for regular commercial use by the U.S. Environmental Protection Agency. The car was first introduced as a concept vehicle in 2005 at the Tokyo Motor Show. Starting in July, Honda plans to offer the hydrogen-powered FCX Clarity through a lease program at three dealerships in California: Power Honda Costa Mesa, Honda of Santa Monica, and Scott Robinson Honda in Torrance. Honda also plans to make the cars available in Japan. The cars will be leased on a three-year basis for about $600 per month, according to Honda. The biggest obstacle in mass market appeal of hydrogen-powered vehicles vs. gas-electric hybrids is where owners could fill up their cars. While the U.S. Department of Energy has been a proponent of hydrogen fuel as an alternative energy for cars, there are currently few hydrogen-fuel filling stations the U.S. There is also an ongoing debate as to whether hydrogen, a fuel that requires large amounts of electricity to be produced, is truly energy efficient when its entire food chain is taken into consideration.

## 11.6.13. Toyota to build electric town car, plug-in hybrids

Source: Martin LaMonica. January 2009: http://news.cnet.com/8301-11128_3-10140083-54.html?tag=mncol;posts

Toyota Motor Sales announced an expanded commitment to electric vehicles on Saturday, disclosing plans to manufacture an all-electric city car by 2012 and a wider fleet of gas-electric hybrids. At the North American International Auto Show (NAIAS) in Detroit, Toyota showed off a concept car called the FT-EV, a battery-powered four-seat compact car. Although it is a concept car, Toyota said it will release an "urban commuter" electric car in 2012. Based on an existing car sold in Japan called the iQ, the FT-EV runs entirely on batteries and has a range of about 50 miles. Like many all-electric cars planned for release in the next few years, the FT-EV is designed for commutes and short trips, potentially as a second car. A number of auto companies, including Mitsubishi, Nissan, and Think, plan to bring out small all-electric cars in the next two years. The commitment of Toyota--maker of the iconic Prius hybrid car--adds more validity to the small electric commuter car category. Toyota said that it will move up its previously announced plan to test plug-in hybrid cars using lithium-ion batteries. Current Priuses use Nickel-metal hydride technology but most auto makers are pursuing lithium-ion chemistry for an upcoming wave of electric cars. Toyota's goal is to sell one million gas-electric hybrids a year in the early 2010s. It will have 10 new hybrid models in that time, including the third-generation Prius and the Lexus HS250h, both of which it introduced this week in Detroit at the NAIAS.

## 11.6.14. Yet more rumours of a solar Prius

Source: Candace Lombardi. January 2009 http://news.cnet.com/8301-11128_3-10130380-54.html?tag=mncol;title

This wonder-car-in-the-making has gone from being a Toyota Prius that uses solar roof panels from Kyocera to power its air conditioning unit, to "a vehicle that will be powered solely by solar energy" to quote one recent Associated Press article. This latest rumour seems to be timed to follow Toyota's December news that it, too, has succumbed to the world auto industry slump, reporting its first annual operating loss in 70 years, and a series of consolidations and changes in its organizational structure. Of course, there is already an available solar option for some Toyota owners in the U.S. Solar Electrical Vehicles (SEV) has been offering an after-market Prius solar overhaul since June 2007. It includes a customized solar panel for a Prius roof that can improve the car's efficiency by about 29 percent. SEV also offers kits for the Toyota Highlander, Rav4 EV, and Ford Escape Hybrid.

## 11.6.15. Battle hardened, robot-driven cars by 2030

Source: Dane Muldoon. February 2007

http://www.autobloggreen.com/2007/02/20/battle-hardened-robot-driven-cars-by-2030/

A scientist speaking at the American Association for the Advancement of Science annual meeting in San Francisco has predicted robot-driven cars that could drive humans around by the year 2030. Intelligent robot vehicles are likely to be used on battlefields even sooner though predicts Sebastian Thrun, an associate professor of computer science and electrical engineering at Stanford University. Thrun is leading the Stanford team again in this year's 60 mile DARPA Urban Challenge. Computer aided driving systems are already filtering into luxury cars and fully robotic systems are sure to follow. Autonomous Cruise Control is a good example that is already available on a wide range of both luxury and mainstream car brands. The system utilises radar or lasers to monitor the distance between the car and the vehicle in front and will automatically slow the car down or speed up when required. Another example of computer aided driving is Adaptive Braking, a technology found in the new 2008 Mercedes-Benz C-Class. Adaptive braking includes hill assist and panic brake assist. The hill assist detects when you are starting on a slope and maintains some brake pressure in the callipers when you move your foot to the accelerator until you actually apply the gas, to keep you from rolling back down the hill. The panic brake assist detects when you do a quick brake apply and helps to apply full pressure.

## 11.6.16. Aptera EV opts for front-wheel drive

Source: Noel McKeegan. December 2008: http://www.gizmag.com/aptera-ev-opts-for-front-wheel-drive/10633/

The already unmistakable Aptera 2e three-wheeler is continuing to evolve as it approaches its promised 2009 release with the latest development being the introduction of front-wheel drive to replace the original belt-driven rear wheel set-up. Front-wheel drive will now be used in all production vehicles with the company citing improved traction, stability and greater efficiency at high-speed as the key reasons for making the switch. The change to front-wheel drive will also give the Aptera-2e (which was previously known as the Typ-1 before a branding change back in November) increased durability, better noise insulation and more room for cargo over the previous configuration. With a focus on safety as well as efficiency, the 2e will reach the market with standard features such as driver and passenger airbags, an energy-absorbing and impactdeflecting passenger Safety Cell, LED lighting inside and out, a RFID Key Fob, plus Solar Assisted Climate Control powered by a roof mounted panel. GPS navigation and a CD/MP3/DVD player will be optional. The company is taking refundable $500 deposits for the all-electric 2e which is slated for release in 2009 and hopes to have 100,000 Apteras on the road by 2015. The all-electric model will deliver 160 kilometres per charge (which takes 8 hours via a standard 110v outlet) and a second plug-in hybrid version (now known as the Aptera-2h) promises an incredible 300 mpg when it's released in 2010.

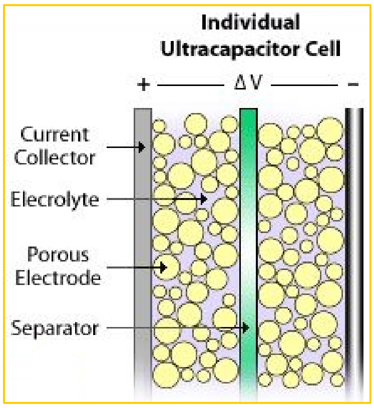
## 11.6.17. A Zero Emission Car By Tata Uses Compressed Air To Push The Pistons of Motor

Source: George Angus. January 2009. http://www.examiner.com/x-934-Alaska-Transportation-Examiner~y2009m1d1-Finally-a-zero-emission-car

Dubbed the MiniCat, This car uses compressed air to push the pistons of the motor instead of a combustible fuel mixture. That is right. This means *zero* emissions. The construction is completely different from the standard stamped sheet metal welded to make a unibody frame. It consists of tubular steel and fibreglass married together with industrial adhesive. There could very well be a market for this kind of vehicle in a congested large city where travel distances are short anyway. Tata Motors are indicating a range of about 300 kilometers between fill ups. In India, a fill up should cost less than $2. The top speed is 65mph. It is anticipated that 6000 of these hit the streets of India in 2008.

## 11.6.18. EnerG2 aims to improve ultracapacitors for electric cars industry

Source: Jennifer Kho. November 2008: http://venturebeat.com/2008/11/18/energ2-aims-to-improve-ultracapacitors-for-electric-cars-industry/?obref=outbrain




EnerG2 Inc., an ultracapacitor startup that has kept quiet until now, was launched with the official announcement that it has raised $8.5 million in its first round of financing. Founded in 2003, it has spent five years developing electrode materials that it claims can boost the performance of ultracapacitors, devices that are useful in electric cars and smaller electronic devices. Unlike batteries, which store electricity chemically, ultracapacitors store energy as electrical fields and physically separate the positive and negative charges with an insulator. Some describe ultracapacitors as "mechanical batteries", attractive for their ability to deliver large bursts of power, charge and discharge quickly and efficiently and last through many more cycles than batteries, as well as tolerate changes in temperature, shocks and vibration. And where a traditional battery lasts about 1,000 cycles (one charge and discharge), an ultracapacitor could last 1 million cycles or more, according to Rick Luebbe, EnerG2's chief executive. Working with technology initially developed at the University of Washingon, EnerG2 has taken the pure activated carbon typically used in today's ultracapacitor electrodes, the plates that hold the electrical fields, and restructured it at the nano level, increasing its surface area and making it more porous so that ions can flow more easily, he said. Despite the improvements, EnerG2 is not targeting ultracapacitor applications that compete head-on with batteries, at least at first. Even with its new materials, ultracapacitors will not approach the energy densities of batteries, so the company has set its sights on applications where other attributes, such as power density, cycle life or fast charging, are more important. Aside from the industrial and electric-rail applications, EnerG2 plans to sell materials for ultracapacitors in hybrid-electric vehicles, consumer electronics, power tools and backup power in data centres, telco switching stations and even the grid, he said. It should have plenty of potential customers. Big companies making ultracapacitors now include Panasonic Corp. and Okamura Laboratory Inc. in Japan and NessCap Co. in South Korea. The United States' Maxwell Technologies is also going after the transportation market, along with APowerCap Technologies and EEStor.

## 11.6.19. Electric Cars Are Unlikely to Help Carmakers Cut $CO_2$ Emissions

Source: The Boston Consulting Group. January 2009: http://finance.yahoo.com/news/Electric-Cars-Are-Unlikely-to-iw-14066917.html

An estimated 14 million electric and hybrid cars may be sold in 2020 in the world's four largest automotive markets -- Western Europe, North America, Japan, and China -- up from some 400,000 in 2008, according to a report by The Boston Consulting Group (BCG) published today. But despite growing pressure on the automotive industry to produce cars with lower carbon dioxide emissions, the world's automotive markets will remain dominated by cars powered by the next generations of traditional internal-combustion engines (ICEs) unless governments intervene with incentives for car manufacturers, power The electric car, which was first marketed in the early 1900s and then revived unsuccessfully in the 1990s, has long been hailed as the answer to the problem of how to cut the car industry's contribution to $CO_2$ emissions. In Europe, electric cars are able to generate around 60% ess in $CO_2$ emissions, calculated on a well-to-wheel basis, than those powered by ICEs. In a study, BCG analyzed possible markets in 2020 for electric, hybrid, and ICE-based cars under different scenarios. In the most likely, the steady-pace scenario -- which assumes that fears of climate change are high, the price of a barrel of oil is around $150, and governments enforce existing regulations for reducing $CO_2$ emissions -- some 1.5 million fully electric cars and some 1.5 million range-extended electric vehicles would be sold in 2020, as well as 11 million hybrid cars. These vehicles, together with those powered by compressed natural gas, would constitute 28% of the cars sold in the major markets. The number of cars powered by alternative fuels -- for instance, second-generation biofuels and hydrogen -- would be insignificant, even though they actually offer the highest potential for reducing $CO_2$ emissions, cutting them by up to 90%. Western Europe would develop the biggest appetite for fully electric cars in 2020 -- some 600,000, more than one-third of the total sold. North America would be the biggest market for hybrid cars, accounting for 5.4 million of the 11 million sold in the major markets.

## 11.6.20. Scientists explore putting electric cars on a two-way power street

Source: University of Michigan. Physorg.com website. October 2008.
http://www.physorg.com/news142165210.html


Scientists at the University of Michigan, using a $2 million grant from the National Science Foundation (NSF), are exploring plug-in hybrid electric vehicles (PHEV) that not only use grid electricity to meet their power needs, but return it to the grid, earning money for the owner. The concept, called vehicle-to-grid (V2G) integration, is part of a larger effort to embrace large-scale changes that are needed to improve the sustainability and resilience of the transportation and electric power infrastructures. If V2G integration succeeds, it will enable the grid to utilize PHEV batteries for storing excess renewable energy from wind and the sun, releasing this energy to grid customers when needed, such as during peak hours. This will lead to more sustainable transportation and grid infrastructures, and will also increase the resilience of these infrastructures to sharp changes in energy costs, supply, or demand.V2G is an opportunity to look at vehicles beyond shaving miles per gallon. A team of experts in mechanical and power systems engineering, economics, and industrial ecology will examine every aspect of a PHEV and how it interacts with the electrical grid. If PHEVs, which are anticipated to be on the market in 2010, fulfil their promise, millions could be on the road in the decades to come. This potentially will provide unprecedented shared battery storage to the grid and transportation infrastructures, thereby allowing these infrastructures to store renewable energy when available and use it when needed. The team's success will depend on its ability to bring together expertise in transportation and grid systems, economics, industrial ecology, and natural resources

## 11.6.21. Zero-Emission Double Decker Buses Coming to London

Source: Ariel Schwartz. December 2008: http://www.greenbiz.com/blog/2008/12/23/zero-emission-double-decker-coming-london

As if visitors to London did not already have enough to see, the London Transportation Department has just unveiled a sleek zero-emissions double decker bus design. London's redesign of its historic red bus will join Burbank's zero-emissions hydrogen fuel cell bus in making city-wide public transportation more sustainable. The bus, which will be turned into a prototype by 2011, was created by architecture firm Foster + Partners as part of a contest to redesign the city's double decker buses. The firm's winning entry comes complete with leather upholstery, wooden floors, panoramic views, and a glazed roof featuring energy-generating solar cells. If London's double decker inspires just one other major metropolis to take on the sustainable redesign of iconic structures, I think it will have done its job.

## 11.6.22. Japan races to build a zero-emission car

Source: Physorg.org website. January 2009: http://www.physorg.com/news150347980.html

As mass-produced electric cars come closer to reality, their makers are trying to polish the image of what experts say could be a hard sell in the current recession. Zero-emission vehicles may not be a novel concept for long. Japanese carmakers are racing to develop electric cars, and US and European manufacturers have also announced plans to roll them out within a few years. The dream of an electric car, which has been around since the time of Thomas Edison, has so far failed to break into the mainstream because of limited battery life that makes such vehicles impractical for most purposes. Mitsubishi's electric car now runs 160 kilometres on one charge, which takes 14 hours when using a conventional 100-volt outlet on the wall, or 30 minutes to charge 80 percent of the battery using a special quick charger. Nissan Motor Co. aims to start selling an electric car in the United States and Japan in 2010 and the rest of the world in 2012. Other Japanese automakers have been working to create fuel cell cars, which produce electricity through a chemical reaction between hydrogen and oxygen, with water the only by-product. Honda began selling the latest FCX Clarity in the United States in July, with the first five cars to be delivered to celebrities including film producer Ron Yerxa and actress Jamie Lee Curtis. Toyota Motor Corp., which has already won strong interest in its petrol-electric hybrids, is developing a range of fuel cell, electric and other clean cars that run on biofuel or clean diesel. Japanese automakers have enjoyed brisk demand for their smaller, fuel-efficient cars in recent years. But even Japanese automakers still have more work to do before fuel-cell or electric vehicles are completely environmentally friendly. While fuel cell or electric vehicles emit no carbon dioxide themselves, $CO_2$ is produced when hydrogen or electricity is produced from fossil fuels.

## 11.6.23. Gordon Murray Design T25 city car: the scoop

Source: Tim Pollard. CAR Magazine online. October 2008: http://www.carmagazine.co.uk/Secret-new-cars/Search-Results/Spyshots/Gordon-Murray-Design-T25-city-car-the-scoop2/

CAR Online exclusively revealed how two versions of Gordon Murray Design's radical new T25 city car will look when they go on sale in Europe and Japan in 2012. The T25 could go on sale in the Unites States just two years later. The first and most popular variant of the T25 will be the mini-MPV pictured in our main artist's impression: it's a 'multi-seat' car with a flexible interior layout similar to the Toyota iQ's, which can be configured to suit adults, children or luggage. Plastic panels mean that other T25 bodystyles can be introduced quickly and cheaply using the same front-engined running gear. A convertible and pick-up are already under consideration, and it might be possible for owners to switch between some body styles – the pick-up and a commercial van, for instance – on their own driveway using a kit of panels. Work on the T25 is understood to be progressing rapidly but under conditions of strict secrecy. Murray plans to license the design to another firm to manufacture, and is already in talks with two major industrial companies. But the $25 billion US federal loan package to help car makers start building low-emission vehicles has prompted a fresh surge of interest from America. The company says talks include designing cars significantly different to the T25 but which use its 'revolutionary' manufacturing process. GMD is on track to have the first running prototypes on the road by early 2009. Wind-tunnel testing of the final designs is already well advanced and design of the major internal components is almost complete. Our artist's impressions are based on insider info and give the best look yet of how the T25 will look when production versions hit the road in 2012. Real-world analysis for the final design are said to show that the T25 will hit its ambitious targets on weight, cost and carbon dioxide emissions. Simplicity is the key here – the T25 represents a welcome return to less is more. It will weigh just 550kg and cost from £5500. Murray claims that it will produce 40% less $CO_2$ than a standard car throughout its lifecycle, and one ton less over a typical year's motoring. Equipped with a 51bhp three-cylinder petrol engine, it will return 81mpg and 78g/km, says Murray.

## 11.6.24. Ford Promises Pure Electric Vehicle for 2011

Source: Hank Green. January 2009: http://www.ecogeek.org/content/view/2463/69/

Ford announces aggressive new electric vehicle plan to bring pure battery-powered vehicles, hybrids and plug-in hybrid vehicles to market. To start, Ford will introduce in North America: a new battery electric commercial van in 2010; a new battery electric small car in 2011; next-generation hybrid vehicles, including a plug-in version in 2012. These vehicles pave the way for additional applications in the future, using Ford's high-volume global small car and midsize car platforms. Ford is partnering with high-tech partners to bring electric-powered vehicles to market quickly and more affordably. Ford Motor Company today launched an aggressive plan to bring pure battery-electric vehicles, next-generation hybrids and a plug-in hybrid to market quickly and more affordably during the next four years. The plan, unveiled at the 2009 North American International Auto Show, signals the next phase in Ford's commitment to deliver the best or among the best fuel efficiency with every new vehicle it introduces and to make fuel efficiency solutions affordable for millions of customers. Ford is partnering with high-tech partners to bring electric-powered vehicles to market quickly and affordably. Today, the company announced a new collaboration with Magna International to bring a new lithium ion battery-powered small car to market in North America in 2011. The new electric vehicle will have a range of up to 100 miles on a single charge, without using a single drop of gasoline. Ford also has entered into a four-way "Eco-Partnership" in China to expand its global expertise with electric-powered vehicles. Ford, Changan Auto Group and the cities of Chongqing, China and Denver, Colo., are exploring ways to develop projects to help further energy security and promote economic and environmental sustainability. Areas of focus could include developing electrified vehicle technologies, green city planning, efficient urban transportation and grid integration. Ford's aggressive new electrification plan represents the next step in the company's sustainability plan. Unveiled in 2007, the plan includes a commitment to greater vehicle fuel economy and lower $CO_2$ emissions as part of Ford's longer-term commitment to addressing climate change and energy security.

## 11.6.25. Solar electrical systems

Source: http://www. solarelectricalvehicles.com/


Founded in mid 2005, SEV was created to develop a true solar charging system for Hybrid Electric Vehicles that provides increased electric driving range and improved fuel economy. Founded by Greg Johanson, with over 20 years of experience in the solar electric vehicle industry, SEV is the sister company to the oldest and largest systems integrator of solar power systems in Southern California, Solar Electrical Systems. The Solar Electric Vehicle system was designed and engineered as an easy to install (2 to 3 hours) integrated accessory system with a custom molded low profile solar module, supplemental battery pack and a proven charge controlling system. The SEV system generates energy from sunlight and converts this energy to high voltage, which is utilized to charge the supplemental battery and the Hybrid Vehicle (HV) battery pack. This allows the Hybrid Vehicle to operate for extended driving range in the electric mode With the SEV solar system, the Toyota Prius can operate up to 20 miles per day in electric mode thus improving fuel economy by up to 29% (depending on driving habits and conditions).

## 11.6.26. Hybrid cars

Source: http://hybridcars.com/calculator/index.php


"From 1990 to 2000 world oil consumption rose by 10 billion barrels. Of this, more than half of the growth occurred in the US. The major reason for this growth in US consumption was the SUV. The SUV percentage of the market has increased from 5% in 1990 to 55% now. SUVs violate fuel economy standards, but are allowed under a ridiculous exemption that classifies them as light trucks. The US is the only industrialized country whose overall fuel economy has decreased since 1990. The US uses nearly half of the world gasoline production." Driving a Toyota Prius instead of a Ford Explorer for 15K miles per year reduces Carbon Dioxide emissions by 15,000 lbs and saves $2500 in gasoline per year.

## 11.6.27. Solar Bug

Source: http://www. freedrive-ev.com/info.html

This is a neat little two person 4 wheel electric vehicle being developed right in the Bozeman, Montana area by Steve Titus. Steve is now offering the production version and has 53 pre-orders: Top speed 35 mph- Range 96 kilometres on a full charge- 200 watts of PV on car -- good for 10 to 32 kilometres per day- Capacity 2 persons- Recharge in 4 to 6 hours for 50 cents- Roll bar and seat belts- Weighs 408 kg.

## 11.6.28. Accelerated Composites Aptera

Source: http://apteramotors.com/

The Accelerated Composites Aptera will be produced as an all electric and as a plug in hybrid. Seating for two adults + an infant seat behind. Zero to 60 in 10 seconds, top speed around 136 km/h. Drag coefficient of 0.05., weight 385 kg, range 193 kilometres. While it is licensed as a motorcycle, they have put a lot of emphasis on safety including air bags and front, side, and rollover protection. Their goal is to offer the EV version in late 2008 and the hybrid version in late 2009 -- prices projected to start at $27K.

## 11.6.29. Solar Trike

Source: www.solartrike.com/electricrecumbenttrike.html

A solar and pedal powered tricycle kit. 170-watt solar panel/roof. Can actually run directly off solar panel at 6 to 12 km/h without pedaling. 12 to 22 km/h with battery. They sell plans and part kits for several different models.

## 11.6.30. AC Propulsion provided the electric drive systems for the MINI E

Source: Sam Abuelsamid. November 2008: http://www.autobloggreen.com/2008/11/19/la-2008-confirmed-ac-propulsion-provided-the-electric-drive-s/

In conjunction with the official unveiling of the MINI E a the LA Auto Show, AC Propulsion has confirmed that it has produced the electric drive system for the car. When BMW first released some of the details on the new battery powered MINI E a few weeks back we speculated based on the description of the drive system and battery pack that perhaps Tesla was the supplier. In fact, the Tesla system was originally based on the work of AC Propulsion. The ACP tZero prototype was the car that inspired Martin Eberhard to get the Tesla ball rolling. ACP provided over 500 complete sets of hardware to BMW for installation into the new MINIs. The full system consists of the 150 kW motor, a 35 kWh battery pack, charger and all the electronics. The charger is capable of operating at 120V, 208V and 240V with automatic switching and bi-directional capability. That latter element is important because it means that the charger can send power out from the battery to the grid for V2G capability. The AC Propulsion press release is after the jump.

## 11.6.31. The "It" electric car

Source: Christian Gulliksen. June 2004. http://www.itiselectric.com /

In 1988, the National Highway Traffic Safety Administration (NHTSA) created a new class of transport called Low Speed Vehicles (LSV), intended for gated communities, resorts, and universities. According to NHTSA guidelines, an LSV must have safety equipment such as turn signals, mirrors, wiper blades, head- and taillights, and seatbelts, and may be driven only on roads with posted speed limits of 56 km/h or less. Currently, 35 states have approved LSVs under these conditions. The four-seat IT can be ordered with a fully enclosed body, as a convertible, or as a two-seat pickup, and comes with amenities such as a heater and a defroster. The IT has a spacious interior and provides a surprising level of utility. It is easy to see why LSVs have become especially popular with retirees, who consider them practical runabouts with room for groceries and grandchildren. It is not hard to imagine an open-topped IT on the back lanes of Martha's Vineyard or navigating the Thunderbird Country Club in Rancho Mirage. The ITs also appeal to universities and city governments, and one San Diego company has a fleet of ITs in service as taxis. ITs are priced from $13,000 and have only a few options; among the most popular are service-free batteries that retail for $500 and accessories such as wheels that vary in price. Dealers are located in California, Florida, Arizona, Washington, and Hawaii, as well as in British Columbia and Ontario.

### 11.6.32. Pedallec Electric Scooter

Source: http://www.webspawner.com/users/treelifer1/

Pedallec Electric Scooters are the future mode of city transport. You can own a Pedallec from less than the money you spend on your travel for one year and gives you freedom with comfort. There is no engine but a DC Electric motor to drive your Pedallec. They are fitted with a rechargable battery, supplied with a charger unit. The cost of charging is less than 20 pence a day and will only takes about 4 - 6 hours. They make No noise when running, No fume, less maintenance, no reported failure in service over the past 10 years of manufacture. Road tax is only £15.00 a year and some models requires no road tax, registration or driving licence to ride on the road. The side car Scooter is available in Petrol engine 150cc but will be available in Electric Model in the near future. Buy your Pedallec Today, Save some money for your other needs. Pedallecs can be bought with a Petrol engine as well from 49cc to 150 cc depending on your requirement for speed and distance travelling. They come in a variety of lovely colours of your choice.

### 11.6.33. BudE

Source: http://www.webspawner.com/users/treelifer1/

A very nice and efficient little three wheel, one passenger, electric vehicle with some weather protection. Offered as a kit for about $4000. Range around 48 kilometres. Top speed around 80 km/h. Powered by 4 12-volt lead-acid batteries.Empty weight 385 lbs.Small luggage compartment at front. Uses about 170 watt-hours per mile -- nearly 10 times the efficiency of a typical gasoline car. Could be charged via a solar PV array at home. Lots of detail on the website.

## 11.6.34. Volvo premieres world's most powerful truck

Source: Gizmag website. January 2008: http://www.gizmag.com/volvo-premieres-worlds-most-powerful-truck/10724/

With its 700 hp and 3,150 Nm of torque, the new Volvo FH16 is the most powerful commercially produced truck in the world. Its turbocharger and intercooler 16-litre 6-cylinder diesel D16G engine is derived from Volvo's previous 16-litre engine and has more torque and an additional 40 bhp. Quite spectacularly, the truck achieves the same economy as the previous 660 bhp version, and fewer emissions. Through a number of measures - including redesigned pistons - Volvo's engineers have optimised the combustion process and met demands for high performance combined with efficient fuel utilisation, low emissions and long lifetime. Both maximum power and maximum torque span a wider rev range than before, contributing to excellent driveability. The engine now also features a new oil thermostat that has a favourable effect on fuel consumption. The noise level during idling has now been lowered by 2dB(A). With the help of pre-injection, where a small amount of fuel is sprayed into the cylinder, the result is a gentler combustion sequence and a far lower noise level. Another important change is that in the two most powerful engine variants is a new and larger exhaust after-treatment system. Since the system can handle a larger flow of exhaust gases, counter-pressure is reduced and power losses are minimised. A larger-capacity system also results in better cleaning capacity. As with the current model, the Selective Catalytic Reduction (SCR) system is used, taking effective care of harmful emissions. The Volvo D16G is equipped with a new, electronically-controlled exhaust brake (EPG) as standard with an output of 230 kW. Electronic control makes it possible to reduce the number of moving parts, promoting simpler operation, higher reliability and lower weight. There is also the option of the Volvo Engine Brake (VEB+) with 425 kW maximum braking effect. The Volvo FH16 is certified for the new Euro 5 European emission requirements that come into force this October, which means that oxides of nitrogen emissions have been cut by more than 40 per cent. In other words, the new Volvo FH16 has become even more powerful, but without compromising on the environment. In addition to the 700 hp version, the Volvo FH16 is also available in variants producing 540 and 600 hp respectively.

## 11.6.35. Net-Centric Systems to Guide Trucks

Source: Lance Winslow: http://ezinearticles.com/?Net-Centric-Systems-to-Guide-Trucks&id=547249

The car's systems will all work together like a company office and its computer system. Even better, all these four-wheeled net-centric systems will have a system like the wireless Internet and they will communicate with each other and the Smart Highways of the Future. This means no car can ever crash into another car, because the other car will be talking to it at all times, giving its changing coordinates. How is this possible you ask? Well each car will be using the same systems and satellites with the same information. Sounds to Sci-Fi for you? Well that is okay, because in a way it is really, as this is some ways off in the future. Although once these systems are in place and working, well fewer people will be killed in auto-accidents and that is a very good thing. Losing 40,000 people per year to accidents is a horrific thing indeed. The truck's transponder talks with the computer system at the truck scale, toll-ways and at border checkpoints. Soon more and more roads will also contact the truck for warnings and traffic alerts. Therefore, all that is really left is simply allowing them to talk together with all the other cars and that is the net-centric vehicle vision of the future and it will save lives. Of course, many modern trucks are already on their way to doing some of this. The truck's digital nervous system is already in constant contact with all its components. The truck itself may be in constant contact with the satellite and the dispatch office. The car would then communicate with all the other cars as to what was going on and this system would line up all the cars by size and allow them to go down the road together at various speeds. This would allow them to drive very close together and very fast and break the wind resistance to increase efficiency.

## 11.7. *Emerging air technologies*

### 11.7.1. Boeing flies first ever battery fuel cell plane

Source: Jorge Chapa. April 2008 http://www.inhabitat.com/2008/04/09/transportation-tuesday-boeing-flies-first-fuel-cell-plane/


Hydrogen fuel cells are not new technology but are an continually intriguing alternative power source. A fuel cell is a device that can convert hydrogen into electricity and is effectively a zero-emissions fuel source in operation (though not in manufacturing). It is commonly deployed in automobiles, and has also been used as a supplementary source of energy within buildings. Last week, Boeing demonstrated a small manned Dimona motor glider using only hydrogen fuel cells, making it the first time that a manned airplane has ever flown on this technology. The plane was a two-seat Dimona motor glider with a 53 feet span adapted to fuel cell technology by an engineering team at Boeing Research & Technology Europe (BR&TE) in Madrid, with assistance from industry partners in Austria, France, Germany, Spain, the United Kingdom and the United States. The milestone manned flight reached an altitude of 3,300 feet, using a combination of battery power and power generated by hydrogen fuel cells, and then flew an additional 20 minutes on hydrogen power only at a speed of 99 kilometers per hour. Boeing says fuel cells are unlikely to be able to power a larger commercial plane, but they can certainly be used for smaller planes, unmanned aircraft and to power the smaller, secondary systems of large airliners. Still, it sure would be nice if Boeing could develop the system to be powerful enough to replace the more common petroleum based fuels required to fulfil our current aviation needs.

## 11.7.2. Research on supersonic planes

set to revolutionize air travel NASA's successful test flight of an experimental plane called the X43A achieved speeds of 7,200 miles per hour and demonstrated the future possibilities for less-expensive supersonic commercial trave.l

Source: Joey Natoli. November 2004: http://daily.stanford.edu/article/2004/11/23/researchOnSupersonicPlanesSetToRevolutionizeAirTravel


Since the 1950s, governments and aeronautic scientists around the world have explored options to make planes go faster — much faster. Presently, average commercial planes fly at 550 to 600 m.p.h., and with the official retirement of the Concorde in 2003, the Boeing 747 is narrowly the fastest commercial airliner, capable of speeds up to 720 m.p.h. Within military technology, the fastest jet is the SR-71 — unofficially known as the "Blackbird" — capable going up to 2,400 m.p.h. Originally created for long-range reconnaissance missions, the planes are now mostly used for high-speed, high-temperature aerodynamics research, according to the Dryden Flight Research Center. Yet the SR-71 is relatively inefficient in fuel use, making it unviable for commercial use. The X43A, utilizing supersonic combination ramjet — or scramjet — technology proposes to take the next aeronautic leap. Scramjet technology dramatically increases speeds and has the possibility of greater fuel efficiency than the technology used in the military's SR-71.Scramjet technology used in the X43A operates in a manner very different from traditional planes or rockets. The engine occupies the entire lower surface of the airplane body, as opposed to the sides of a typical aircraft. Once the plane achieves speeds of approximately 2,800 m.p.h., the scramjet compresses the air passing through the engine, allowing combustion to occur. It is believed that this technology has the potential of achieving speeds up to 10,000 m.p.h. One specific area of research the team is looking at involves the Stanford expansion tube — a low-impulse flow device that mixes gases of different pressures to achieve a mixture that can reach a high velocity. The research lab is also using super-fast imaging techniques to study the physics of scramjet technology. Besides the speed, the greatest advantage of scramjet technology is that it does not require additional oxygen, carried in oxygen canisters. Currently used to achieve speeds above Mach 3, oxygen canisters are typically used for booster rockets. Scramjet technology allows oxygen to be taken directly from the atmosphere, lightening the load necessary for flight. In turn, the vehicle can carry heavier payloads, including larger satellites. As oil prices continue to fluctuate, it is unlikely that the airline industry will invest in a fuel-inefficient plane. However, if the scramjet technology continues to develop and can attain fuel costs lower than the Concorde, it holds the possibility of revolutionizing the airline industry.

## 11.7.3. Air New Zealand tests biofuel Boeing

Source: Candace Lombardi. January 2009.http://news.cnet.com/8301-11128_3-10130320-54.html

Air New Zealand, along with Boeing, Rolls-Royce, and Honeywell, retooled one of the four Rolls-Royce RB211 engines on a Boeing 747-400 to run on an unusually fruity blend of half Jet A1 fuel and half jatropha oil, according to Air New Zealand. Jatropha is a succulent plant commonly grown in the semi-arid areas of India that produces seeds containing an oil that can be harvested and processed into a biofuel. Jatropha has been used in making biodiesel for cars and trucks, but this is one of the first known attempts to use it as a biofuel in a commercial-size airplane. Air New Zealand is not, however, the first commercial airline to try flying on a mixture containing biofuels. Several airlines, including Virgin Atlantic, have been testing out the sustainable idea of bio jet fuel mixed with jet fuel. The jatropha bio jet fuel was supplied by Terasol Energy, which certified that the fuel supply met sustainability criteria. The two-hour test flight took off and landed from an Auckland, New Zealand, airport on Tuesday. The test run was part of a program to research better sustainable air travel. International Air Transport Association (IATA) lists jatropha as a promising next-generation bio-jet fuel for the airline industry because the hardy plant can be grown in poor quality soil needing little water.

## 11.7.4. Terrafugia Transition

Source: Terrafugia website: http://www.terrafugia.com

Terrafugia has been dedicated to bringing the Transition® Roadable Aircraft (often called a "flying car") to the General Aviation community since 2006. The two-place Transition® will be a certified Light Sport Aircraft (LSA) expected to have its first customer delivery in 2010. Every pilot faces uncertain weather, rising costs, and ground transportation hassles on each end of the flight. The Transition® combines the unique convenience of being able to fold its wings with the ability to drive on any surface road in a modern personal airplane platform. Stowing the wings for road use and deploying them for flight at the airport is activated from inside the cockpit. This unique functionality addresses head-on the issues faced by today's Private and Sport Pilots. Terrafugia's award-winning MIT-trained engineers have been advancing the state-of-the-art in personal aircraft on-schedule since 2006. Now you can streamline your flying experience with the revolutionary integration of personal land and air travel made possible by the Transition® Roadable Aircraft.

### 11.7.5. Pal-V: Personal Air and Land vehicle

Source: Pal-V website. http://www.pal-v.com


PAL-V Europe NV started in 1999 to study many technologies and evaluated various concepts. It made numerous designs and patented all its findings, leading to the PAL-V One, the first Personal Air and Land Vehicle (PAL-V) available for anybody. PAL-V Europe NV combines the safe and easy principle of flying, the gyrocopter with the recent “tilting car” technology of the Carver . PAL-V has the exclusive rights to all the basic patents covering this magnificent concept. In addition, PAL-V Europe NV has patents pending for, amongst others, a foldable rotor. European and American regulations allow people to fly the PAL-V with a sports aviation license. It takes between 20-40 hours getting a pilot’s license while driving can be done with a regular car driver’s license. Potential customers for professional applications like police surveillance, first aid or courier services as well as consumers for mobility and fun are registering at our company on a daily basis. A gyroplane is a flying machine. Like a helicopter, it is a rotary wing aircraft- which means that it has a rotor to provide lift instead of wings like conventional airplanes. Unlike a helicopter, the rotor is not powered by the engine. It is made to spin by aerodynamic forces, through a phenomenon called autorotation. Since the rotor is not powered, a gyroplane needs a separate source for propulsion, like an airplane. Mostly propulsion comes from an engine driving a propeller. A gyroplane, also known as gyrocopter or autogyro, has in fact the same controls as a fixed wing airplane. Pitch control of the gyroplane is by tilting the rotor fore and aft; roll control is by tilting the rotor laterally (side to side). Tilt of the rotor is effected by a tilting hub. Yaw control is done with a rudder, just like any conventional fixed wing airplane.

### 11.7.6. Jet packs

Source: Erik Sofge. July 2007. http://www.webspawner.com/users/treelifer1/

To some extent, everyone's in the market for a jet pack. But since Bell Labs built the first rocket belt (the correct, if less exciting, name) in 1953, potential buyers have been stymied by two problems: Rocket belts aren't for sale, and even prototypes run on modern-day fuel (as opposed to whatever the Jetsons use) — which means rocket belts can weigh upwards of 100 pounds, with only enough fuel to stay aloft for under a minute. Mexican start-up Tecnologia Aeroespacial Mexicana (TAM) offers its custom-built TAM Rocket Belt for $250,000, which includes flight and maintenance training. On a full tank of hydrogen peroxide the belt weighs 124 to 139 pounds (the bigger the pilot, the bigger the belt), and provides 30 seconds of flight. TAM's sole competitor is Jetpack International, a Colorado-based company that sells what it calls "the world's longest-flying jet pack." Technically speaking, it's true — the hydrogen-peroxide-burning Jet Pack H202 can stay in the air for 33 seconds, 3 seconds longer than TAM's model. The H202 weighs 63 kilograms, and is competitively priced at $155,000, flight classes and all. Jetpack International founder Troy Widgery is the first to point out the drawbacks of current short-flight rocket belts. "If something goes wrong, you can get killed," Widgery says. "Thirty-three seconds of fuel makes an inexperienced pilot twitchy." The solution? Ditch the rocket belt, and build a bona fide jet pack (okay, jet belt). Widgery plans to release the T73 Turbine by the end of the year; it is a $200,000 model that will burn jet fuel, allowing it to stay airborne for 19 minutes. Not to be outdone, TAM is working on a propane-burning jet belt, though it hasn't said when it will be available.

### 11.7.7. Gryphon Single Man Flying Wing

Source: Flight International. June 2006: http://www.flightglobal.com/articles/2006/06/01/206910/james-bond-style-strap-on-jet-pack-flying-wing-to-extend-special-forces.html


A parachute system equipped with a 1.5m (4.9ft)-span delta wing and two micro-turbojets, which could propel a paratrooper 200km (110nm) from a drop point could be tested from third-quarter 2007. The wing has aileron- and flap-like control surfaces along its trailing edge, and around 2 litres (0.5USgal) of jet fuel housed in flexible containers in its leading edge. The surfaces would be controlled by the parachutist using handles linked to servomechanisms. The engines are likely to be built into the wing, which also has a cargo compartment. The turbojets are expected to weigh around 7kg (15.4lb) each and could be model aircraft engines, industrial impellers or a new design. The wing system will weigh approximately 30kg with engines but no cargo. A parachutist could jump from up to 33,000ft using the system, with oxygen equipment and thermal clothing. On reaching an altitude of 3,000-5,000ft, the parachute is opened and the wing lowered on a cord to hang several metres below the user. Carreras has been working for the parachute system's developers, German electronics and technology companies ESG and Dräger, which originally developed an unpowered version for the German army. Flight testing of this 14kg system is expected to finish by year-end, after which the prototype will be used for marketing. With the unpowered system, a soldier could glide for 50km from a 33,000ft jump.

## 11.8. *Emerging train technologies*

### 11.8.1. Eco-friendly Trains

Source: Eric Leech. December 2008: http://planetgreen.discovery.com/tech-transport/eco-friendly-trains.html?campaign=daylife-article%20

Trains are one of the world's cleanest and greenest sources of transportation today. Not that their motors are necessarily the cleanest burning always, but it remains a much lower carbon consuming form of transportation than taking a plane or driving alone. Today's technology has greatly advanced trains over the past decade. Not only have they become faster, lighter, cleaner burning, and more comfortable, but they are also coming back into style as a viable option, especially in Europe. The most eco-friendly trains in the world: The Swedish Gröna Tåget "Green Train"; is a technological marvel designed and built by Banverket (the Swedish Railway Administration) and Bombardier. It features a permanent magnetic motor capable of speeds of around 289 km/h. The new engine design has improved its energy consumption by 20 to 30 percent of your average modern-style train. France's AGV (Automotrice Grande Vitese) is one of the newly designed high-speed trains made to actually compete with the airplane industry. It does this with its top speed of about 362 km/h, which is just fast enough to get you down the line approximately 600 miles (1,000 kilometers) on relatively flat ground in no more than 3 hours.Spain's AVE S103; is a beautiful example of why the airline industry is losing more and more passengers with each passing month. This electric motor train will travel between Madrid and Barcelona and promises that the journey will take no more than about 2 ½ hours (410 miles) and they mean that rather literally. In China the Mainline Evolution Series locomotive by General Electric is another eco-friendly train currently in service. These trains are part of China's plan to reduce pollution and transport its growing population much more efficiently. There are only a few of these locomotives in use right now, but the plan is to have a fleet of 300 delivered to China by the end of 2010. While the newly designed 16-cylinder diesel-electric achieves a 5% improvement in fuel efficiency with up to 84% less emissions, the real magic of the Mainline lies in its lightweight design.

### 11.8.2. Maglev Shinkansen plan

Source: Asahi.com October 2008. http://www.asahi.com/english/Herald-asahi/TKY200810310088.html

Plans for the magnetically levitated (maglev) Chuo Shinkansen by Central Japan Railway Co. (JR Tokai) are starting to move forward. The company submitted the results of its survey to the Ministry of Land, Infrastructure, Transport and Tourism, saying it is possible to build the railway in a straight route through the Southern Japanese Alps. JR Tokai will now look into technical and economic viability and advance procedures to obtain approval. The company plans to start construction within two to three years and open the line in 2025. The superconductive maglev train, which holds the world speed record in rail travel at 581 kph, is a product of advanced transportation technology. In the envisioned commercial operation, it will link Tokyo and Nagoya in 40 to 50 minutes, travelling at a maximum speed of 500 kph. There are also future plans to extend the line to Osaka. The potential economic effects of the maglev train service are enormous. If the major urban areas of Tokyo and Nagoya are directly linked and the line is extended to Osaka, the three cities could form a single economic bloc that includes Kansai. If Tokyo and Osaka can be linked within an hour or so, air travelers could shift to the maglev service, allowing Haneda Airport in Tokyo to increase the number of international flights and strengthen its role as the gateway to Tokyo by air. In 2025, the Tokaido Shinkansen Line will be over 60 years old. If the line's operation is suspended due to major repair work or disasters such as earthquakes, the maglev line would serve as a bypass. The world's first superconductive maglev technology is expected to revitalize Japanese industries. Countries around the world are taking a new look at railway services, which are more energy-efficient than transportation by airplanes and cars. Already, there is an investment rush. The maglev project can lead the move. Although the project may be undertaken by a private company, railways have a major impact on national life, the economy and society, and are highly public in nature.

## 11.8.3. Japan's hybrid train hailed as the future of rail travel

Source: David McNeill. August 2007: http://www.independent.co.uk/news/world/asia/japans-hybrid-train-hailed-as-the-future-of-rail-travel-459809.html

The brightly coloured Hybrid Train E200 pulled quietly out of the station carrying about 100 passengers. It was waved off by cheering schoolchildren, a crew of traditional Taiko drummers and several ecstatic trainspotters. Looking like a slightly sleeker version of the mechanical warhorses that ferry millions of Japanese to work and school every day, the train might pass unnoticed by the keenest trainspotter. But inside it is quieter than a conventional train, thanks to a battery-powered motor that powers it at low speeds. The clean-energy prototype will hum its way between picturesque Yamanashi and Nagano Prefectures in central Japan, a hikers' paradise where the revolutionary engine can be tested on all the hills. In the summer, the line is packed with families on day trips and in winter, it ferries people to ski resorts whose managers are increasingly alarmed by a lack of snow in the warming climate. Japan is a world leader in the development of hybrid cars and low-emission buses and plans are already well advanced to run a hybrid tram in Tokyo. But a JR spokesman said it was "too early" to contemplate selling the E200 on the open market. "We're still trying to modify and improve its performance," he said. JR said that it wanted to make the E200 10 per cent more fuel efficient than conventional trains, but admitted that compared to standard diesel trains, its current prototype was expensive.

## 11.8.4. Japan plans world’s fastest maglev train: More than 500 km/h by 2025

Source: AFP. December 2007: http://afp.google.com/article/ALeqM5jks9rWTSoaNZk6h9wXJpjlmhfoHg

Central Japan Railway Co. (JR Central) plans to build a maglev linear-motor train between Tokyo and central Japan at a cost of 5.1 trillion yen (44.7 billion dollars) by the 2025 financial year, a company spokesman said. The Shanghai train, launched in 2002, travels at 430 kph for the 30.5 kilometre run from Pudong airport to the financial district, according to the Shanghai Maglev Transportation Development Co.'s website. JR Central's magnetic-levitated train hit 581 kph in 2003 in a trial run on a test course in Japan's central Yamanashi prefecture, the spokesman said. The maglev train would enter service at a time when Japan looks for a successor to its famed "Shinkansen" bullet trains, which were first rolled out to the world's awe for the 1964 Tokyo Olympics. Japan's fasted train remains the Sanyo Shinkansen run by JR West in western Japan, which travels at 300 kph. The world's fastest train using conventional railway technology is currently France's TGV, which runs at 320 kph. The company's board approved the plan and estimated that it would leave the company with a five trillion debt when the train goes into service in the financial year to March 2026. The firm projects the train will bring in five percent additional revenue in the first year, shrinking JR Central's debt to the current level within eight years of operation, a statement said. JR Central initially had waited on the plan in hopes of government subsidies. "The reason why the plan has not moved even a bit is because the government isn't able to bankroll it," JR Central president Masayuki Matsumoto said, as quoted by the Nikkei business daily. The approval of the maglev, made by engineering groups Siemens and ThyssenKrupp, came despite a test last year in which it crashed into a parked maintenance vehicle, killing 23 people. China has planned to extend is maglev from Shanghai to Hangzhou, 170 kilometres (105 miles) away, by 2010, although state media reports this year said the project could be delayed or cancelled. The United States has also been studying locations to build its first commercial maglev service, with one proposal to construct a line between Washington and Baltimore.

## 11.9. *Emerging maritime technologies*

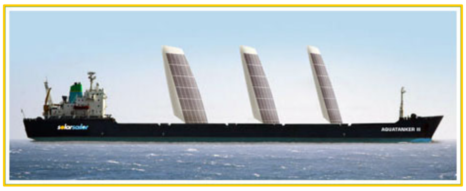
### 11.9.1. Up to 9.000 TEU containerships in 2010.

Source: Philip Damas. 2006: http://www.americanshipper.com/paid/MAY01/how_much_bigger.asp

Several shipping lines are close ordering the first containerships of more than 8,000-TEU capacity, but others in the industry are warning of the associated risks. China Shipping Container Lines is talking to the Korean shipyard Samsung Heavy Industries about orders for a series of 9,000-TEU containerships. When concluded, the orders will be for the world's largest containerships, overtaking Maersk Sealand's "S-class" vessels of about 8,000-TEU effective capacity. Samsung, a shipyard that has led the development of larger post-Panamax containerships in Asia, has designed a 9,000-TEU prototype containership with a length of 330 meters, a draft of 14.5 meters, a width of 45.6 meters and a speed of 26 knots. The width of the ship implies that it will carry 18 containers abreast, one more than the largest containerships afloat today. The vessels would be considerably wider than the 13-container-wide, 32.3-meters Panamax vessel type. The wider vessels will require container terminals to invest in longer cranes that can work 18-container-wide vessels. Meanwhile, Dutch academics are continuing studies about the suitability of introducing, by 2010, a revolutionary vessel type called the Malacca-max. The 18,000-TEU Malacca-max vessels would have the maximum size and draft to transit the Strait of Malacca in Southeast Asia. For shipping lines and for ports, another risk associated with the operation of very large vessels is the prospect that they could spend of higher proportion of their time in port than today, despite their substantially higher daily capital costs. Relatively little is known publicly today about the additional land and rail link requirements of future large vessels. But many large terminals have already installed large container gantry cranes that can handle 19-container-wide vessels.

## 11.9.2. Chinese Cargo Ships Will Have Solar Sails

Source: Megan Treacy. November 2008: http://www.ecogeek.org/content/view/2276/69/



Australian company Solar Sailor has signed a deal with the largest Chinese shipping line COSCO to fit their tankers with large solar-powered sails The sails are 30 meters long, covered with solar PV panels that will provide 5 percent of the ships' electricity and will harness enough wind to reduce fuel costs by 20 to 40 percent. The sails are controlled by a computer that angles them for maximum wind and solar efficiency and the company claims that the sails will pay for themselves within four years. The shipping and air travel industries have been the hardest to conform to new efficiency demands. Planes and tankers require a lot of fuel, but our global economy depends on both of them to survive, so they have been hard industries to regulate. Even the latest environmental standards set by the EU included passes for shipping and airline companies. It is good to see a global company taking a dramatic step toward cleaner shipping.

## 11.10. *New urban developments*

### 11.10.1. Masdar City Project: World's first carbon-neutral city

Source: Abu Dhabi Future Energy Company: http://www.masdaruae.com/

Masdar City is the most ambitious sustainable development in the world today - it will be the world's first zero carbon, zero waste city powered entirely by renewable energy sources. Masdar City will be built over seven years at an investment in excess of US$20 Billion. Its master plan design meshes the century-old learning of traditional Arabic urban planning and architecture with cutting-edge technologies to create a sustainable, high-quality living environment for all residents. The city will be built in seven carefully designed phases, incorporating the latest technological advances generated in its clean-tech cluster and globally. Strategically located at the heart of Abu Dhabi's transport infrastructure, Masdar City will be linked to surrounding communities, as well as the centre of Abu Dhabi and the international airport, by a network of existing road, and new rail and public transport routes. The city will be car free and pedestrian friendly. With a maximum distance of 200 meters to public transport and amenities, and complemented by an innovative personal rapid transport system, the compact network of streets will encourage pedestrians and community social life. Infrastructure support projects at the City will include landscaping, common areas, leisure areas, access roads, bridges, tunnels and Information & Communication Technology (ICT) services as well as development management. To accomplish its ambitious endeavour, Masdar requires access to leading edge thinkers and companies through mutually beneficial partnerships. Masdar is currently embarking on a global drive to attract industry partners to participate in this historic endeavour. Masdar City will take sustainable development and living to a new level and will lead the world in understanding how all future cities should be built. The development will have multiple phases, each with different requirements and therefore different strategies, objectives, and partnership structures.

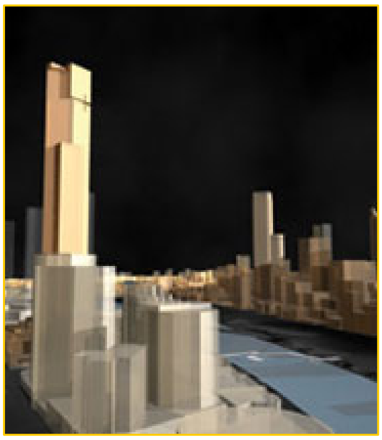
### 11.10.2. Future Cities: Sustainable solutions. Radical Designs.

Source: World Science Festival. 2008 Festival. http://www.worldsciencefestival.com/2008-festival/events/all-events/future-cities

We stand at a crossroads. Cities must change radically to achieve long-term sustainability. Energy, food and water sources, transportation systems and basic infrastructure, must all adapt to emerging pressures from climate change, dwindling resources and growing urban populations. How will we meet this immense challenge? In a program that is part celebration of human ingenuity and part stark reminder of the problems we face, urban planner Peter Head, architects Blaine Brownell and Mitchell Joachim, environmentalist Majora Carter, and microbiologist Dickson Despommier laid out radical blueprints and innovative solutions as they imagine housing, feeding, transporting and sustaining city dwellers of the not too distant future. The event was moderated by President of the Aspen Institute and noted journalist, Walter Isaacson.

### 11.10.3. Reshaping cities for a more sustainable future

Source: CSIRO webpage http://www.csiro.au/science/ReshapingCities.html#4



CSIRO study titled *Reshaping Cities for a More Sustainable Future* predicts that if Australia's cities continue to grow as urban sprawl, in just 10 to 15 years air pollution in our cities will increase as much as 70 per cent compared to 1990 levels. The cost of air pollution to Australia is already high. The human health cost is estimated at between A$3 billion and A$5.3 billion every year, and annual damage to materials, property and buildings is between A$3 billion and A$5 billion – one per cent of gross domestic profit (GDP). Cars are the biggest cause of air pollution. Because most Australians shun public transport and rely on cars for transport, we are among the highest per capita air polluters in the world. The report "Towards a sustainable urban future" suggests a number of strategies to improve urban air quality: changes to urban planning and public infrastructure: the role of the construction industry and education of the public.

## 11.11. *Developments in New Buildings*

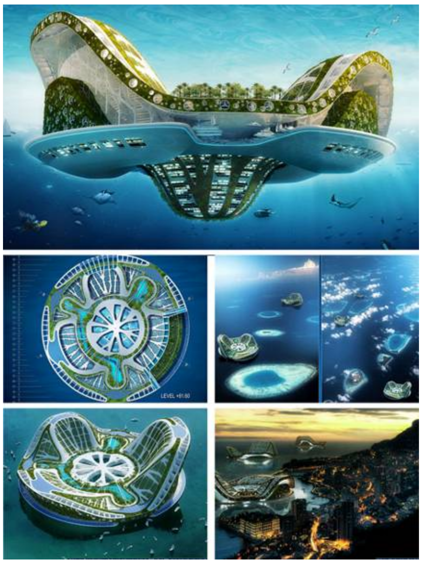
### 11.11.1. Green buildings

Source: Future Hi website and Emilo Ambasz website: http://www.futurehi.net/archives/000020.html; http://www.emilioambaszandassociates.com/

There are many architects who are working hard to bring our civilization back into harmony with the environment. Emilio Ambasz is an architect who has designed buildings that do just that. They are passively solar, evaporatively cooled, extremely energy efficient, seamlessly bringing the built and natural environment together. All the rain water falling onto his building is either collected for the buildings flora or recycled for drinking water by its inhabitants. Additionally, much of the buildings waste is processed using Living Machinery. Such projects as the landmark Lucille Halsell Conservatory at the San Antonio Botanical Centre, the Phoenix History Museum, the Mycal Sanda Cultural Centre, the Fukuoka Prefectural International Hall, the Torino Environment Park and many others, exemplify Emilio Ambasz' distinctive design sensibility. By completely integrating the building and the landscape, the amount of garden space available for public enjoyment far exceeds that of conventional designs. Natural processes are utilized in ways that maximize the efficient use of energy throughout the building while creating enchanting opportunities for the enrichment of peoples' relationship with the natural environment. This unique "green" approach offers great possibilities for such large-scale projects as power stations, railroad terminals, large residential and hotel developments in fragile environmental areas, commercial buildings in restrictive urban settings and other situations where the client needs to overcome difficult legal, planning and community requirements.

## 11.11.2. 7 Modern Wonders of Green Technology

Source: Urbanist. June 2008. http://weburbanist.com/2008/06/09/modern-wonders-of-green-technology/



Green architecture comes in many forms though lately it seems like these forms are stranger than ever. With all of these emerging green technologies it seemed an appropriate time to take a look at seven of the most amazing real and conceptual designs currently at the forefront of ecological innovation. The so-called Lilypad Project.The idea is to create a series of floating self-sufficient ocean-going eco-city islands. The new Bahrain World Trade Centre is, no doubt, the three massive wind turbines situated between the two towers comprising the main building. It is by far the largest wind-powered design incorporated into a massive building project to date. The MagLev Wind Turbine is a big step forward in the world of wind power. The MagLev has a low threshold velocity for producing energy, could theoretically survive for centuries and can power up to 750,000 homes. Urban skyscraper farms are still purely conceptual for now but are amazing theoretical propositions. They are massive in scale and would cost a great deal to build. This huge initial outlay is part of what is keeping them out of production. The Dongtan Eco-City is designed to be the world's first not only an environmentally but also a "socially, economically and culturally" sustainable city. The city relies on its own wind and solar energy as well as organic farming strategies. Public transportation will be entirely emissions free. In many ways, this is a prototype for large-scale city planning within a fully eco-friendly mindset. The so-called Lighthouse skyscraper is a 1000-foot-tall office skyscraper that is designed to use about half the water and energy of a typical high-rise building. The tower design employs solar energy collection and wind farming techniques coupled with strategies to reduce the use of and improve recovery of energy and water within the building. While these projects are extremely impressive in terms of their scope, scale and innovation many of them are expensive and difficult to replicate. They are, in short, large-scale solutions to a pervasive problem that exists on all scales with respect to sustainability in design.

## 11.12. *Energy*

Energy is of major importance for the transport sector. Therefore it is of interest to follow the possible developments of future energy production, particularly energy which can be used to power vehicles.

### 11.12.1. Hydrosol Project

Source: Plataforma Solar de Almería website.: http://www.psa.es/webesp/index.html

The Plataforma Solar de Almería (PSA), a dependency of the Centre for Energy, Environment and Technological Research (CIEMAT), is the largest centre for research, development and testing of concentrating solar technologies in Europe. PSA activities form an integral part of the CIEMAT Department of Renewable Energies as one of its lines of R&D. The PSA is located in southeastern Spain in the Desert of Tabernas at 37º05'27.8" north and 2º21'19" west. It receives a direct annual insolation above 1900 kWh/m2/year and the average annual temperature is around 17ºC. The capacity to offer researchers a place with climatic and insulation conditions similar to those in developing solar-belt countries (where the greatest potential for solar energy is found) but with all the advantages of a large scientific installation in the most advanced European countries, makes the PSA a privileged site for evaluation, demonstration and transfer of solar technologies.

### 11.12.2. Hydrogen Program

Source: United States Department of energy and United States Department of Transportation: www.hydrogen.energy.gov/pdfs/hydrogen_posture_plan_dec06.pdf

The Hydrogen Posture Plan was prepared by the U.S. Department of Energy (DOE) Offices of Energy Efficiency and Renewable Energy; Fossil Energy; Science; Nuclear Energy, Science and Technology; and the U.S. Department of Transportation (DOT) to outline the activities, milestones, and deliverables that the Federal government plans to pursue to support the development of hydrogen-based energy systems. The Hydrogen Posture Plan integrates the planning and budgeting for program activities that will aid in this development. More specifically, this plan outlines the DOE role in hydrogen energy research and development, in accordance with the National Hydrogen Energy Vision and Roadmap. Its key points: Use of hydrogen as an energy carrier; Technical challenges to developing cost effective hydrogen technologies; The Hydrogen Posture Plan integrates existing and future activities Hydrogen and fuel cell technologies must meet market-based requirements for cost, operability, safety, maintenance, and overall performance.

### 11.12.3. ORNL study shows hybrid effect on power distribution

Source: Larisa M. Brass. Oak Ridge National Laboratory . March 2008: http://www.ornl.gov/info/press_releases/get_press_release.cfm?ReleaseNumber=mr20080312-02

A growing number of plug-in hybrid electric cars and trucks could require major new power generation resources or none at all - depending on when people recharge their automobiles. A recent Oak Ridge National Laboratory study, featured in the current issue of the ORNL Review examined how an expected increase in ownership of hybrid electric cars and trucks will affect the power grid depending on what time of day or night the vehicles are charged. In an analysis of the potential impacts of plug-in hybrid electric vehicles projected for 2020 and 2030 in 13 regions of the United States, ORNL researchers explored their potential effect on electricity demand, supply, infrastructure, prices and associated emission levels. Electricity requirements for hybrids used a projection of 25 percent market penetration of hybrid vehicles by 2020 including a mixture of sedans and sport utility vehicles. Several scenarios were run for each region for the years 2020 and 2030 and the times of 5 p.m. or 10:00 p.m., in addition to other variables. The report found that the need for added generation would be most critical by 2030, when hybrids have been on the market for some time and become a larger percentage of the automobiles Americans drive. In the worst-case scenario—if all hybrid owners charged their vehicles at 5 p.m., at six kilowatts of power—up to 160 large power plants would be needed nationwide to supply the extra electricity, and the demand would reduce the reserve power margins for a particular region's system. The best-case scenario occurs when vehicles are plugged in after 10 p.m., when the electric load on the system is at a minimum and the wholesale price for energy is least expensive. Depending on the power demand per household, charging vehicles after 10 p.m. would require, at lower demand levels, no additional power generation or, in higher-demand projections, just eight additional power plants nationwide.

### 11.12.4. Poop-Powered Hydrogen Cars Show Promise

Source: Hybrid cars website. January 2009: http://www.hybridcars.com/fuels/poop-powered-cars-promise-25386.html


New research from Kajima, a Japanese company, and Tokyo University, suggests that microbes from human waste could be a good source of energy for hydrogen fuel cell cars. According to a report yesterday on Japan's Nikkei, the company has produced a fuel cell that generates 130W from each cubic meter of waste. Kajima believes it will take another decade to commercialize the product. Researchers from the University of California, and administrators at California's Orange County Sanitation District, appear to be further along. Last fall, they installed an $8 million fuel-cell device to convert human waste into hydrogen fuel. In an interview with the Orange County Register, Scott Samuelsen, director of UC Irvine's National Fuel Cell Research Center who helped develop the device, said, "The waste stream from society is being turned around, and providing energy and transportation fuel for the society. The Sanitation District has used methane gas from sewage to power its systems for years, but the new device—built by Air Products of Pennsylvania and FuelCell Energy of Connecticut—is able to separate the methane into three streams of energy: one to help heat the sewage, one to generate electricity, and one for storage tanks ready for use in hydrogen cars. While the performance of the poop-powered vehicles left something to be desired, perhaps converting methane from human and animal waste into vehicle fuel could help the Environmental Protection Agency control global warming from methane pollution. A 2007 US Supreme Court ruling concluded that greenhouse gases emitted by the "belching and flatulence" of livestock does indeed constitute air pollution. Despite false reports that the current EPA was proposing a "cow tax," any plan to deal with the environmental consequences of cow flatulence will be among the pile of problems left to the incoming Obama administration.

### 11.12.5. Gasoline from Trash as a Cheap New Alternative

Source: Jaymi Heimbuch. August 2008: http://www.ecogeek.org/content/view/2043/

Old cars that run on gas are not going away soon, and it will take a fair sized paradigm shift to get most people to convert their gas-powered cars into something that runs on anything else, or even convert them to hybrids. Therefore, technology that can make gasoline from a renewable resource is pretty dang handy for the time between now and when the last gas-powered car goes into a museum or Jay Leno’s garage. We have seen the potential of gasoline from algae, but there is also a push to turn trash into gas – a concept that has many appeal factors. Byogy, out of Bakersfield, CA, is claiming its process converts trash, manure (both animal and human), landscaping wastes, and other food wastes into high-grade, 95 octane gasoline at a production cost of only $1.20-$2.00 per gallon. Byogy hopes that by 2022, it can fill 2% of the nation’s gas tanks. If the technology is successful, I suspect that a larger percentage than that will be obtained by several companies picking through waste sites – a very happy image. While gasoline simply isn’t a perfect option for our energy needs, this new tech is definitely an exciting prospect and, in keeping with reality, we need a sustainable alternative to gasoline that the masses can use while our nation, and the world, shifts mindsets to realize that gas-powered vehicles are so last season.

### 11.12.6. Chinese Planning World's Largest Solar Project

Source: Hank Green. December 2008: http://www.ecogeek.org/content/view/2420/69/


Planned solar projects in the U.S. seemed to be one-upping each other throughout 2008, ending with the enormous planned 500 MW facility in San Luis Obispo CA. Now the Chinese are in on the game and, surprise, they are even bigger. They are currently planning a solar project twice as large as any currently planned, with a capacity of a full gigawatt. The project is planned for the Qaidam Basin, a large, sunny desert and The China Technology Development Corporation just signed a deal with local officials to start working on the project. The project will use only photovoltaic cells (no solar thermal) though it looks like some of the solar cells will be silicon, and others will be thin film. Unfortunately, there is no word on who will be supplying the panels, but we assume it will be one of the several Chinese companies currently producing solar panels. We also assume that they are using both thin-film and crystalline cells because there would be no other way to get that many solar panels together. The first phase of the project will bring 30 megawatts of solar power to China, costing roughly $150M and beginning construction in 2009. Whether or not the next phases will be completed, we imagine, depend on the success of this first installation. Compared to the scale of other solar projects, this is truly massive. Unfortunately, compared to the scale of fossil fuel projects in China, it is minuscule. China reportedly added around 90 gigawatts of coal-fired power in 2006 alone.