ASSIST

Assessing the social and economic impacts of past and future sustainable transport policy in Europe

ASSIST Deliverable D5.1:

Approach and Results of the Validation of the ASTRA-EC Model

Due date of submission:	30.11.2013	
Actual date of submission:	11.04.2014	
Dissemination level:	Public	
Start date of project:	01.04.2011	Duration: 32 months

Lead contractor for this deliverable:	Fraunhofer-ISI	
Work package:	WP5	Final Report

Grant Agreement Number: 265381

Contract No: MOVE/FP7/265381/ASSIST

Instrument: Coordination and support actions – Support – CSA-SA

Project co-funded by the

European Commission – DG MOVE

7th Research Framework Programme

ASSIST

Assessing the social and economic impacts of past and future sustainable transport policy in Europe

Co-ordinator:

Fraunhofer ISI

Fraunhofer-Institute for Systems and Innovation Research, Karlsruhe, Germany

Dr. Wolfgang Schade

Partners:

FÖMTERV

Mernoki Tervezo ZRT, Budapest, Hungary

CNRS-LET

Centre National de la Recherche Scientifique, Lyon, France

Panteia

Panteia B.V., Business Unit NEA

ProgTrans

ProgTrans AG, Basel, Switzerland

TRT

Trasporti e Territorio SRL, Milan, Italy

ASSIST

Assessing the social and economic impacts of past and future sustainable transport policy in Europe

Report information:

Report no.:	D5.1	Work package no:	5
Title:	Approach and Results of the Validation of the ASTRA-EC Model		
Authors:	Michael Krail, Wolfgang Schade, Francesca Fermi, Davide Fiorello, Konstantina Laparidou		
Version:	1.2	Date of publication:	11.04.2014

This document should be referenced as:

Krail, M., Schade, S., Fermi, F., Fiorello, D., Laparidou, K. (2014): *Approach and Results of the Validation of the ASTRA-EC Model,* Deliverable D5.1 of ASSIST (Assessing the social and economic impacts of past and future sustainable transport policy in Europe). Project co-funded by European Commission 7th RTD Programme. Fraunhofer-ISI, Karlsruhe, Germany.

Project information:

Project acronym:	ASSIST
Project name:	Assessing the social and economic impacts of past and future sustainable transport policy in Europe
Contract no.:	MOVE/FP7/265381/ASSIST
Duration:	01.04.2011 – 30.11.2013
Commissioned by:	European Commission – DG MOVE – 7th Research Framework Programme.
Lead partner:	Fraunhofer-ISI - Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, Germany.
Partners:	FÖMTERV - Mernoki Tervezo ZRT, Budapest, Hungary
	CNRS-LET - Centre National de la Recherche Scientifique, Lyon, France
	Panteia B.V., Business Unit NEA, Zoetermeer, the Netherlands
	ProgTrans - ProgTrans AG, Basel, Switzerland
	TRT - Trasporti e Territorio SRL, Milan, Italy.
Website:	http://www.assist-project.eu/

Document control information:

Status:	Public
Distribution:	ASSIST partners, European Commission
Availability:	Public
File name:	ASSIST_D5.1_ Approach_and_Results_of_the_Validation_of_the_ASTRA-EC_Model .doc
Quality assurance:	Claus Doll – Fraunhofer-ISI
Coordinator's review:	Michael Krail, Wolfgang Schade

Signature: Michael Krail Date: 11.04.2014

Table of Contents

List of Tables

List of Figures

Abbreviations

BEV	Battery-electric vehicle
BIO	Bioethanol (E85) vehicle
Bn	Billion
CNG	Compressed natural gas
COICOP	Classification of Individual Consumption by Purpose
EU27+2	EU27 member states plus Norway and Switzerland
EV	Electric vehicle
FCEV	Fuel cell electric vehicle
FTE	Full-time-equivalent
G	Giga
GDP	Gross domestic product
GHG	Greenhouse gas
GVA	Gross value-added
HDV	Heavy duty (goods) vehicle
HEV	Hybrid electric vehicle
IWW	Inland waterway
LDV	Light duty vehicle
LPG	Liquefied petroleum gas
Mio	Million
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne
NUTS	Nomenclature des unités territoriales statistiques
OD	Origin and destination

OECD	Organisation for Economic Cooperation and Development
PHEV	Plug-in hybrid electric vehicle
Pkm	Passenger-kilometres
REEV	Range-extended electric vehicle
REF	ASSIST Reference Scenario
RoW	Rest-of-the-World
Tkm	Ton-kilometres
Toe	Ton Oil-Equivalent
TPM	Transport Policy Measure
UN	United Nations
Vkm	Vehicle-kilometres

1 Introduction

The main objective of the ASSIST project is to policy advice for the European Commission by assessing social and economic impacts of sustainable transport policies. For this purpose the project is separated into two main lines of research. The first line focuses on ex-post analysis of transport policy measures (TPM) via comprehensive desk research and interpretation of social and economic impact assessment studies and their results. The second line of the project should develop a simulation model at European level to strategically assess social, economic and environmental impacts of sustainable transport policies: ASTRA-EC. The ASTRA-EC model follows the approach of the ASTRA model (ASsessment of TRAnsport Strategies) model[1], which has been developed and applied over the last ten years for the integrated assessment of transport strategies in Europe. Building on the ASTRA approach specific features of ASTRA-EC have been designed to focus the model on the needs of the ASSIST project and to improve the user-friendliness of the tool. A detailed description the ASTRA-EC model based on the System Dynamics methodology is provided by Deliverable D4.2 of the ASSIST project (Fermi et al. 2012)

The reliability and the quality of a quantitative impact assessment strongly depend on the quality of the applied simulation model. This implies that the model results are accurately calibrated against statistical data or model calculations from other reliable models. Therefore, ASTRA-EC starts to simulate each indicator already from 1995 in order to provide a time series that allows calibrating the model behaviour towards observed real-world behaviour. The description of the calibration process as well as a documentation of the quality of the calibration is the first task of this deliverable. This report provides comparison between statistical development of major social, economic, environmental and transport indicators with simulation results from ASTRA-EC.

The second task of this deliverable consists of the validation of ASTRA-EC for selected trends of key transport, economic and environmental indicators until 2050. Validation means in this sense the ability to reproduce certain developments. The trends that need to be reproduced between 2010 and 2050 are taken from the 2013 PRIMES-TREMOVE Reference Scenario (EC 2013). This report reflects the quality of this matching of via comparing ASTRA-EC trends to those estimated by the PRIMES-

1 A comprehensive description of the ASTRA model is provided in [Schade 2005] and [Krail 2009]. Documentation on the model and its application is available on the website http://www.astra-model.eu/.

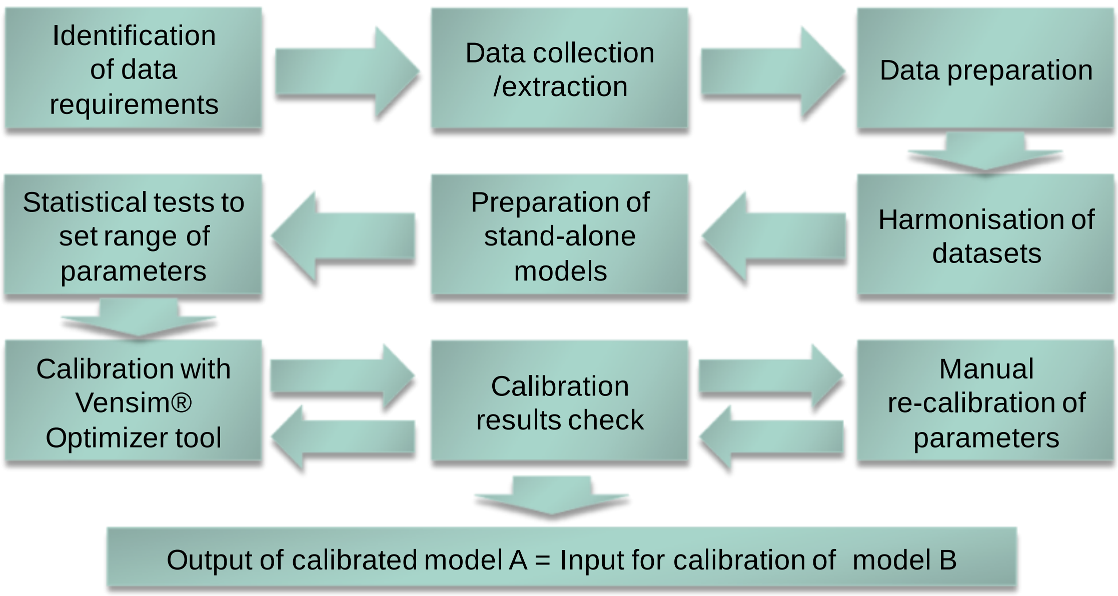
TREMOVE Reference Scenario. Another important step to test the reliability of impact assessment results is to validate the ASTRA-EC model reactions. Findings from the desk research line of the project as well as from the work package dealing about implications of future challenges on TPM impacts are used to make this validation for six selected transport policy measures.

Besides the analysis of the quality of calibration and validation for ASTRA-EC this deliverable provides a description of major trends in the Reference Scenario highlighting also differences between the ASTRA-EC and the PRIMES-TREMOVE projections. Finally, the deliverable presents key transport, social, economic and environmental impacts of six transport policy measures compared with the Reference Scenario.

2 The calibration of ASTRA-EC

2.1 The calibration approach

The accurate consideration of model development rules, for example described by Bossel (1994), and a comprehensive research of statistical correlation of indicators do not guarantee an exhaustive description of the behaviour of systems reflected by the established ASTRA-EC model. The modelling of complex social and economic systems like in ASTRA-EC can only provide a simplified picture of reality. In order to be able to provide a good basis for decision-making, models should consider uncertainties as well. The only way to integrate such factors, to make the model valid and to allow the comparability with other models is the implementation of calibration parameters. But before searching for an optimum value for these calibration parameters, the ASTRA-EC calibration approach has to follow a sequence of steps. Figure 10-1 presents an overview of the sequence of 10 steps which are required to calibrate the single modules of ASTRA-EC properly. Each module in ASTRA-EC needs to be calibrated stand-alone. ASTRA-EC is a large-scale and complex System Dynamics model. The dimension of the ASTRA-EC model including several million objects does not allow the calibration of the whole ASTRA-EC model within one calibration step.



Source: Fraunhofer-ISI

Figure 2-1: Overview of the ASTRA-EC calibration approach

After implementing the model structure for the single modules in ASTRA-EC, the data requirements for each module need to be identified. ASTRA-EC requires three different types of data as input. The first consists of time series data as well as projections for the time horizon to 2050 for exogenous inputs. As an example, purely exogenous inputs in ASTRA-EC are passenger trip rates which are requested to simulate the number of generated trips or labour productivities per sector which are essential to estimate the evolution of full-time-equivalent employment per sector. The second type of data concerns the variables that are represented via stock or so-called *level* variables. Mathematically, these level variables are composed of differential equations which require an initial value for the starting point. Hence, all these level variables need to be initialised with data from 1995. The last type of data required is time series data ideally from 1995 to 2010 for each major indicator simulated endogenously by ASTRA-EC. These time series data are a prerequisite for the calibration of the single ASTRA-EC modules. The major endogenous indicators need to match the development of the statistical data.

The second step in the calibration approach is then the data extraction and collection of the identified set of indicators from harmonised and validated data sources. Preferably, the majority of the time series and initializing data is taken from one major database. In the case of ASTRA-EC this database is Eurostat. Even if the majority of data is provided by Eurostat it does not fulfil all data requirements of ASTRA-EC. Therefore, other databases like the OECD database (e.g. for full-time-equivalent employment per sector) or the UN Comtrade database (e.g. for exports and imports per sector) are considered.

In the ideal case, the databases are able to provide the time series data in the specific level of detail requested by the ASTRA-EC model. This is only the case for some few examples. Therefore, the preparation of datasets to fit to the needs of ASTRA-EC is a very important further step belonging to the calibration approach. Three major cases appear in this context. Very often, the time series data from 1995 to 2010 are not completely available such that there are gaps in the time series. In this case, other databases are an option to fill these gaps. If no other database contains the requested type of data, then the gaps are filled by approximating the growth trend via:

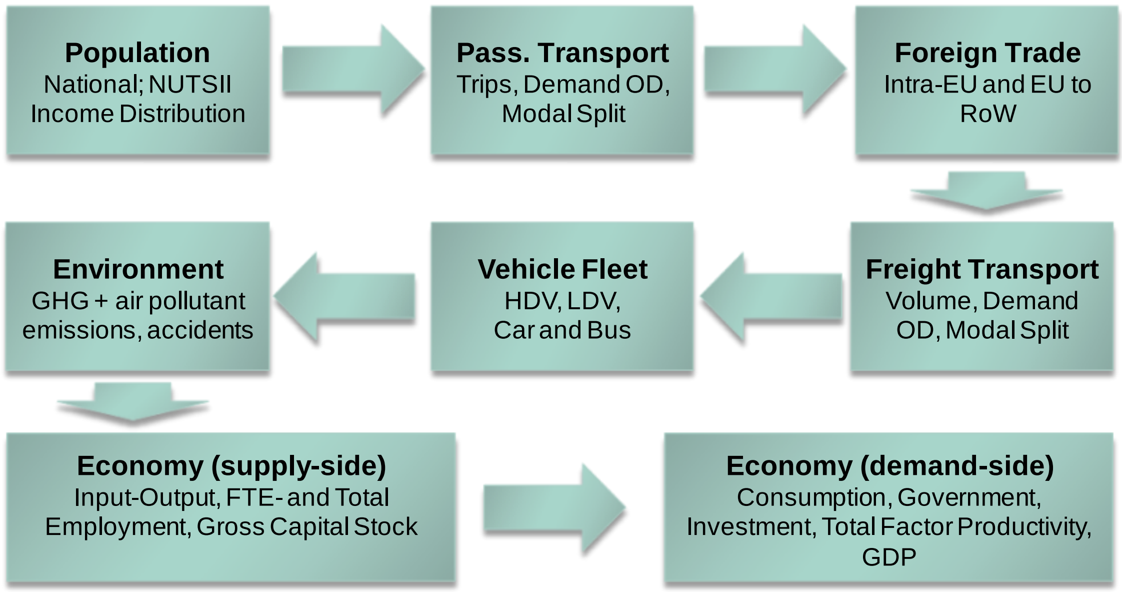
- related indicators (e.g. consumption of private households by final demand),
- available but more aggregate data,
- comparison with available data from countries that have a similar structure or
- linear interpolation.

Especially for economic indicators on a sectoral level there are often differences in the classification of economic sectors. ASTRA-EC uses a classification of economic sectors derived from NACE-CLIO (see Table 2-2) consisting of 25 sectors. The NACE classification is the dominant classification for most economic indicators in Eurostat. Nevertheless, there are different revisions used for different time periods (Revision 1, Revision 1.1 and Revision 2) and different number of economic sectors in each classification varying from 11 sectors at minimum (in NACE rev. 2) up to 89 sectors (in NACE rev. 2). Consumption of private household is differentiated by the COICOP classification of sectors while full-time-equivalent follows a specific classification used by the OECD database with 106 economic sectors. Hence, the transfer to the used specific level of aggregation plays a significant role in this step.

For some specific variables like labour productivity, the major European databases do not offer any datasets. Then, the data is calculated if possible by following the accounting framework or other economic theories. In the case of labour productivity a division of gross value added by the number of full-time-equivalent employment per sector is used to calculate this indicator.

Another important step in the calibration approach following the data preparation is the harmonisation of data. In the Economic module this step is crucial as the demand side is supposed to affect the supply side as well as freight transport via the sectoral interweavement model. Therefore, the components of final use (consumption of private households, investments, government consumption and exports) need to match the demand-side data of the second quadrant of the input-output tables. In practice the sectoral demand-side data available at Eurostat or other databases differ from the numbers in the input-output tables.

After finishing the preparatory work on the input, initializing and calibration data, the single ASTRA-EC models which are calibrated in sequence need to be extracted into a separate Vensim® model file. All variables that are used in these so-called *stand-alone models* as an input coming from other models in ASTRA-EC need to be converted into variables of the type *Data*. Hence, the sequence of calibration of all ASTRA-EC stand-alone models starts preferably with the ASTRA-EC sub-model that receives the fewest inputs from other parts of ASTRA-EC. This sub-model is the Population model as the calculation of the demographic development in ASTRA-EC does not assume inputs from the Economic or any other ASTRA-EC module. Figure 10-2 shows the sequence of calibration of the single ASTRA-EC stand-alone models.



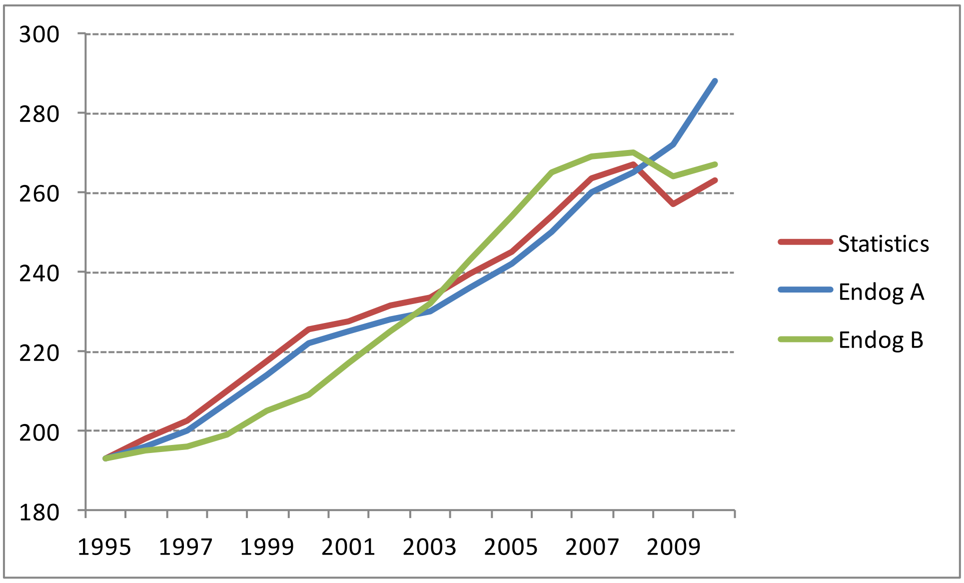
Source: Fraunhofer-ISI

Figure 2-2: Calibration sequence for the ASTRA-EC sub-models

After separating the stand-alone models from the full ASTRA-EC model, calibration parameters need to be determined and set. Therefore, statistical tests are carried out to check the degree of correlation between the expected driving factor and the main indicator in the single stand-alone models. These tests mainly consist of linear or multiple regression analysis. Carrying out these tests does not only validate the model structure in terms of a proven correlation between an input factor and an output factor. It also provides quantitative values for the calibration parameters and allows setting a range for these parameters from a minimum to a maximum value.

This is necessary as the automatic calibration with the Vensim® calibration toolset requires a definition of the calibration parameters with a range and an initial value. Furthermore, target values for the major indicators are set. The internal calibration tool applies the Powell Search algorithm. It is derived from the Taxi Cab method for finding a minimum deviation between an endogenous indicator and statistical data. The algorithm tries to optimise the set of calibration parameters such that the sum of annual deviations for the whole calibration period from 1995 to 2010 reaches a minimum.

The results of the automatic calibration need to be checked carefully as the search method only considers the minimum deviations between simulated indicator and the statistical time series data of this indicator. It does not take into account the shape of the curve over time. Figure 2-3 reflects this issue as an example. Two different results of a calibration can be seen in this figure in comparison with the statistical time series for an exemplary indicator from 1995 to 2010. According the search method, the minimum sum of annual deviations is achieved by the blue curve (Endog A). The problem with the resulting setting of calibration parameters is that the end of the curve shows just for two years a completely different shape than the statistical development. In this case, the green curve would be more valid even if the sum of deviations is higher than for the blue curve. Hence, a manual check of the calibration results is crucial to validate the projections until 2050.



Source: Fraunhofer-ISI

Figure 2-3: Manual check of calibration results

In the case that a calibration result is partially not acceptable in terms of relative and absolute deviations from the statistical value, the calibration needs to be improved by setting different ranges for calibration parameters. This can be done as well via the Vensim® calibration toolset or via a manual calibration in the case that an automatic calibration does not lead to an acceptable shape of the curve for the period from 1995 to 2010.

After achieving an acceptable result of the calibration, the next stand-alone model in the sequence of calibration is calibrated. For the following calibrations, the stand-alone models use the output indicators of previously calibrated stand-alone models as an input. When the sequence of calibration is finished, the single ASTRA-EC stand-alone models are merged to one ASTRA-EC Vensim® file again. A comprehensive check of the simulation results of the merged model needs to follow. In general, closing the various reinforcing or balancing feedback loops leads to changes in the quality of the calibration. In case that parts of the ASTRA-EC model could not remain the good quality of calibration such that the deviation between an endogenous indicator and the statistical values does not remain in an acceptable range, the specific stand-alone models need to be re-calibrated. This re-calibration is then using the most up-to-date input in terms of variables calculated in other parts of ASTRA-EC.

As opposed to static models (like for most network-based transport models or computed general equilibrium models), ASTRA-EC as a System Dynamics model is not able to be calibrated such that there is a deviation of zero is reached for each year between 1995 and 2010. The major benefit of a System Dynamics model that is used for assessing long-term impacts of transport policies until 2050 is that the causal relations between indicators are validated over a long period of calibration (1995 to 2010).

2.2 Calibration of ASTRA-EC modules

2.2.1 Transport and environmental module

The main source of information for calibrating the transport demand module has been the EUROSTAT database, providing data of passenger and freight transport demand by mode from 1995 to 2010 (expressed in terms of pkm/tkm). The same source have been used as reference for the trends of CO_2, NOx and PM transport emissions as well as transport fuel consumption by fuel type.

For passengers, forecasts for all modes implemented in the ASTRA-EC model (car, bus, train and aviation) are available in the dataset at aggregate level (i.e. EU27), while aviation data are not provided by country. Data is comparable in terms of definitions. For freight, the trends of inland modes (HDV trucks, rail and inland waterways) are provided in the dataset and comparable with modelled indicators, while the data related to maritime is available only aggregate level (i.e. EU27). LDV trucks demand is not included in the EUROSTAT database.

Reference data in terms of pkm and tkm by country for maritime and aviation (national and international intra-EU) have been estimated on the basis of other indicators (passengers carried by air, matrices of goods transported by maritime, etc.).

In addition, it should be noted that, especially for freight transport demand, specific definitions are related to EUROSTAT data. In particular:

- EUROSTAT tkm performances by HDV trucks include cabotage. Therefore, since it is not considered in the ASTRA-EC model, the reference data have been adjusted on the basis of EUROSTAT data on cabotage in order to rebalance the values and estimate tkm performances by HDV trucks from origin country..

- EUROSTAT tkm and pkm performances by train and inland waterway are reported according to the transport performed on the declaring country's territory, regardless of the nationality of the freight forwarder who performs this transport. Therefore, this aspect has been taken into account for the comparison with the output of the model (estimating the transport demand in transit through the country and not originated from). In addition, since the ASTRA-EC model does not include for land modes the transport demand between EU and the rest of Europe (e.g. Russia or Turkey), the data for peripheral countries have been adjusted (namely reduced according to detailed EUROSTAT data) to take into account this aspect.

EUROSTAT data are available on an yearly basis: this time step have been used in the calibration process. Finally, the reference data covers EU27 Countries, Norway and Switzerland, in line with requirements for the ASTRA-EC model calibration.

The following table summarise the list of variables for the calibration of the transport and environmental modules from the year 1995 to 2010.

Table 2-1: List of data sources used for calibrating the transport and environmental modules

Module	Variable	Level	Unit	Reference data 1995 - 2010
Transport modules	Passenger transport activity generated	Country and mode	Mio Pkm/ year	EUROSTAT (statistical pocketbook and database)
	Freight transport activity generated	Country and mode	Mio Tkm/ year	EUROSTAT (statistical pocketbook and database)
	Passenger modal split (on pkm)	Country	%	EUROSTAT (statistical pocketbook and database)
	Freight modal split (on tkm)	Country	%	EUROSTAT (statistical pocketbook and database)
Environmental module	CO2 transport emissions	Country and aggregated mode	Mio tons/ year	EUROSTAT (statistical pocketbook and database)
	NOx transport emissions	Country and aggregated mode	Mio tons/ year	EUROSTAT (database)
	PM transport emissions	Country and aggregated mode	Mio tons/ year	EUROSTAT (database)
	Transport fuel consumption	Country and fuel type	Mio Toe/ year	EUROSTAT (statistical pocketbook and database)

Source: TRT

The calibration of the transport module consists of modifying some variables and parameters in order to reproduce with a reasonable level of precision the observed trend of passenger and freight demand by country and mode. Some variables produced by other modules of ASTRA-EC represent given determinants of transport demand which cannot be adapted, namely:

- Population by group,
- Domestic production by sector,
- Intra-EU trade by sector and country-to-country paper,
- Fuels price.

The calibration involves all the three steps managed by the transport model: demand generation, demand distribution and mode split. For each step there are specific parameters which can be somehow modified in order to adapt model results:

- Passenger generation: trip rates by purpose, income and population group,
- Freight generation: sensitivity of domestic transport demand growth rate with respect to domestic production of goods; sensitivity of international transport demand growth rate with respect to trade of goods,
- Distribution: elasticity of shift between distance bands with respect to generalised cost
- Mode split: cost elasticities by mode and demand segment; time elasticities by mode and demand segment; trend of non-fuel costs; trend of travel time.

Even if the goodness of fit is checked against aggregated figures (e.g. total passengers-km by mode) which are those available from reference sources, other checks are made. Indeed, the same number of e.g. total passengers-km can be obtained with different numbers of generated trips and average trip distance. Even if observed data about these elements are not available, checks are made to make sure that model results are plausible.

Given the amount of parameters and given the dynamic nature of the model, the variation of the parameters is basically a trial and error process. Automated procedures (external to the model can be set up to speed up the process, but the calibration of the transport module is mainly a manual work.

The calibration of the environmental module follows a similar line. However this module is highly constrained as emissions are the result of average emission factors applied to total transport performance in terms of vehicles-km. The average emission factors depend on the fleet composition, which is provided by the fleet module whereas the transport performance is the output of the transport module. Once the fleet module and the transport module are calibrated, the result in term of fuel consumption and emissions is largely determined. If discrepancies with reference data are detected, limited possibilities are given to correct the results.

The main leverage is the value of the fuel consumption and emission factors. Despite in principle they are exogenous technical parameters, the values implemented in the environmental module can be somewhat adapted. For instance, the external sources provide road vehicles emissions function depending on speed. The average speed considered in the model in different distance bands corresponds to a specific factor. Within reasonable limits, choosing a different reference speed can help to revise total fuel consumption or emissions.

Like the calibration of the transport module, also the calibration of the environmental module is basically a manual work.

2.2.2 Economic and trade module

The economic as well as the trade module are calibrated in a sequence as described by Figure 2-2 (see also Krail 2009). The reason for this separate and sequential calibration is the number of feedback loops that can hardly be handled within one single calibration of several key economic and trade indicators. The calibration is carried out using time series from 1995 to 2008. Economic data for the years of the crisis (2009-2011) have not been considered for the calibration. ASTRA-EC as a macro-scale model is has limited capabilities to simulate this type of crisis endogenously. Hence, this period could not be covered by the calibration in order to avoid an unrealistic optimisation of calibration parameters.

The calibration starts with the trade module separated into exports between EU27+2 countries (Intra-EU) and exports from EU27+2 to regions in the rest of the world (RoW). The main data sources for the calibration of exports Intra-EU as well as exports to RoW are EUROSTAT and the UN Comtrade database. The total export volume is taken from EUROSTAT but as the UN Comtrade provides a better sectoral variation, the sectoral share as well as the distribution into importing countries is given by the UN Comtrade data.

The economic module is separated into several separate sub-modules. The economic key indicators displayed in Table 2-2 are all calibrated separately. The main data source is EUROSTAT. For all monetary values the original EUROSTAT data has been converted into real terms by EU27 GDP deflators from EUROSTAT. GDP, gross capital stock and disposable income are extracted from EUROSTAT for each EU27+2 country. Gross value added, employment, private household consumption, investments and government consumption have a further disaggregation by economic sector. EUROSTAT provides these indicators with different classifications of economic sectors. E.g. investments are allocated according to NACE rev. 2 into 11 economic sectors while employment is differentiated into 89 economic sectors using NACE rev. 2.

ASTRA-EC requires a harmonised database for all demand side indicators as the resulting final use feeds into the input-output table development and in the following into gross value-added and finally into employment. Therefore, consumption of private households, investment, government consumption and gross value-added were taken as far as possible from domestic input-output tables by country offered by EUROSTAT.

Table 2-2: List of data sources used for calibrating the economic and trade module

Module	Variable	Level	Unit	Reference data 1995 – 2008
Economic modules	Gross Domestic Product	Country	Mio Euro 2005	EUROSTAT (database)
	Final Demand	Country	Mio Euro 2005	EUROSTAT (database)
	Disposable Income	Country	Mio Euro 2005	EUROSTAT (database) – derived value
	Consumption of private households	Country and sector	Mio Euro 2005	EUROSTAT Input/Output-Tables
	Investment	Country and sector	Mio Euro 2005	EUROSTAT Input/Output-Tables
	Capital Stock	Country	Mio Euro 2005	EUROSTAT (database)
	Gross Value Added	Country and sector	Mio Euro 2005	EUROSTAT Input/Output-Tables
	Employment	Country and sector	Mio Euro 2005	EUROSTAT (database)
Trade modules	Exports Intra-EU27	Country pairs and sector	Mio Euro 2005	EUROSTAT and UN Comtrade
	Exports to Rest-of-the-World	Country pairs and sector	Mio Euro 2005	EUROSTAT and UN Comtrade

Source: Fraunhofer-ISI

During the calibration of the trade modules the different drivers, GDP, labour productivity and generalised costs from the transport modules are outbalanced via an optimisation approach in order to reduce the distance of the statistical sectoral export flows to the endogenously calculated development. GDP and labour productivity are exogenous inputs at this moment and are purely statistical values.

In the Economic module at first all supply side sub-modules are calibrated. Gross value-added (GVA) is the first indicator in the sequence of calibration. It is a result from the national production value and the input of intermediates per sector in the national input-output tables. Inputs and outputs of the input-output tables are adapted in order to match the statistical development of GVA per sector. Employment per sector follows the GVA calibration. Via adaption of labour productivity trends and the share of part-time employment on total employment per sector and its full-time factor the labour market is set to EUROSTAT time series data. Finally, the calibration of capital stock on aggregate level is carried out by varying the average depreciation time for private and public investments such that the statistical trend can be reflected.

The calibration of demand side indicators begins with the adaption of disposable income of private households. The main leverage for the following calibration of consumption of private households in net terms is the respective saving ratio per income group. Consumption and exports are supposed to be the main drivers of sectoral investments. Factors that weight the impact of those drivers are used to calibrate sectoral investments according to the EUROSTAT input-output table investments.

The potential output is optimised by varying the output elasticities of the Cobb-Douglas function and the initial level in 1995 to match the development of GDP from 1995 to 2008.

2.2.3 Population module

As opposed to all other ASTRA-EC modules the national and regional (NUTS2) population is calibrated by using projections until 2050. This can be done via the internal Vensim optimisation approach because both modules do not get any input from other ASTRA-EC modules. The main sources of information for calibrating national and NUTS2 population is the EUROSTAT database and the national PRIMES Reference Scenario population projections until 2050. Data for the calibration of income distribution comes from the work in Krail (2009). The data is derived by data from the Luxemburg Income Study (LIS).

Table 2-3: List of data sources used for calibrating the population module

Module	Variable	Level	Unit	Reference data 1995 – 2011
Population module	Population	Country	Persons	EUROSTAT (database)
	Regional population	NUTS2	Persons	EUROSTAT (database)
	Income distribution	Country and income group	Persons	Luxemburg Income Study (LIS)

Source: Fraunhofer-ISI

The calibration of national and regional population is the same. Both population stocks are calibrated by varying the age structure and the level of migration, the country-specific death rates as well as a factor representing the evolution of the health sector leading changing life expectancy and therefore death rates.

Socio-economic drivers of income distribution like the structure of the labour market are adapted in order to match the endogenously calculated income distribution to the statistical distribution derived from the micro-census in the LIS.

2.2.4 Vehicle fleet module

The Calibration period is limited to 1995 up to 2008 in order to prevent unintended impacts from the Economic and Euro Crisis. Therefore, only statistical data up to 2008 has been used to calibrate the vehicle fleet modules. The main data source for the number of vehicles in the stock is the EUROSTAT database. It provides historical data of fleet composition (in terms of fuel type) as well as the absolute number of purchased cars and the fleet size for all the considered countries. Table 2-4 shows an overview of the used reference data for the calibration process.

Table 2-4: List of data sources used for calibrating the vehicle fleet module

Module	Variable	Level	Unit	Reference data 1995 – 2011
Vehicle fleet module	Car stock	Country, fuel type and emission standard	Cars	EUROSTAT (database) and EU Transport in Figures
	Bus stock	Country and emission standard	Buses	EUROSTAT (database) and EU Transport in Figures
	Light duty vehicle stock (LDV)	Country, fuel type and emission standard	LDVs	EUROSTAT (database) and EU Transport in Figures
	Heavy duty vehicle stock (LDV)	Country, weight class and emission standard	Trucks	EUROSTAT (database) and EU Transport in Figures

Source: Fraunhofer-ISI

Depending on the module different calibration parameters where chosen: Every stock model (bus, ldv, hdv, car) contains scrappage ratios which are calibrated to meet the historical data of the fleet size. The scrappage ratios are differentiated in five age classes.

As the bus and truck (ldv and hdv) fleets are driven by the transport demand, the only parameter to calibrate is the annual mileage. The calibration process tries to find the optimal mileage to fit transport demand (input from the transport module) and transport offer (vehicle kilometer provided by the fleet) in respect to existing values for annual mileages.

The calculation of the demand for new purchased cars proves to be more difficult. Besides the already mentioned scrappage ratios, the weights between the different influence factors for the fleet growth are the important calibration parameters. Each influence (income, cost, etc) got its own weight factor in order to meet the past fleet growth values. The result is a fleet growth rate with different, weighted influence factors.

The technology choice with its integrated logit-model uses a general utility level parameter and on the other hand different weight factors within the cost components of the utility function. The aim is to fit the model to the existing developments of diesel and gasoline vehicles as well LPG and CNG. The experiences concerning the calibration factors gained from the past are transferred to the fuel cell and battery technologies.

2.3 Comparing indicators in the calibration period

This chapter includes several comparisons between statistical and modelled data, provided to document the quality of calibration of ASTRA-EC for the period from 1995 to 2010. ASTRA-EC calculates each indicator in every year between 1995 and 2050. Therefore, the calibration cannot only concentrate on one single point of time but on a whole time series. Deviations between statistical and calculated indicators are common. Nevertheless, the objective of the calibration is to match in a sufficient way the historical development of indicators. The definition of a sufficient calibration varies from indicator to indicator according to its significance in the ASTRA-EC model structure. The calibration of indicators like GDP which directly influence the demand side of the economy and therefore also freight transport need to be more accurate and closer to the statistical trend then indicators that influence only one following part in ASTRA-EC.

2.3.1 Transport and environmental indicators

Past passenger and freight transport demand is well reproduced by ASTRA-EC. As shown in Figure 2-4 and Figure 2-5, the modelled trend of passengers-km corresponds to the observed one for both EU15 and EU12. Namely, for EU15 it is clearly visible the turn in the growth rate after the year 2005, while for EU12 the trend is more regular across the fifteen years considered.

Some short term fluctuations which are not reflected in the modelled trend. It should be always remembered that ASTRA-EC serves for looking at trends and especially long term trends rather than for point estimates at certain point of times.

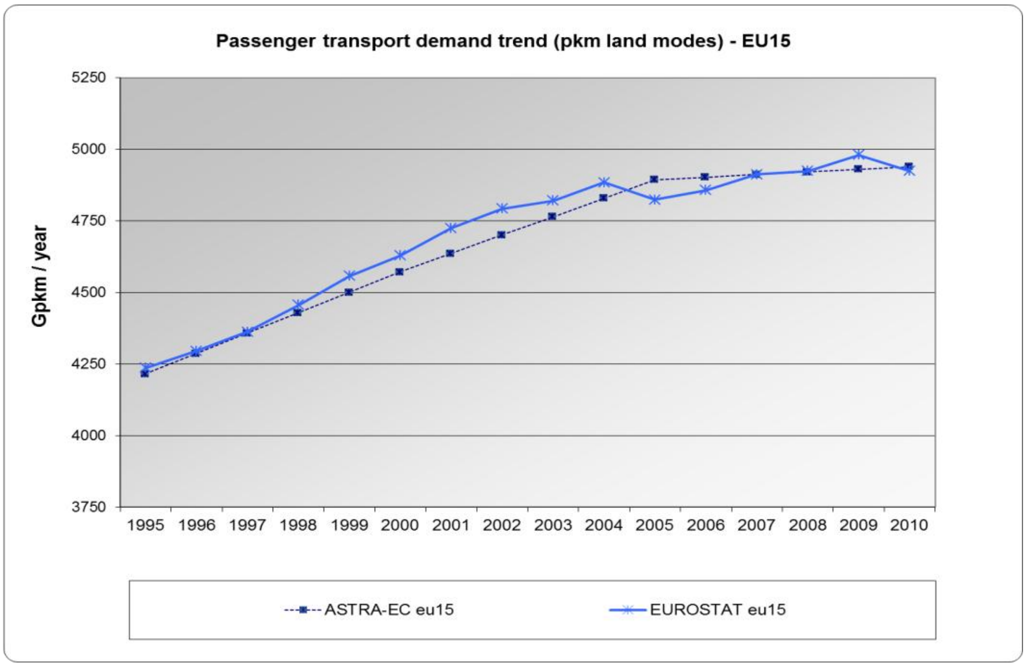
Therefore, also looking at the average growth rates of passenger-km by mode (Table 2-5), the model results are very close to the observed figures when the whole period between 1995 and 2010 is considered. When shorter time spans are taken into account some larger differences may be detected, however the modelled growth rates always provide a realistic picture of the demand trend.

Also regarding freight, the simulated trend of demand is close to the observed data for both EU15 and EU12 (Figure 2-6 and Figure 2-7). Apart the short term changes from one year to another, the growth of tonnes-km in EU15 has basically stopped since 2005, while in EU12 the growth has been faster in the second half of the period considered. Both these circumstances are well reflected in the modelled trend.

Growth rates by freight mode (Table 2-6) compare well looking at the overall period with only a slight overestimation of rail growth (even if the basic message of the observed trend is maintained: rail freight demand has been basically stagnating from 1995 to 2010). Considering intermediate periods some differences are more significant but most of the comparisons are very good also for some “extreme” values like the large growth rates of Inland Navigation in EU12 countries.

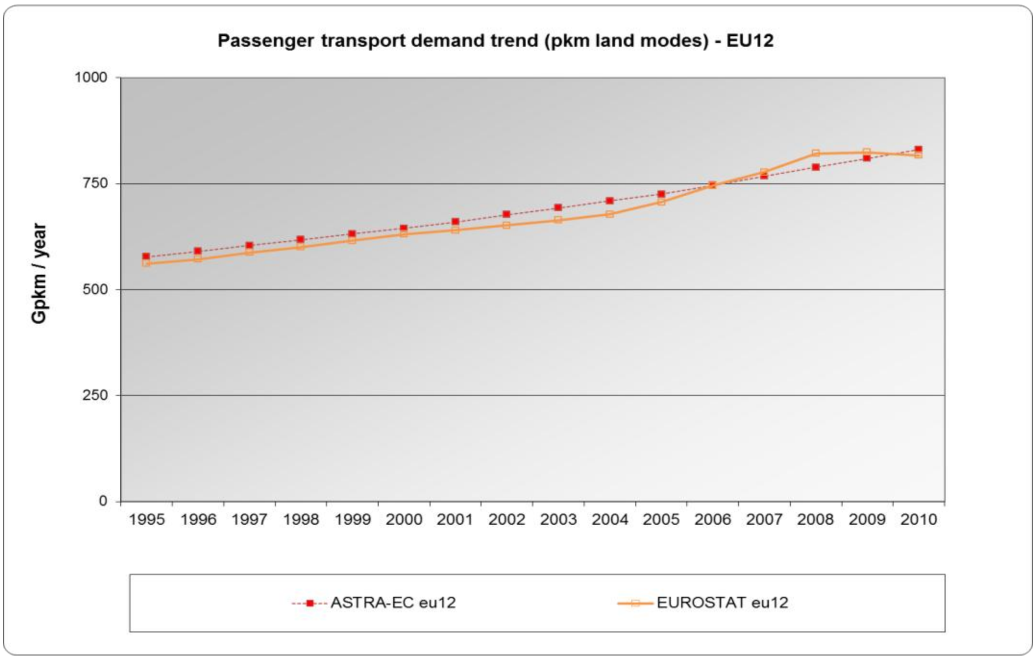
Also looking the absolute values of passenger and freight demand at the ASTRA-EC results compare positively for all countries (Table 2-7 and Table 2-8).

Finally, ASTRA-EC replicates mode split and its evolution over time for both passenger and freight. The stability of mode shares for the EU15 is correctly simulated. In the EU12 some visible changes have occurred in the period considered. On the passenger side there has been a growth of car share at the expense of rail. Also on the freight side train has lost market share quite significantly while the role of maritime (short sea shipping) has increased. Both these two changes are correctly reflected in the ASTRA-EC data as shown in Table 2-9 and Table 2-10.



Source: TRT

Figure 2-4: Total motorised land passenger demand (Gpkm) in EU15



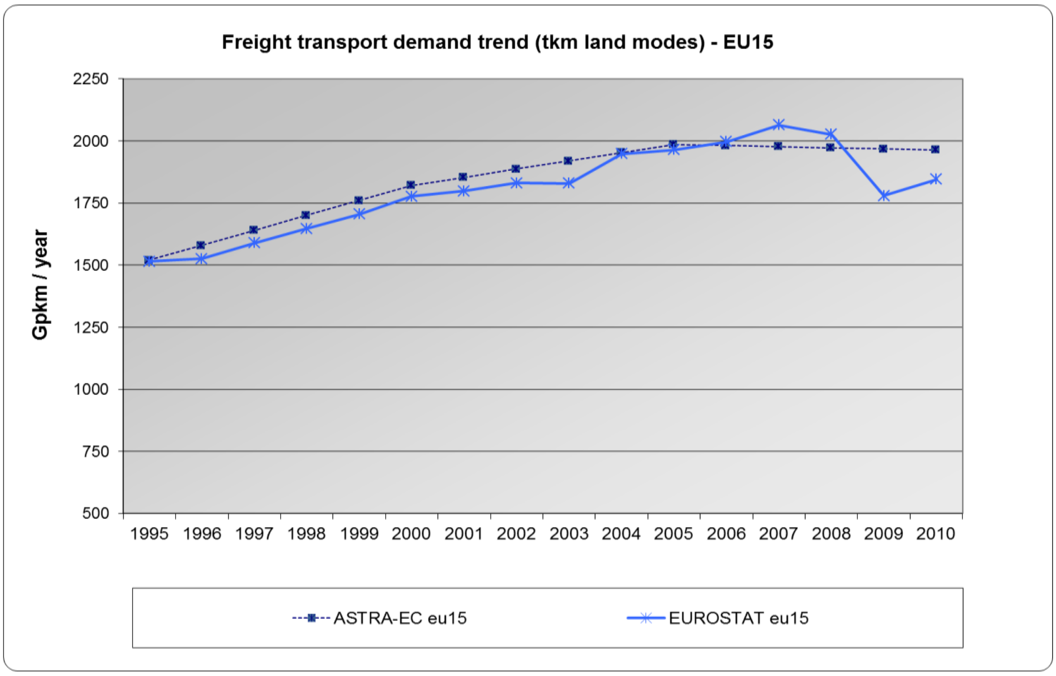
Source: TRT

Figure 2-5: Total motorised land passenger demand (Gpkm) in EU12

Table 2-5: Trend of passenger demand by mode in EU regions: average yearly growth rate

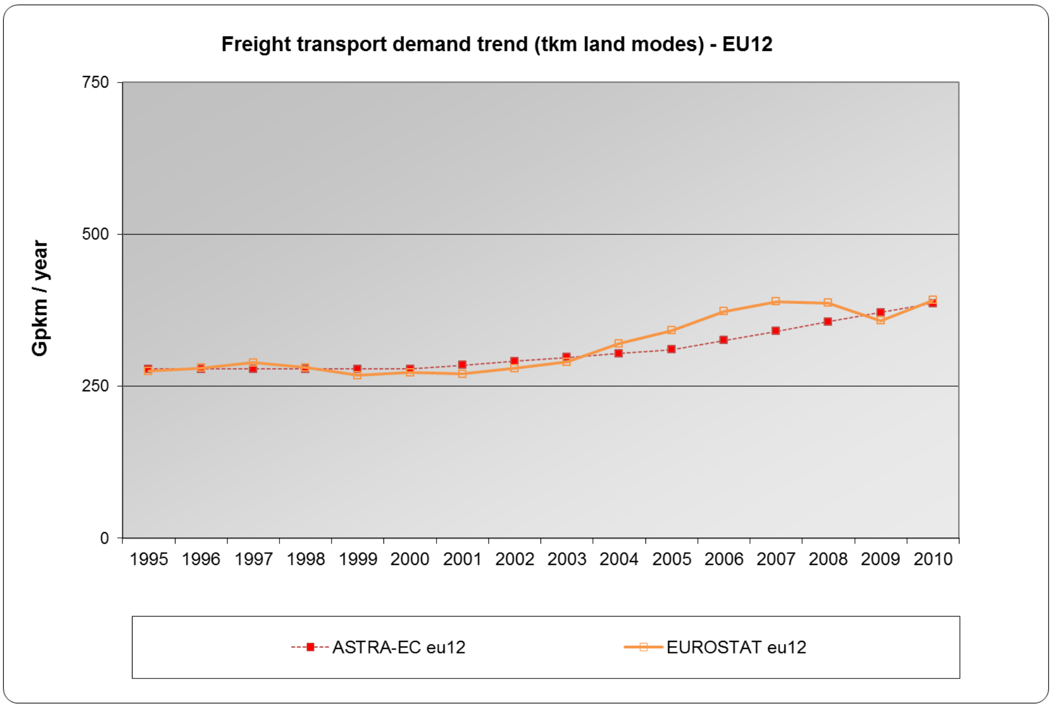
Mode	1995 - 2000		2000 - 2005		2005 - 2010		1995 - 2010	
	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC
EU15								
Car	1.8%	1.7%	0.8%	1.5%	0.3%	0.1%	1.0%	1.1%
Bus	1.3%	0.9%	0.6%	0.4%	0.1%	-0.3%	0.7%	0.4%
Train	2.3%	1.7%	1.3%	1.2%	1.9%	1.8%	1.8%	1.6%
Air	6.1%	5.5%	2.5%	3.3%	-0.2%	1.2%	2.8%	3.3%
EU12								
Car	4.7%	4.2%	3.9%	4.1%	4.5%	4.0%	4.4%	4.1%
Bus	-1.0%	-0.4%	-0.8%	-1.7%	-3.1%	-1.6%	-1.6%	-1.2%
Train	-2.8%	-2.7%	-3.0%	-1.6%	-1.0%	-0.8%	-2.3%	-1.7%
Air	1.0%	5.4%	7.1%	5.6%	2.8%	4.5%	3.6%	5.2%
EU27								
Car	2.1%	2.0%	1.1%	1.8%	0.8%	0.6%	1.3%	1.4%
Bus	0.7%	0.6%	0.3%	0.0%	-0.5%	-0.6%	0.2%	0.0%
Train	1.2%	0.8%	0.5%	0.7%	1.5%	1.4%	1.1%	0.9%
Air	5.7%	5.5%	2.8%	3.4%	0.1%	1.5%	2.8%	3.5%

Source: TRT



Source: TRT

Figure 2-6: Total motorised land freight demand (Gtkm) in EU15



Source: TRT

Figure 2-7: Total motorised land freight demand (Gtkm) in EU12

Table 2-6: Trend of total freight demand by mode in EU regions: average yearly growth rate

Mode	1995 - 2000		2000 - 2005		2005 - 2010		1995 - 2010	
	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC
EU15								
Truck	3.4%	3.9%	2.5%	2.1%	-1.4%	-0.2%	1.5%	1.9%
Train	2.9%	3.1%	0.4%	0.4%	-0.6%	0.0%	0.9%	1.2%
IWW	2.1%	2.7%	-0.2%	1.0%	-0.5%	-0.5%	0.5%	1.1%
Maritime*	2.1%	1.7%	2.6%	1.5%	-0.5%	0.0%	1.4%	1.1%
EU12								
Truck	3.1%	1.4%	7.7%	5.9%	4.2%	6.8%	5.0%	4.7%
Train	-3.5%	-1.2%	-0.9%	-3.1%	-2.0%	-0.7%	-2.1%	-1.7%
IWW	-2.6%	-2.7%	13.8%	10.3%	12.2%	10.4%	7.5%	5.8%
Maritime*	7.4%	5.7%	-0.3%	3.3%	-1.6%	-0.7%	1.7%	2.7%
EU27								
Truck	3.4%	3.7%	3.1%	2.4%	-0.7%	0.6%	1.9%	2.2%
Train	0.6%	1.5%	0.0%	-0.7%	-1.0%	-0.2%	-0.1%	0.2%
IWW	2.8%	2.2%	2.1%	1.8%	-0.6%	-0.1%	1.4%	1.3%
Maritime*	1.8%	2.4%	0.8%	1.6%	1.1%	0.6%	1.2%	1.5%

* Maritime data is estimated on the basis of EU27 EUROSTAT data

Source: TRT

Table 2-7: Total motorised land passenger demand by country (Gpkm/year)

Country	2000		2005		2010	
	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC
Austria	94.3	94.6	101.1	101.4	105.7	104.9
Belgium	136.5	130.7	145.2	142.3	147.6	145.0
Bulgaria	48.0	47.9	55.2	52.1	65.0	53.7
Cyprus	11.9	10.6	13.8	13.3	14.5	15.9
Denmark	69.9	66.0	72.3	69.4	73.8	69.7
Estonia	9.9	9.4	13.8	11.3	13.3	12.2
Spain	466.1	431.8	515.5	504.1	521.2	535.9
Finland	75.7	79.0	82.3	84.2	85.5	84.4
France	873.1	859.1	911.5	945.2	933.8	952.4
United Kingdom	811.7	819.0	874.5	865.4	860.3	873.6
Greece	113.0	119.1	138.6	131.6	152.2	131.8
Hungary	80.2	81.8	83.7	87.7	82.8	89.8
Ireland	52.1	53.1	61.1	65.0	65.1	73.4
Italy	897.8	868.8	876.7	937.4	903.3	932.8
Latvia	15.2	13.5	17.1	16.1	20.9	17.9
Lithuania	29.7	25.8	39.8	29.9	34.2	32.5
Luxembourg	7.2	6.4	8.1	7.2	8.4	7.6
Malta	4.7	4.1	4.9	4.5	4.9	4.7
Netherlands	182.3	179.0	192.9	193.1	186.7	193.6
Poland	216.1	241.4	256.6	283.4	351.3	365.0
Portugal	102.9	102.1	116.2	113.9	115.4	112.2
Czech Republic	100.4	92.0	107.9	105.1	105.9	109.7
Germany	1047.5	1047.1	1079.6	1080.9	1110.2	1094.2
Romania	82.8	91.4	90.3	100.3	105.3	112.8
Slovak Republic	36.7	34.5	38.3	37.0	36.3	39.5
Slovenia	25.0	25.3	26.7	27.9	30.2	30.9
Sweden	125.6	126.0	130.8	134.3	134.6	138.4

Table 2-8: Total inland (truck, train, IWW) freight demand by country (Gtkm/year)

Country	2000		2005		2010	
	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC
Austria	51.1	54.8	53.1	54.1	57.6	57.9
Belgium	78.6	74.5	76.2	72.1	64.4	71.7
Bulgaria	11.2	13.9	17.4	14.5	20.3	17.9
Cyprus	1.3	1.5	1.4	1.0	1.1	1.0
Denmark	26.7	29.2	26.2	27.5	20.9	22.3
Estonia	6.7	7.1	8.9	6.6	5.6	6.3
Spain	158.4	156.9	240.5	199.0	203.3	215.8
Finland	38.8	41.9	38.2	40.5	35.8	41.6
France	298.0	318.8	294.2	324.7	304.5	309.6
United Kingdom	190.0	184.0	191.3	208.9	173.2	178.0
Greece	28.4	33.1	31.5	30.2	30.5	26.5
Hungary	24.0	24.3	29.0	26.8	32.1	32.0
Ireland	12.3	11.6	17.2	18.1	10.7	13.6
Italy	224.1	222.3	261.8	246.5	207.7	231.5
Latvia	4.4	4.0	6.7	6.0	5.9	5.9
Lithuania	7.6	9.2	11.0	9.2	10.7	10.5
Luxembourg	6.7	7.0	6.4	6.7	5.3	6.2
Malta	0.3	0.3	0.3	0.2	0.3	0.4
Netherlands	122.6	125.1	128.0	124.5	103.7	128.4
Poland	114.6	110.7	129.1	118.0	183.4	173.0
Portugal	33.7	34.0	33.3	35.7	26.7	30.3
Czech Republic	46.3	45.1	44.2	45.8	51.9	51.2
Germany	449.6	460.4	500.9	524.2	536.5	552.8
Romania	29.8	32.3	62.8	50.4	45.8	51.4
Slovak Republic	19.7	21.4	21.1	22.0	22.9	24.5
Slovenia	6.5	8.3	9.5	9.6	11.3	12.4
Sweden	58.5	67.7	65.7	73.6	65.0	77.5

Table 2-9: Passenger demand mode split by EU zone (%)

	Mode	1995		2000	
		Eurostat	ASTRA-EC	Eurostat	ASTRA-EC
EU15	Car	78%	77%	76%	76%
	Bus	8%	9%	8%	8%
	Train	7%	7%	7%	7%
	Air*	7%	7%	8%	8%
EU12	Car	58%	59%	65%	65%
	Bus	21%	20%	17%	18%
	Train	16%	16%	13%	13%
	Air*	5%	4%	4%	5%
EU27	Car	75%	75%	75%	75%
	Bus	10%	10%	9%	9%
	Train	8%	8%	8%	8%
	Air*	7%	7%	8%	8%
		2005		2010	
		Eurostat	ASTRA-EC	Eurostat	ASTRA-EC
EU15	Car	76%	76%	76%	75%
	Bus	8%	8%	8%	7%
	Train	7%	7%	8%	8%
	Air*	9%	9%	9%	9%
EU12	Car	70%	70%	76%	74%
	Bus	15%	14%	11%	11%
	Train	10%	10%	8%	9%
	Air*	6%	6%	6%	6%
EU27	Car	75%	75%	76%	75%
	Bus	9%	8%	8%	8%
	Train	8%	8%	8%	8%
	Air*	9%	9%	8%	9%

* Air data is estimated on the basis of EU27 EUROSTAT data

Source: TRT

Table 2-10: Freight demand mode split by EU zone (%)

	Mode	1995		2000	
		Eurostat	ASTRA-EC	Eurostat	ASTRA-EC
EU15	Truck	47%	47%	48%	49%
	Train	9%	9%	9%	9%
	IWW	5%	5%	4%	5%
	Maritime*	40%	40%	39%	38%
EU12	Truck	31%	31%	32%	30%
	Train	33%	34%	25%	29%
	IWW	2%	2%	2%	2%
	Maritime*	33%	33%	42%	39%
EU27	Truck	45%	44%	46%	46%
	Train	12%	12%	11%	11%
	IWW	4%	4%	4%	4%
	Maritime*	39%	39%	39%	38%
		2005		2010	
		Eurostat	ASTRA-EC	Eurostat	ASTRA-EC
EU15	Truck	49%	50%	48%	50%
	Train	8%	8%	8%	8%
	IWW	4%	5%	4%	4%
	Maritime*	39%	37%	40%	38%
EU12	Truck	41%	35%	47%	43%
	Train	21%	22%	18%	18%
	IWW	3%	2%	4%	4%
	Maritime*	36%	41%	31%	35%
EU27	Truck	48%	48%	48%	49%
	Train	10%	10%	10%	10%
	IWW	4%	4%	4%	4%
	Maritime*	39%	38%	39%	37%

* Maritime data is estimated on the basis of EU27 EUROSTAT data

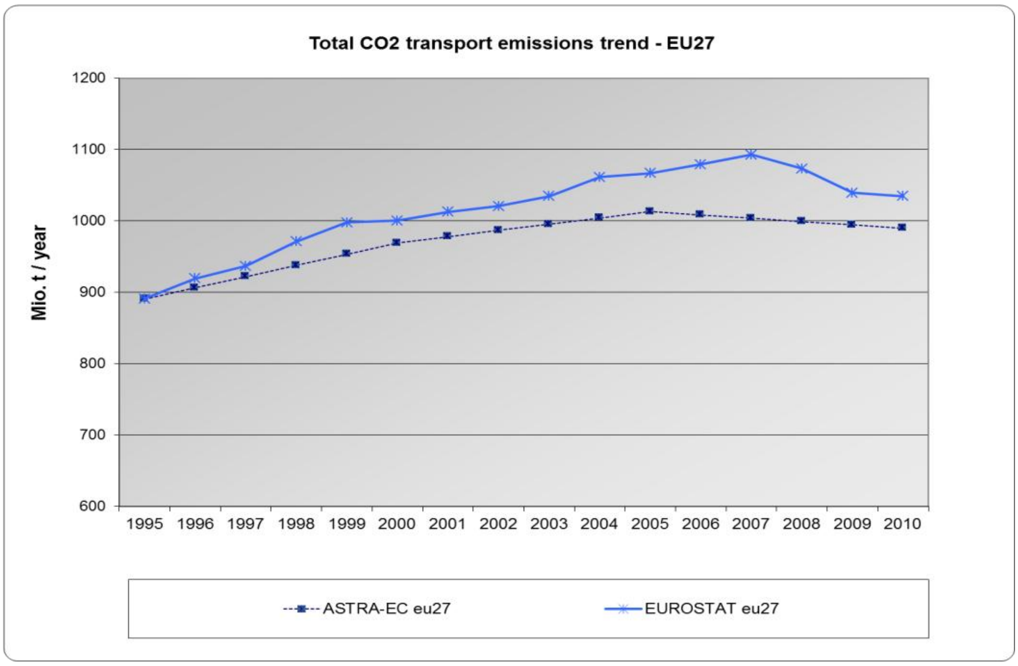
Source: TRT

Regarding environmental indicators, the correspondence between the ASTRA-EC results and the observed Eurostat data is somewhat less precise than for the transport demand but the modelled trends are always correct.

Looking at CO_2 transport emissions, the growth for most of the considered time span and the decrease in the final part of the period are both visible in the ASTRA-EC results (Figure 2-8). In absolute terms the total emissions of ASTRA-EC are below the observed figures, but the difference is in the size of 5% or less for most of the period considered. This slight underestimation of the emissions suggests that real world emissions per vehicle-km are on average a bit higher than the modelled values. This could be due to less favourable local driving conditions (e.g. congestion in urban areas).

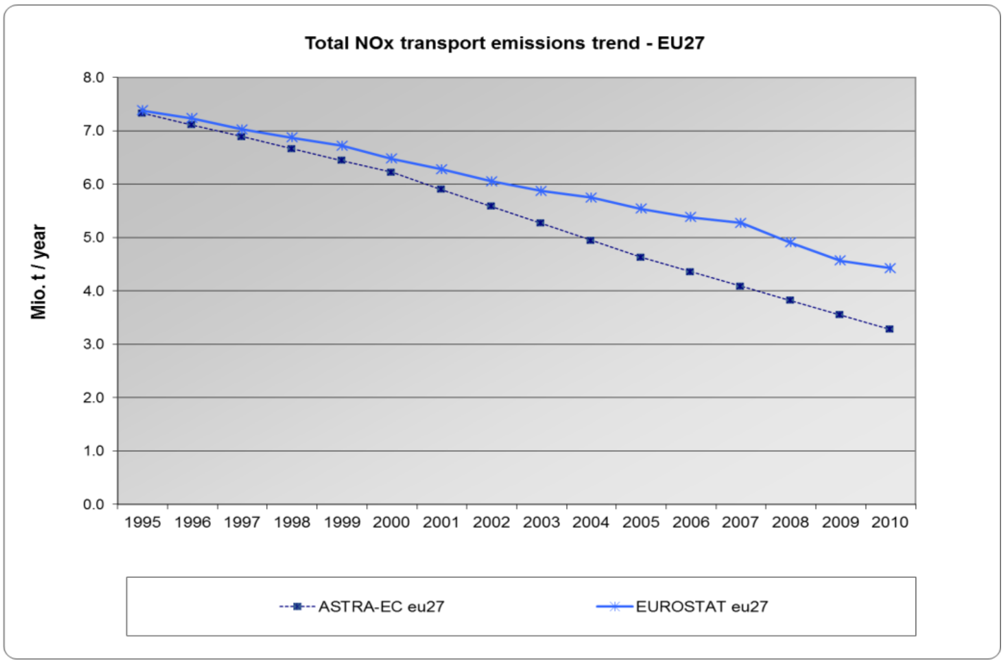
Also for polluting emissions (NO_x and particulate matters) the descending trend is correctly represented while the absolute amount of pollution is somewhat underestimated (Figure 2-9 and Figure 2-10). A possible explanation for this discrepancy is again that in the real world especially road vehicles emit more than the amount expected according to the reference inventory of the emission factors. Furthermore, it might be that in ASTRA-EC the renewal of the fleet in term of Euro standards occur a bit too fast.

Comparisons regarding fuel consumption (Figure 2-11, Figure 2-12 and Figure 2-13) reveal that ASTRA-EC provides a correct representation of the increasing trend of diesel and biofuels consumption and of the decreasing trend of gasoline consumption. Again there are differences in absolute term, but their size is small and especially the fast upsurge of biofuels is clearly simulated.



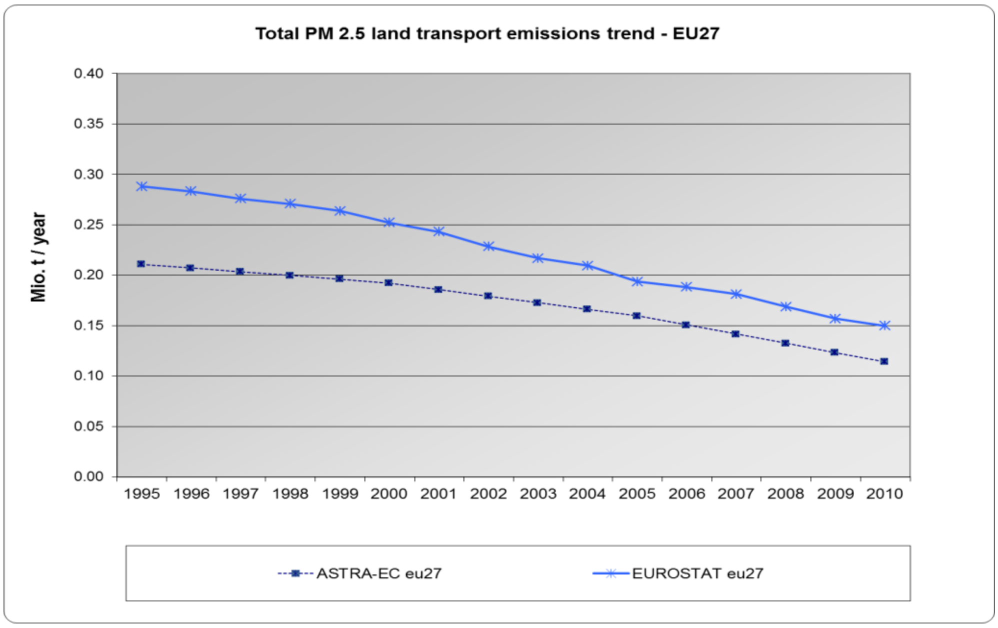
Source: TRT

Figure 2-8: Total CO_2 transport emissions (Mio tons/ year) in EU27



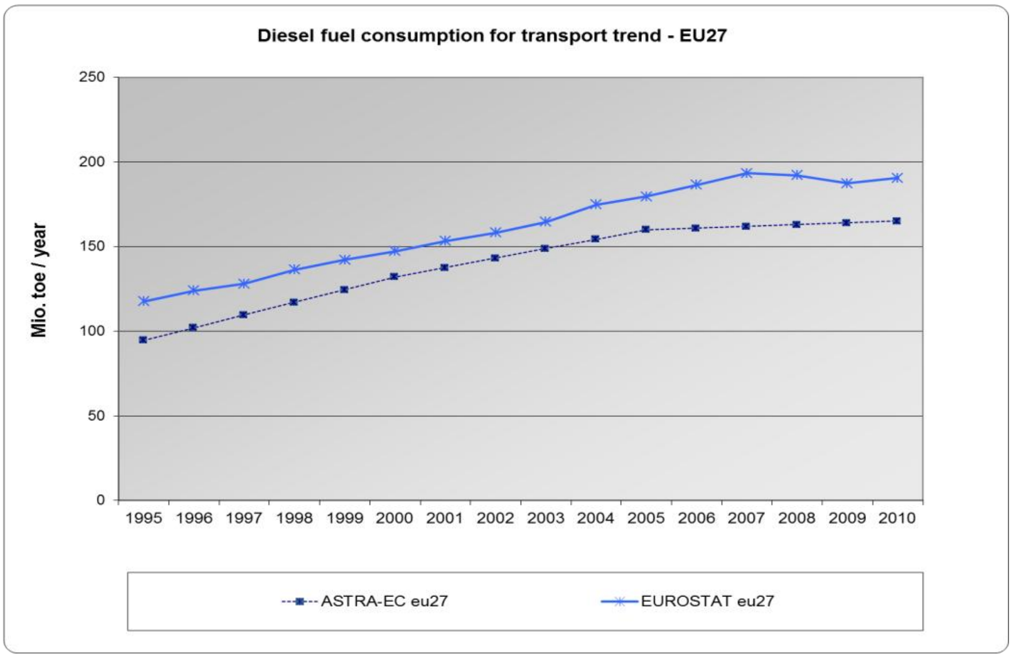
Source: TRT

Figure 2-9: Total NO_x transport emissions (Mio tons/ year) in EU27



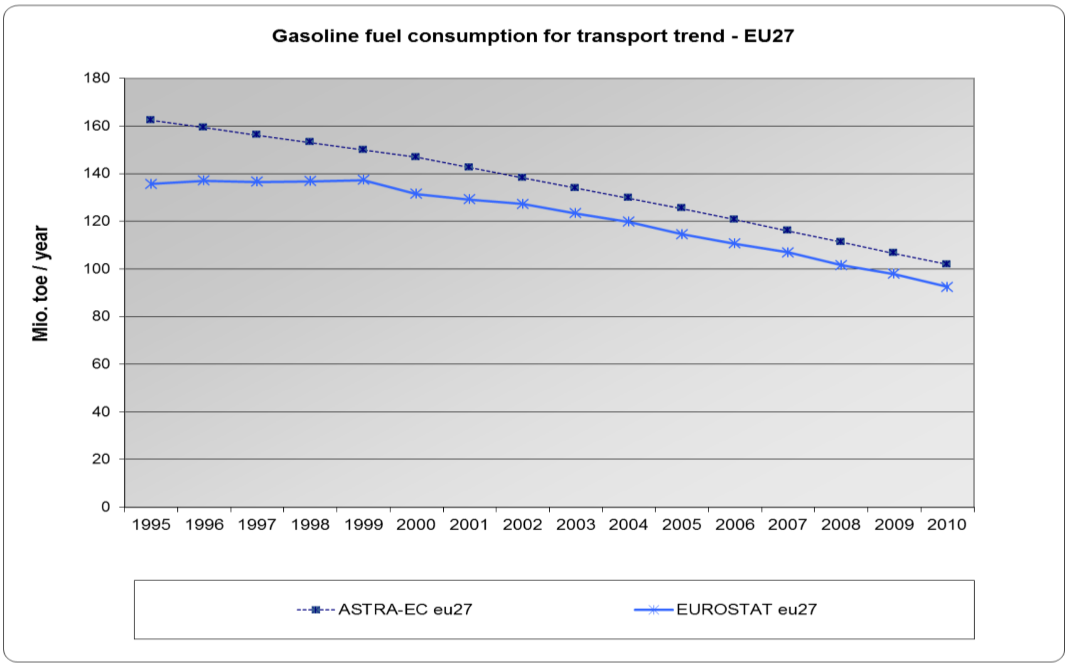
Source: TRT

Figure 2-10: Total PM $_{2.5}$ land (road, rail) transport emissions (Mio tons/ year) in EU27



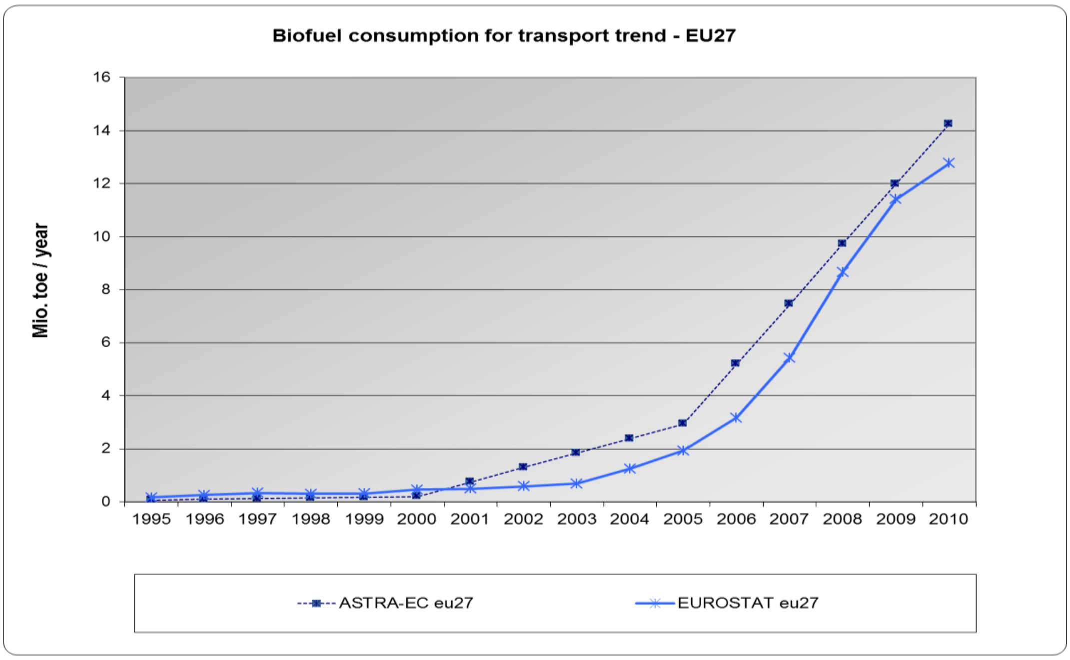
Source: TRT

Figure 2-11: Diesel fuel consumption for transport (Mio Toe / year) in EU27



Source: TRT

Figure 2-12: Gasoline fuel consumption for transport (Mio Toe / year) in EU27

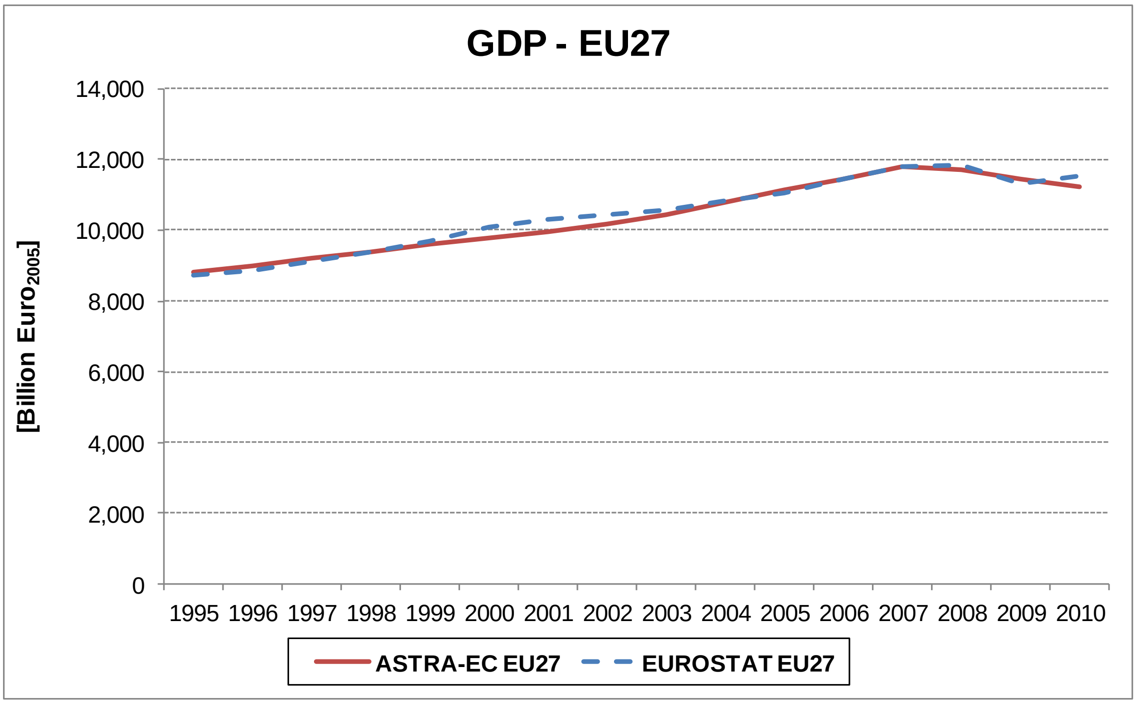


Source: TRT

Figure 2-13: Biofuel consumption for transport (Mio Toe / year) in EU27

2.3.2 Economic and population indicators

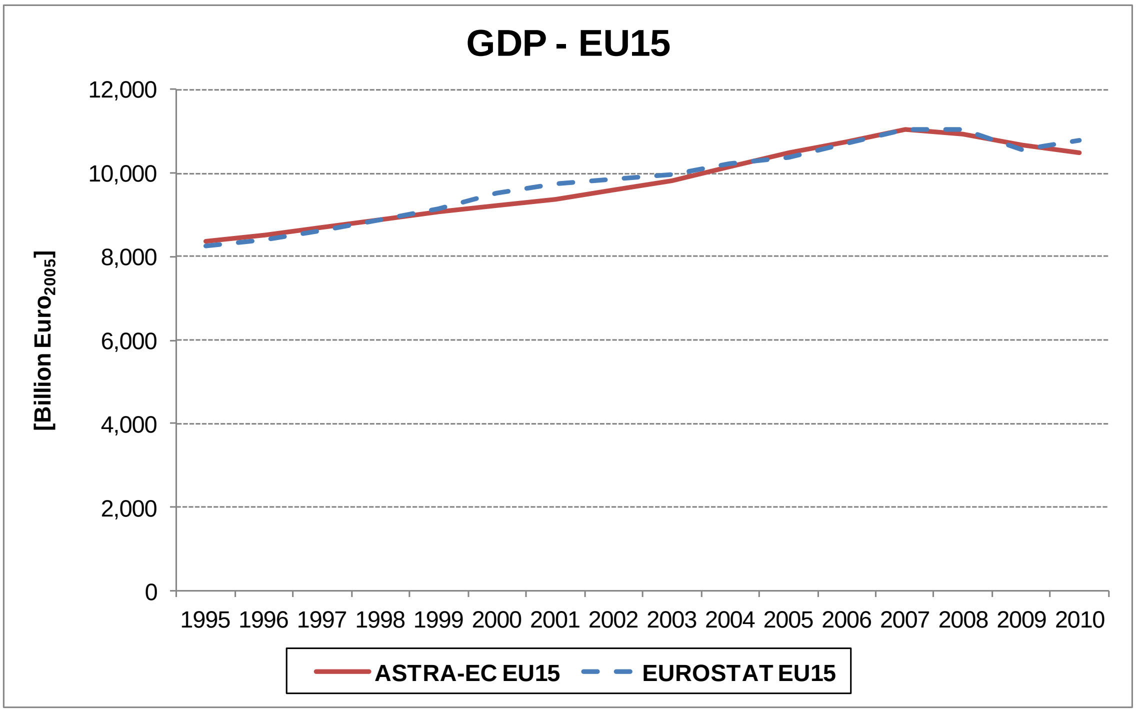
The following tables and figures demonstrate the quality of the calibration of ASTRA-EC for major economic and population indicators. All monetary values, statistical as well as simulated values, are expressed in real terms in constant Euro 2005. They are deflated by a EU27 GDP deflator from EUROSTAT. Therefore, differences between indicators available on the EUROSTAT database and the statistical values presented can occur.



Source: Fraunhofer-ISI

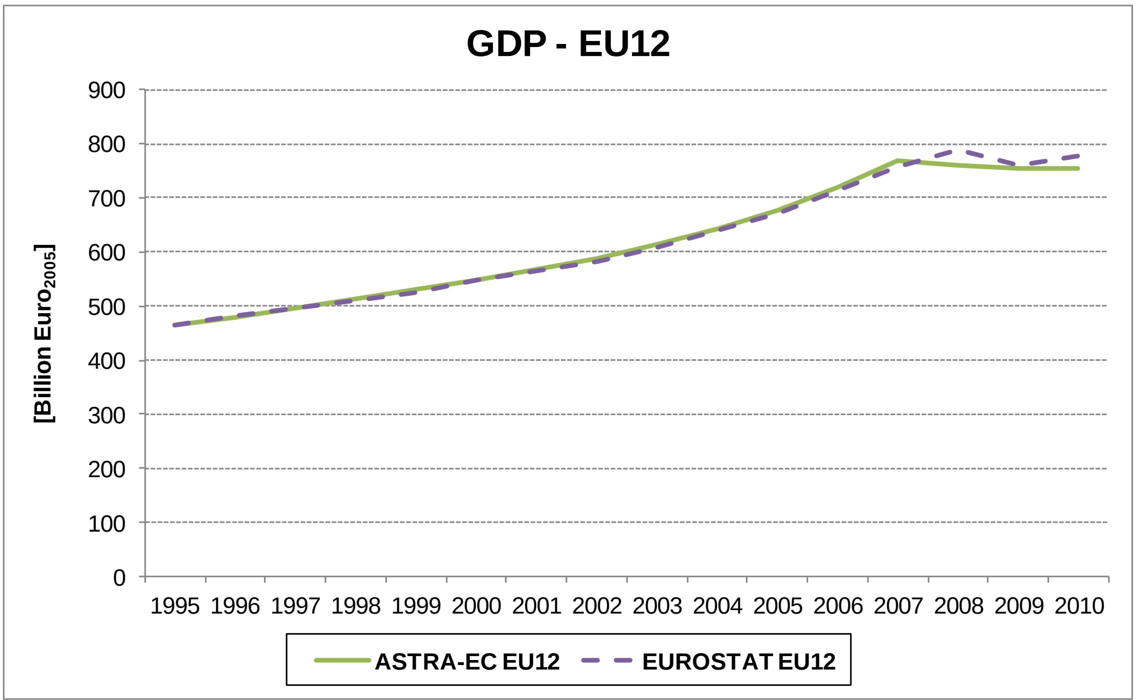
Figure 2-14: Quality of GDP calibration in EU27

GDP is supposed to be the key economic indicator in ASTRA-EC. As many feedback loops end and start at GDP, the average deviation from the calculated to the statistical GDP needs to be less than 10%. For EU27 the average deviation in the period from 1995 to 2010 is by -1.3%, for EU15 -1.3% and for EU12 -0.9%. For countries with lower GDP levels small deviations are more difficult to achieve. Some EU12 member states had a strong growth of GDP in the years after the accession to the European Union. As these impacts can only hardly be modelled by a macro-level model like ASTRA-EC the deviations in respective years can be higher than 10%. Considering the whole time series from 1995 to 2010 a very good quality of calibration for GDP could be achieved. Figure 2-14 up to Figure 2-16 compare the statistical development of GDP with the endogenous GDP trend in ASTRA-EC for EU27, EU15 and EU12.



Source: Fraunhofer-ISI

Figure 2-15: Quality of GDP calibration in EU15



Source: Fraunhofer-ISI

Figure 2-16: Quality of GDP calibration in EU12

Table 2-11 presents a comparison on member state level for 2000, 2005 and 2010.

Table 2-11: Comparison of statistical GDP with ASTRA-EC GDP by country

Country	1995		2000		2005	
	Eurostat	ASTRA	Eurostat	ASTRA	Eurostat	ASTRA
Austria	226	211	245	240	263	256
Belgium	280	270	303	305	322	312
Denmark	195	191	207	210	206	202
Spain	774	747	909	904	950	944
Finland	138	126	157	151	166	164
France	1,587	1,512	1,718	1,681	1,776	1,735
United Kingdom	1,592	1,556	1,834	1,867	1,880	1,819
Germany	2,159	2,124	2,224	2,285	2,369	2,274
Greece	158	154	193	191	196	189
Ireland	128	114	163	162	163	160
Italy	1,368	1,354	1,436	1,468	1,422	1,420
Netherlands	481	442	513	518	551	518
Portugal	148	137	154	162	158	156
Sweden	261	262	298	292	320	307
Bulgaria	18	18	23	22	27	25
Cyprus	12	11	14	15	15	16
Czech Republic	86	91	105	111	120	121
Estonia	8	8	11	11	11	11
Hungary	72	74	89	90	88	82
Latvia	9	10	13	12	12	12
Lithuania	14	14	21	18	22	24
Malta	5	4	5	5	5	6
Poland	210	200	244	249	308	291
Romania	60	62	80	75	90	89
Slovenia	24	24	29	30	31	31
Slovak Republic	30	31	38	40	48	46
Luxembourg	25	24	30	29	33	34

Source: Fraunhofer-ISI

Demography is a driver of passenger transport as well as of the labour market. As opposed to economic indicators like GDP, the ASTRA-EC population module receives no input from other modules. Therefore, on the one hand a good quality calibration is rather simple to achieve. On the other hand, an accurate calibration is necessary as the population and its age structure directly affects passenger transport and employment respectively unemployment.

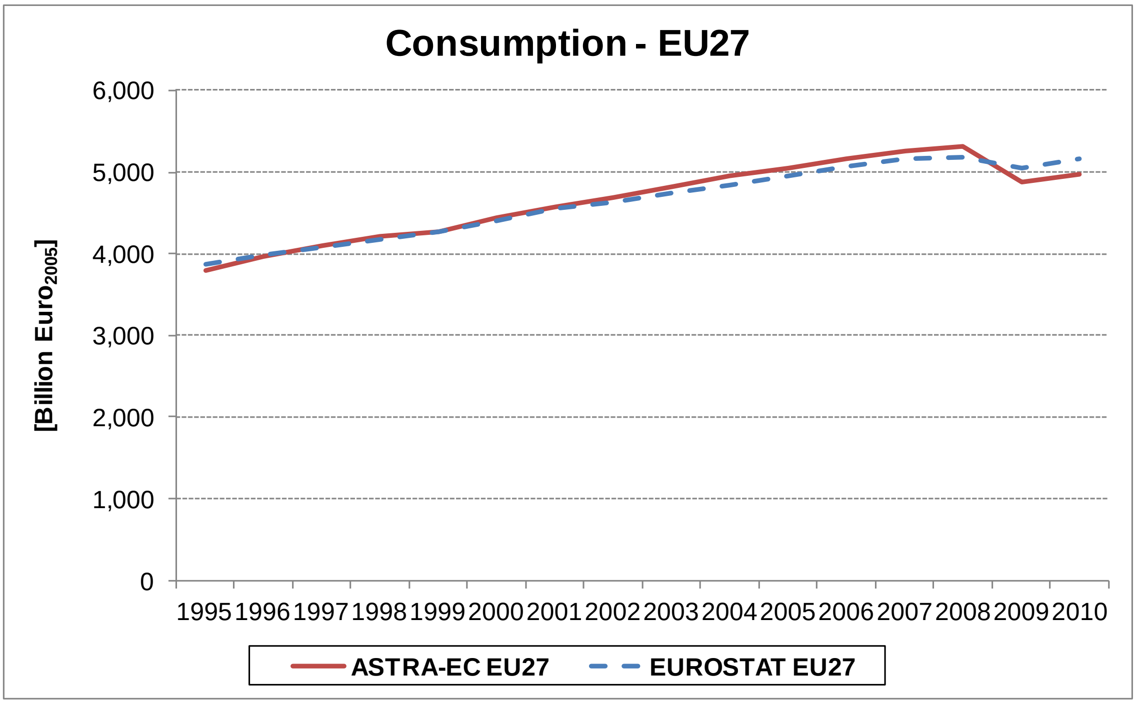
The average deviation from the endogenously simulated population in EU27 to the EUROSTAT population from 1995 to 2010 is with +0.6% in a very good range. For EU15, the calibration is with an average deviation of +0.4% better than for EU12 where the average deviation is +1.5%. Table 2-12 provides a comparison between population numbers from EUROSTAT and ASTRA-EC model results for each member state.

Table 2-12: Comparison of statistical to ASTRA-EC population by country

Country	1995		2000		2005	
	Eurostat	ASTRA	Eurostat	ASTRA	Eurostat	ASTRA
Austria	8,002	8,006	8,201	8,215	8,375	8,397
Belgium	10,239	10,236	10,446	10,475	10,840	10,806
Denmark	5,330	5,296	5,411	5,412	5,535	5,553
Spain	40,050	41,119	43,038	44,012	45,989	47,265
Finland	5,171	5,164	5,237	5,247	5,351	5,355
France	60,545	58,956	62,773	61,176	64,694	63,129
United Kingdom	58,785	58,467	60,039	60,045	62,027	62,128
Germany	82,163	81,973	82,501	82,681	81,802	82,048
Greece	10,904	10,835	11,083	11,042	11,305	11,218
Ireland	3,778	3,845	4,112	4,238	4,468	4,704
Italy	56,924	57,187	58,462	58,381	60,340	60,019
Netherlands	15,864	15,861	16,306	16,434	16,575	16,857
Portugal	10,195	10,175	10,529	10,649	10,638	10,783
Sweden	8,861	8,873	9,011	9,011	9,341	9,330
Bulgaria	8,191	8,210	7,761	8,020	7,564	7,833
Cyprus	690	666	749	744	819	811
Czech Republic	10,278	10,305	10,221	10,315	10,507	10,580
Estonia	1,372	1,414	1,348	1,397	1,340	1,385
Hungary	10,222	10,128	10,098	10,141	10,014	10,153
Latvia	2,382	2,452	2,306	2,416	2,248	2,379
Lithuania	3,512	3,573	3,425	3,515	3,329	3,453
Malta	380	385	403	395	414	401
Poland	38,654	38,868	38,174	39,215	38,167	39,294
Romania	22,455	22,115	21,659	22,187	21,462	22,194
Slovenia	1,988	2,008	1,998	2,028	2,047	2,106
Slovak Republic	5,399	5,396	5,385	5,428	5,425	5,510
Luxembourg	434	430	461	455	502	493

Source: Fraunhofer-ISI

The quality of the calibration of consumption of private households depends strongly on the accurateness of disposable income of private households. The second important factor is the setting of saving ratios for each income group. Figure 2-17 illustrates the development of endogenously calculated consumption and the statistical development for EU27. The modelled consumption in ASTRA-EC can reproduce the statistical development for EU27 over the whole period from 1995 to 2010 with marginal deviations. Like for all economic indicators, the deviations are the highest for the first years of the Economic crisis in 2008, 2009 and 2010. The complex feedback structure and the delays of impacts in some major feedback loops are the reason for this. Nevertheless, the deviations from modelled to statistical consumption values from EUROSTAT input-output tables are by on average +1.3% for EU27 small. With few exemptions, the average deviations are for most EU27 countries below 4%. Compared with previous calibration processes for ASTRA, the quality of calibration could be improved significantly.



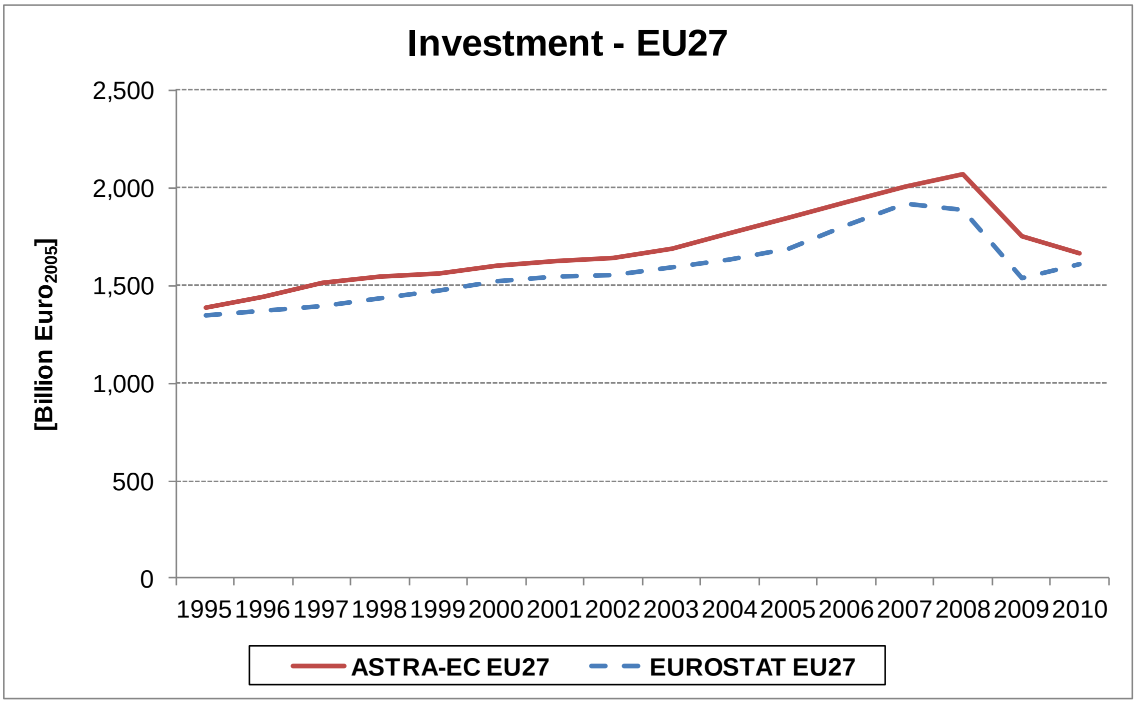
Source: Fraunhofer-ISI

Figure 2-17: Quality of calibration of consumption of private households in EU27

In ASTRA-EC investments are supposed to be directly affected by the growth of consumption and exports. Hence, an accurate development of consumption and exports is also important for a good quality of the calibration of investments. Figure 2-18 shows a comparison between data from domestic EUROSTAT input-output tables and the simulated development of investments for EU27. Even if the general investment level is above the statistical investment, the average deviation is with +6%

on an acceptable level. The shape of both, the statistical and the simulated investment curve, are similar such that the model structure is valid.

Figure 2-18: Quality of investment calibration in EU27

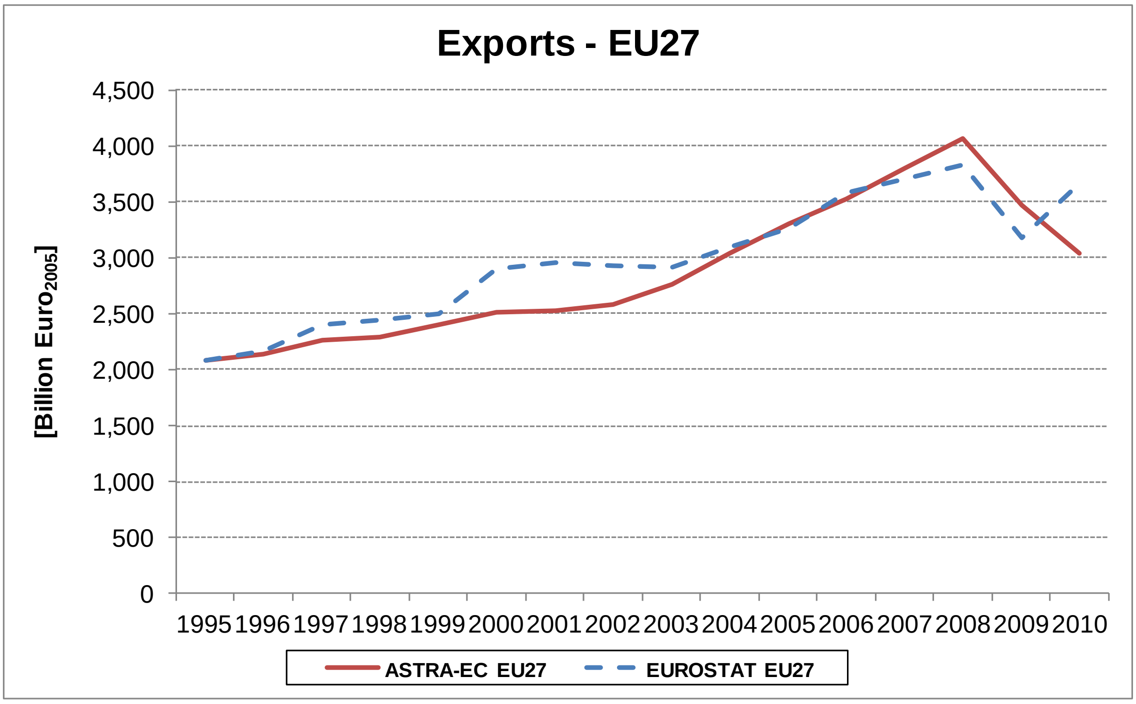


Source: Fraunhofer-ISI

Figure 2-19: Quality of investment calibration in EU27

Foreign trade is influenced by many drivers. Some of them can be simulated within the ASTRA-EC model, others are exogenous inputs. The volatility of exchange rates plays an important role and is one of the reasons for amplitudes in the past export volumes from 1995 to 2010. Furthermore, exports to regions outside the EU depend on the economic development in these regions. ASTRA-EC does not simulate them, but only considers projected and historical growth rates for world regions. Therefore, higher deviations to statistical export flows are common for at least some years in the calibration period.

Figure 2-20 compares statistical to simulated development of total exports from EU27. The average deviation of simulated exports to the statistical values for the period from 1995 to 2010 is -5.4%. Taking into account the several exogenous drivers of exports the result of the calibration is sufficient even if the average deviations on country level are for some member states above 10%.

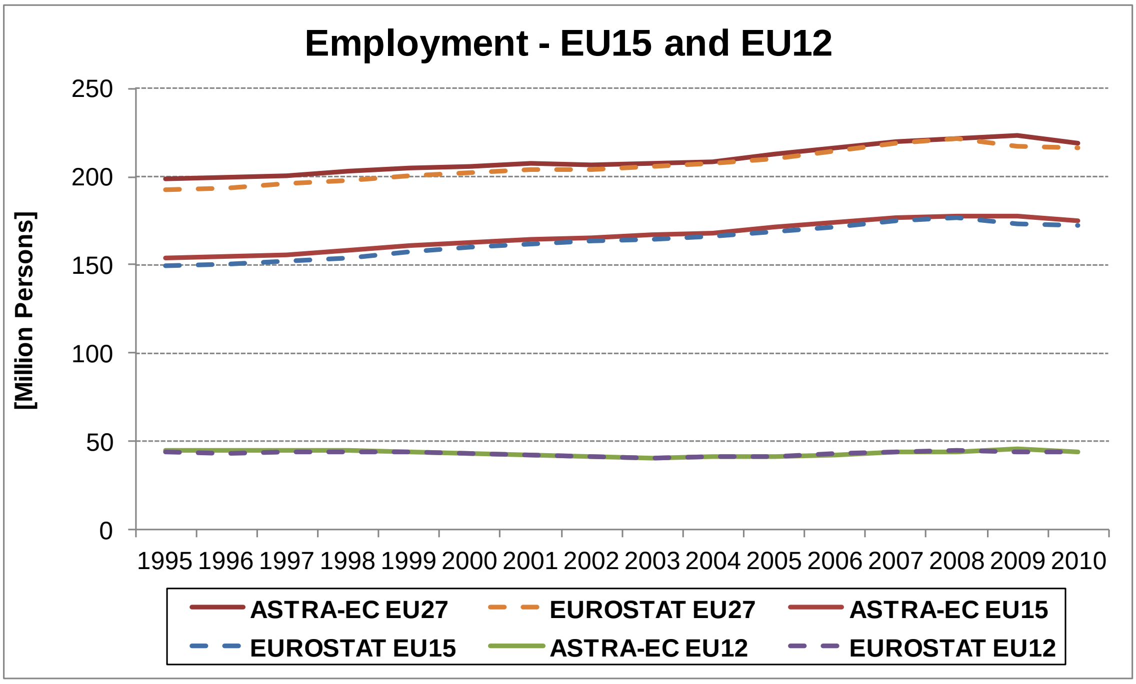


Source: Fraunhofer-ISI

Figure 2-20: Quality of export calibration in EU27

Figure 2-21 demonstrates the simulated and the statistical historical development of total employment for EU27, EU15 and EU12. ASTRA-EC simulates the development of full-time equivalent on the basis of endogenously calculated gross value-added and exogenous labour productivity per sector. Total employment per sector is then computed by adapting the share of part-time employed persons per country and sector and by using a factor representing the average working hours of a part-time employed per sector.

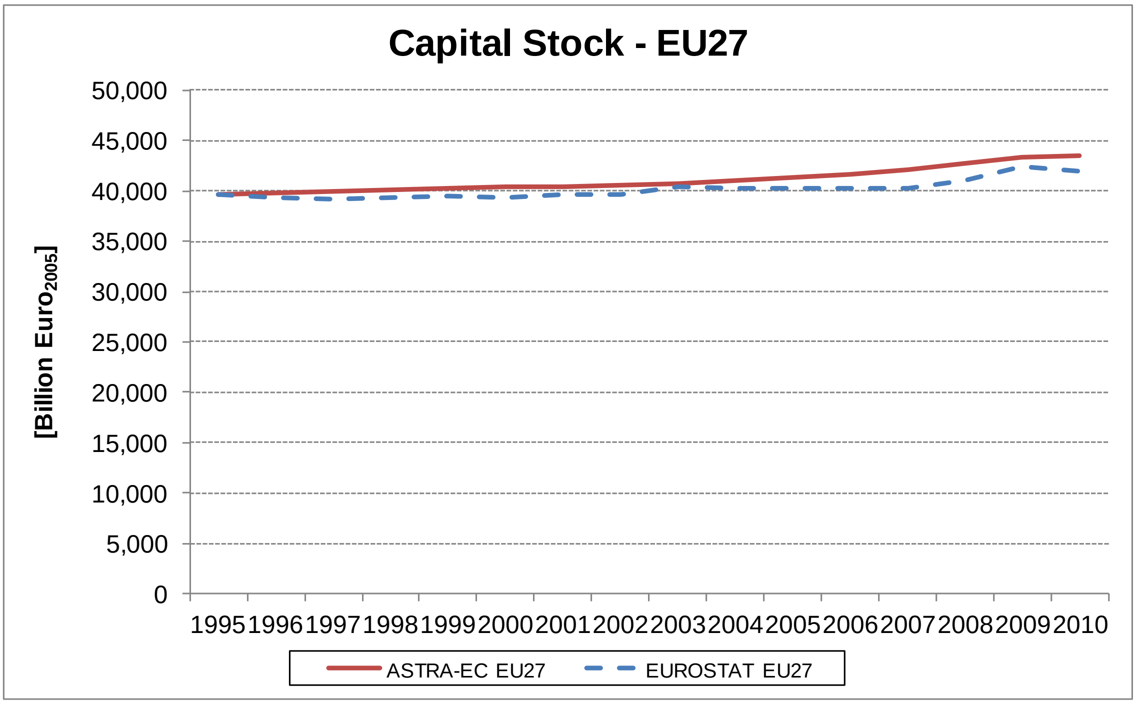
The baseline of a matching development of labour markets is gross-value added. As a result of the good calibration of gross value-added, employment could be optimised. The average deviation of total employment simulated with ASTRA-EC from statistical employment is for EU15 +1.8% and for EU12 -1% for the period between 1995 and 2010.



Source: Fraunhofer-ISI

Figure 2-21: Quality of employment calibration in EU27

Achieving a good quality of calibration for capital stock is comparably difficult. The reason is that the level of capital stock strongly depends on the annual level of depreciation which depends on the timing of the investments as well as on the type of investments from the years before 1995. Given these difficulties the calibration of capital stock is by an average deviation of +2.3% for EU27 in the period from 1995 to 2010 acceptable. Figure 2-22 provides a comparison between capital stock development from the EUROSTAT and the AMECO database and the endogenously calculated development.

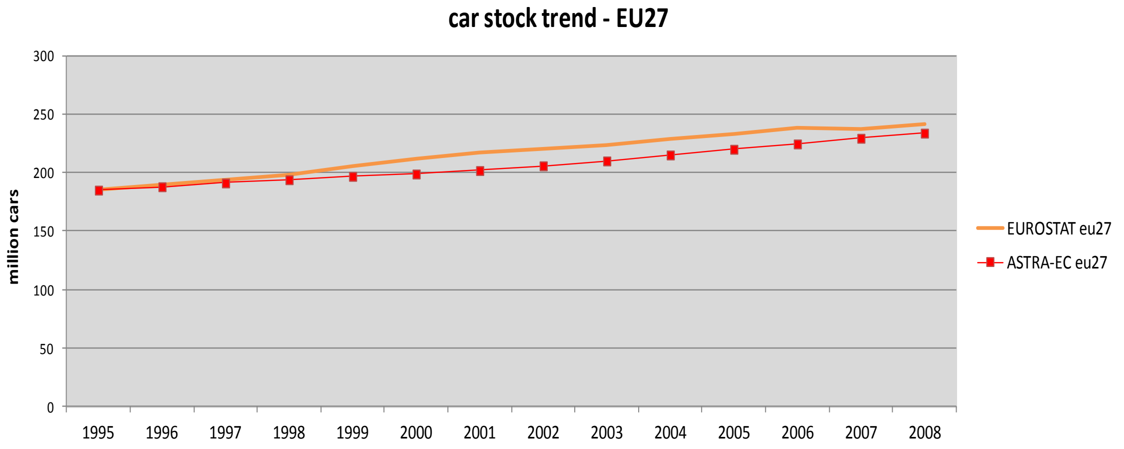


Source: Fraunhofer-ISI

Figure 2-22: Quality of capital stock calibration in EU27

2.3.3 Vehicle fleet indicators

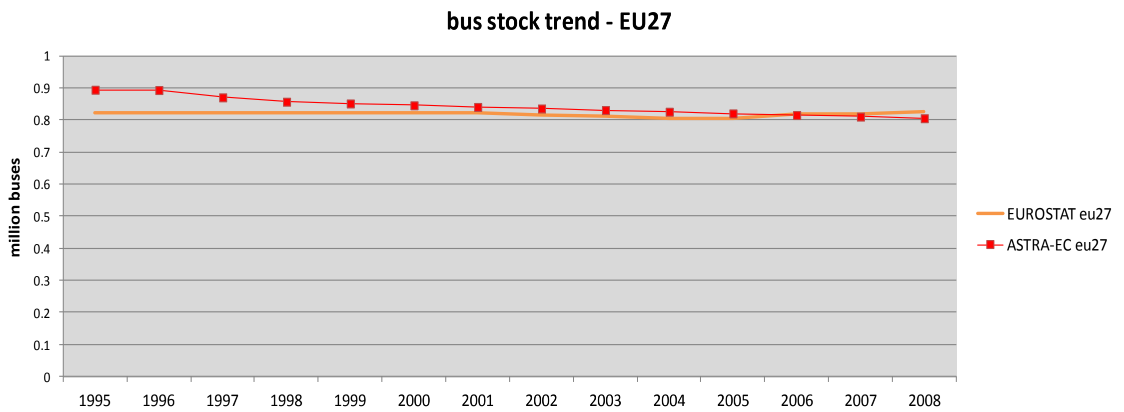
The following figures show the results of the calibration process. As already mentioned above, the process was limited to the time period of 1995 to 2008 due to the economic crises. Figure 2-23 illustrates the development of statistical and endogenously calculated car stock. For EU27, ASTRA-EC is slightly below the statistical values but still in an acceptable range of deviation.



Source: Fraunhofer-ISI

Figure 2-23: Quality of car fleet calibration in EU27

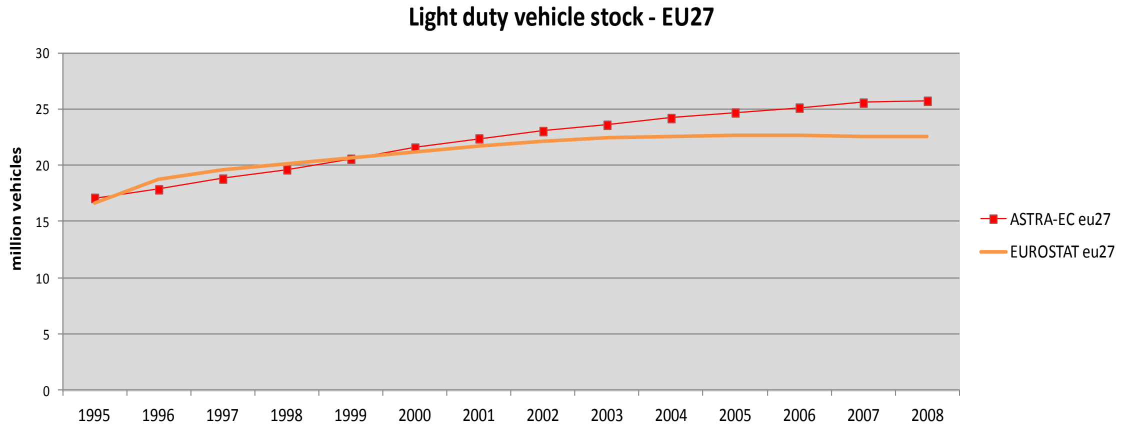
The bus fleet calibration shows a good match, taking into account that the historical database for the early years (1995 - 2000) is relatively poor and that there is a lack of data for some countries. Figure 2-24 publishes both, the historical development as well as the simulated data by ASTRA-EC.



Source: Fraunhofer-ISI

Figure 2-24: Quality of bus fleet calibration in EU27

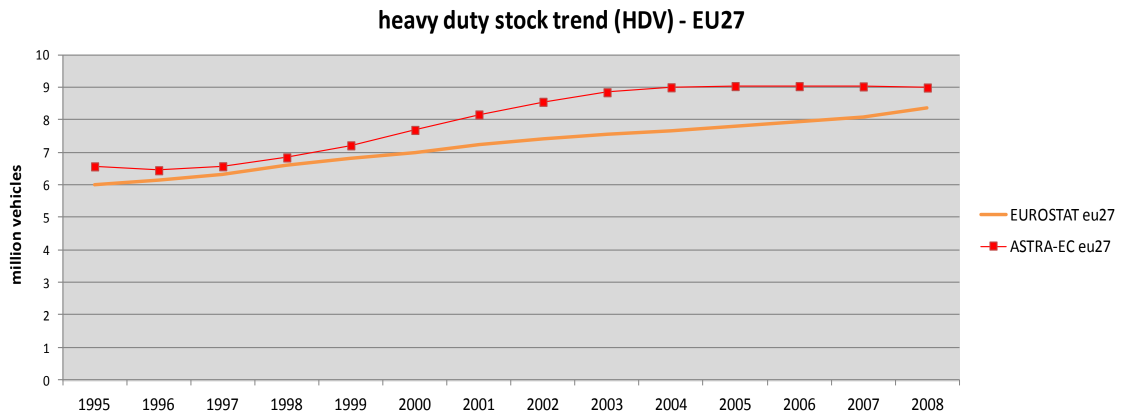
The light duty vehicle (LDV) fleet is the most dynamic one. Due to increasing number of e-commerce clients, especially parcel service providers were growing fast. The dynamic of the model leads to a deviation between data and model output which is a bit greater than the one of the car fleet (see Figure 2-25). Nevertheless the average deviation over the time period from 1995 to 2008 is less than 5%.



Source: Fraunhofer-ISI

Figure 2-25: Quality of light duty vehicle fleet calibration in EU27

The development heavy duty vehicle fleet with its two different weight classes is reflected by Figure 2-26. The development is driven by the transport demand. Especially at the beginning of the time period and after 2007 the simulated values fits good to the historical data. The average deviation lies around 5%, with higher values between 2003 and 2005.



Source: Fraunhofer-ISI

Figure 2-26: Quality of truck fleet calibration in EU27

3 The validation of the ASTRA-EC model

3.1 The validation approach

This chapter provides information on the comparison between reference and modelled data, to document the level of validation of the model in the period 2010 – 2050, with a time step of 5 years.

Although the aim has been to reproduce a good level of validation, it should be always considered that the ASTRA-EC model is a tool to provide endogenous forecasts sensitive to key determinants. Therefore the target of the model is to provide realistic long-term average growth rates rather than point estimations at a given year. Also, the model is not conceived to reproduce yearly differences in growth rates, unless they are due to significant changes in one of the key determinants considered. For instance, one should expect that the model is good to represent the average growth rate of indicators in the period 2010 – 2050. Instead, one should not expect that yearly growth rates (and therefore yearly values of indicators) are always well represented.

Furthermore the calibration of the model is constrained by its integrated structure (see Chapter 2.1). There is some flexibility but if e.g. population is stagnating or decreasing and energy cost is increasing, generating additional transport activity means forcing the model. In other words, unless all the reference trends are fully consistent to each other, it might be difficult to match all of them with the same degree of precision. In this case the reference trends are modelled ones. The tools used to estimate these trends adopt a different logic with respect to ASTRA-EC. Therefore it is possible that sometimes trends which are consistent within the PRIMES-TREMOVE structure (where e.g. the reference transport demand is exogenous) are only hardly reproduced in ASTRA-EC.

3.2 Validating the ASTRA-EC modules

3.2.1 Transport and environmental module

The future trends of transport and environmental variables provided by ASTRA-EC have been compared against the 2013 Reference scenario of the PRIMES-TREMOVE model, released in 2013. The comparison is based on the key elements reported in Table 3-1.

Table 3-1: List of data sources used for validating the transport and environmental modules

Module	Variable	Level	Unit	Reference data 2010 - 2050
Transport modules	Passenger transport activity	Country and mode	Mio Pkm/ year	PRIMES 2013 Reference scenario
	Freight transport activity	Country and mode	Mio Tkm/ year	PRIMES 2013 Reference scenario
	Passenger modal split (on pkm)	Country	%	PRIMES 2013 Reference scenario
	Freight modal split (on tkm)	Country	%	PRIMES 2013 Reference scenario
Environmental module	CO_2 transport emissions	Country and aggregated mode	Mio tons/ year	PRIMES 2013 Reference scenario
	Transport fuel consumption	Country and fuel type	Mio Toe/ year	PRIMES 2013 Reference scenario

Source: TRT

For the transport activity, the trends of passenger-km and tonnes-km by mode and country or EU regions between 2010 and 2050 are considered. For the environmental impacts, the trends of CO_2 emissions from transport and transport fuel consumption by fuel type are considered. The available reference scenario from PRIMES-TREMOVE does not provide forecasts for local pollution.

For passengers the ASTRA-EC results and the PRIMES-TREMOVE projections are directly comparable as the same transport modes are covered (car, bus, train and aviation). For freight, the trends for inland modes (HDV, LDV trucks and rail) are directly comparable between ASTRA-EC and PRIMES-TREMOVE. Instead inland waterways and national maritime are presented under the same mode “inland navigation" in PRIMES-TREMOVE whereas in the ASTRA-EC they are two separated modes. We used the PRIMES projection regarding "inland navigation" to estimate comparison data for the two modes. This means that the reference for validation is less robust for these two modes.

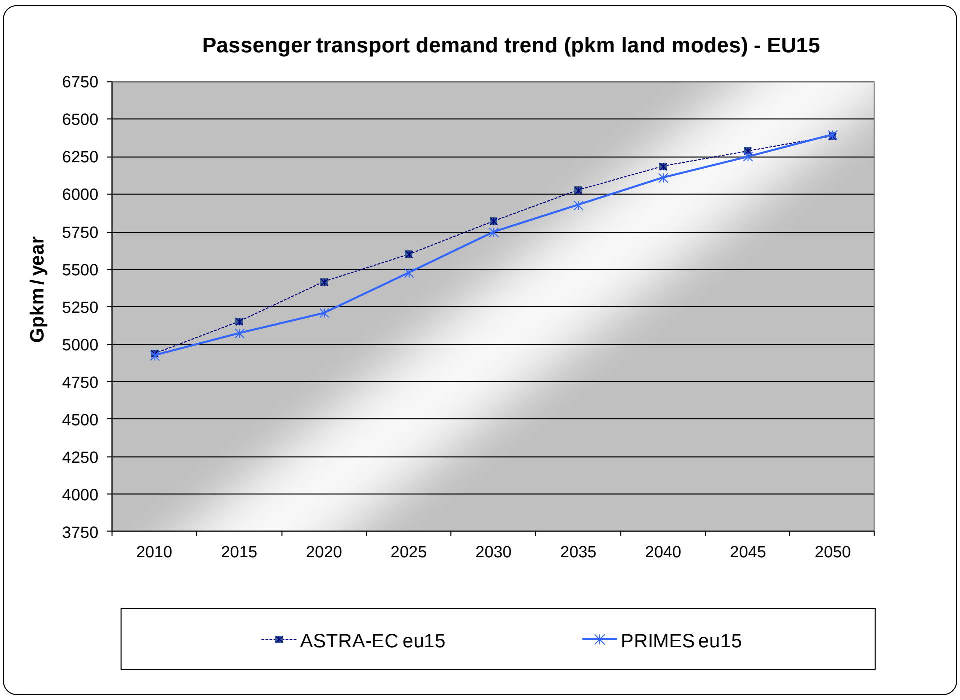
The following tables and figures provide the comparisons of the results of the transport and environmental modules of ASTRA-EC against the PRIMES 2013 Reference scenario. Additional data is provided in Annex 2.

As shown in Figure 3-1 and Figure 3-2, the trend of future total passenger activity (passenger-km) produced by ASTRA-EC is very close to the reference trend provided by PRIMES-TREMOVE, i.e. a regular growth over the forecasting period in EU15 countries and in EU12 countries (with a slightly declining growth rate in EU12 in the last years). The same good correspondence with the reference data emerges when looking at average yearly growth rates by mode (Table 3-2). When the whole forecasting period 2010-2050 is considered, the growth rates are very similar, with air demand growing slower according to ASTRA-EC and rail and bus also growing at a slower pace in EU12. When shorter intermediate periods are compared, the growth rates are sometimes more dissimilar, however in most of the cases the comparison is good.

Also the forecasted trend of total freight transport in both EU15 and EU12 is very similar in ASTRA-EC and PRIMES-TREMOVE (Figure 3-3 and Figure 3-4). This is confirmed by the comparison of the average yearly growth rates by mode in different periods as shown in Table 3-3. As for passengers, the best comparison is the one concerning the overall forecasting period where the main discrepancy is that rail growth is somewhat underestimated in ASTRA-EC, while some larger differences exist in intermediate years.

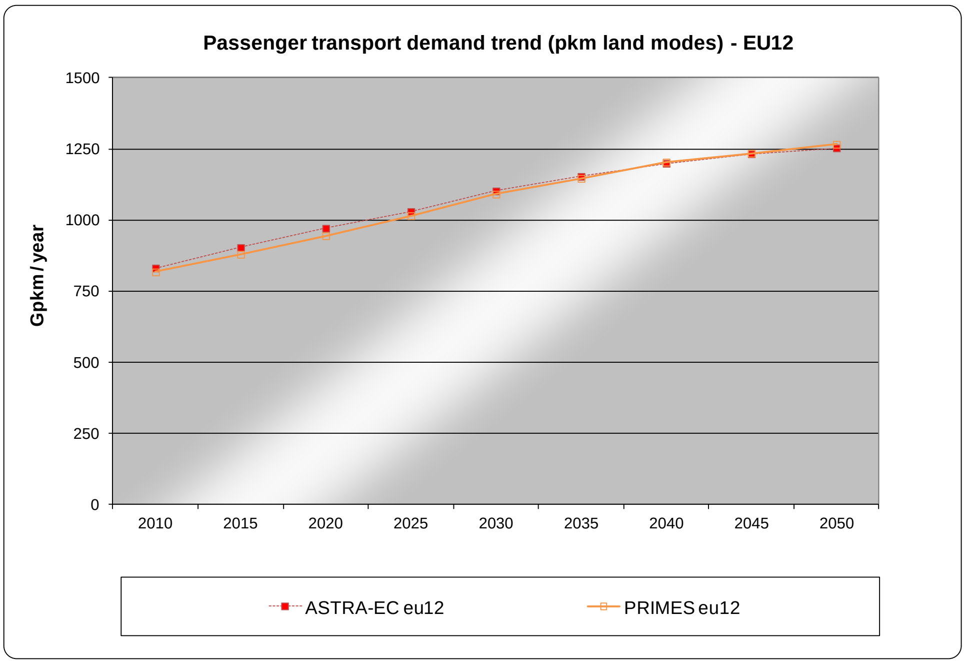
Also looking at the country level, the results of the ASTRA-EC model are well in line with the reference trends, both for passengers (Table 3-4) and for freight (Table 3-5), especially for bigger countries.

Above we have noted that sometimes ASTRA-EC provides different demand trends in comparison to PRIMES-TREMOVE, for some modes in some period. These differences are within reasonable limits and this is demonstrated by the evolution of mode shares over time shown in Table 3-6 and Table 3-7. The relevance of modes is correctly reproduced and also the major changes occurring in the reference scenario – i.e. the reduction of car share and the increase of air share – are visible in the ASTRA-EC modelled future trends.



Source: TRT

Figure 3-1: Forecasted total motorised land passenger demand (Gpkm) in EU15



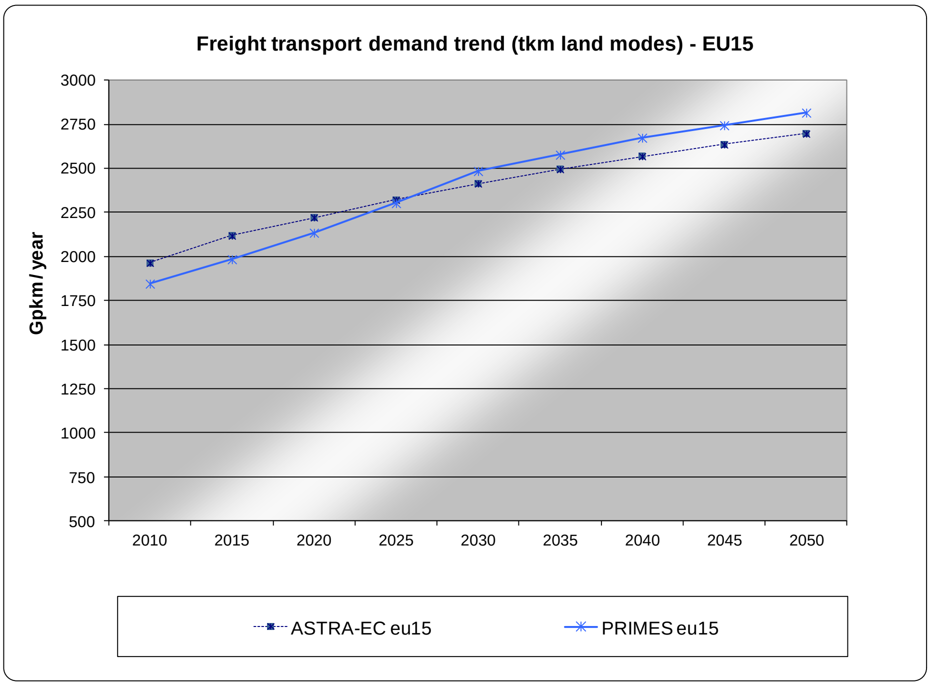
Source: TRT

Figure 3-2: Forecasted total motorised land passenger demand (Gpkm) in EU12

Table 3-2: Forecasted trend of passenger demand by mode in EU regions: average yearly growth rate

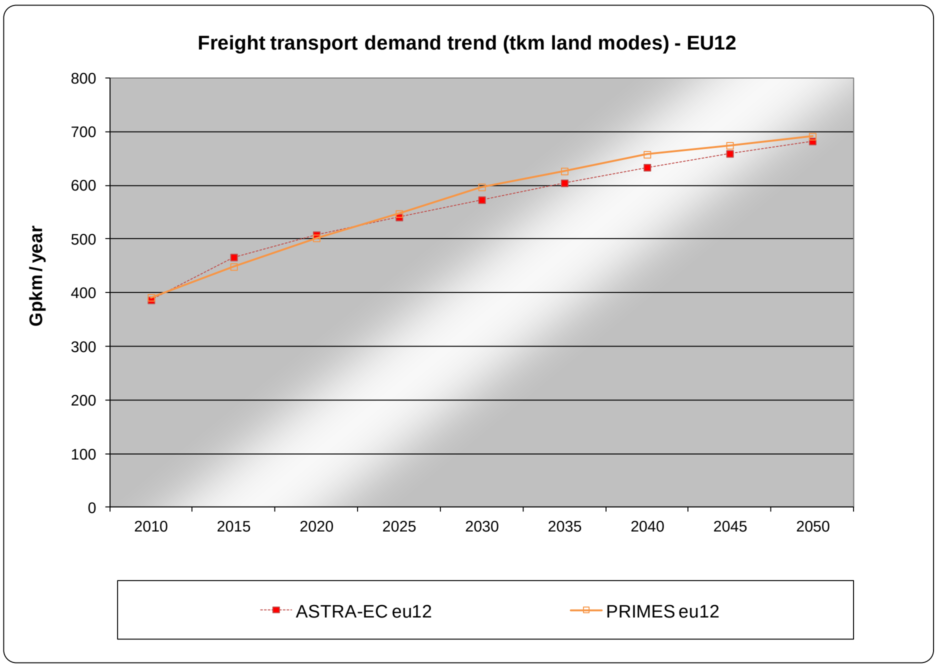
Mode	2010-2020		2020 - 2030		2030 - 2050		2010 - 2050	
	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC
EU15								
Car	0.5%	0.8%	0.9%	0.7%	0.5%	0.4%	0.6%	0.6%
Bus	0.7%	1.3%	0.9%	0.1%	0.6%	0.5%	0.7%	0.6%
Train	1.5%	2.1%	2.0%	1.1%	1.1%	1.2%	1.4%	1.4%
Air	2.4%	1.6%	2.6%	1.3%	1.5%	1.4%	2.0%	1.4%
EU12								
Car	1.4%	1.8%	1.4%	1.4%	0.7%	0.6%	1.1%	1.1%
Bus	0.9%	0.1%	1.0%	0.1%	0.6%	0.5%	0.8%	0.3%
Train	2.3%	1.3%	2.8%	1.1%	1.2%	1.4%	1.9%	1.3%
Air	4.1%	3.2%	3.8%	2.6%	2.2%	2.1%	3.1%	2.5%
EU27								
Car	0.6%	0.9%	1.0%	0.8%	0.5%	0.4%	0.6%	0.6%
Bus	0.7%	1.1%	0.9%	0.1%	0.6%	0.5%	0.7%	0.6%
Train	1.6%	2.0%	2.1%	1.1%	1.1%	1.2%	1.5%	1.4%
Air	2.6%	1.8%	2.8%	1.4%	1.6%	1.5%	2.1%	1.5%

Source: TRT



Source: TRT

Figure 3-3: Forecasted total motorised land freight demand (Gtkm) in EU15



Source: TRT

Figure 3-4: Forecasted total motorised land freight demand (Gtkm) in EU12

Table 3-3: Forecasted trend of total freight demand by mode in EU regions: average yearly growth rate

Mode	2010-2020		2020 - 2030		2030 - 2050		2010 - 2050	
	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC
EU15								
Truck	1.4%	1.2%	1.4%	0.7%	0.6%	0.5%	1.0%	0.7%
Train	2.1%	1.9%	2.1%	1.3%	0.7%	0.6%	1.4%	1.1%
IWW*	2.5%	1.9%	0.8%	1.0%	0.8%	0.7%	1.2%	1.1%
Maritime*	1.2%	0.5%	1.3%	1.2%	0.5%	0.8%	0.9%	0.9%
EU12								
Truck	2.6%	3.3%	1.5%	1.2%	0.7%	0.9%	1.4%	1.6%
Train	2.3%	1.3%	2.3%	1.1%	0.8%	0.9%	1.6%	1.1%
IWW*	3.3%	1.8%	0.4%	1.1%	0.3%	0.4%	1.0%	0.9%
Maritime*	2.4%	3.5%	1.8%	1.7%	0.8%	0.6%	1.4%	1.6%
EU27								
Truck	1.6%	1.5%	1.5%	0.8%	0.6%	0.6%	1.1%	0.9%
Train	2.2%	1.7%	2.2%	1.3%	0.8%	0.7%	1.5%	1.1%
IWW*	2.6%	1.9%	0.7%	1.0%	0.7%	0.6%	1.2%	1.0%
Maritime*	1.4%	0.9%	1.4%	1.3%	0.6%	0.8%	1.0%	1.0%

* IWW and maritime data is estimated on PRIMES “inland navigation”
Source: TRT

Table 3-4: Forecasted total motorised land pass. demand by country (Gpkm/year)

Country	2020		2030		2050	
	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC
Austria	117.2	119.1	129.2	131.5	148.3	141.4
Belgium	160.8	167.0	180.7	177.8	218.8	192.3
Bulgaria	70.8	65.9	76.9	70.9	86.3	78.1
Cyprus	18.7	21.6	24.4	24.5	30.0	25.7
Denmark	80.3	78.8	88.5	88.9	103.9	102.5
Estonia	15.2	13.2	17.5	16.3	20.8	20.4
Spain	579.9	595.1	752.2	705.1	924.6	866.1
Finland	93.2	94.5	100.2	99.1	111.8	111.1
France	1005.2	1032.4	1139.8	1105.8	1330.0	1324.4
United Kingdom	937.9	989.5	1053.8	1068.5	1213.9	1210.6
Greece	165.4	161.4	185.9	183.0	218.7	201.2
Hungary	90.7	107.4	109.4	115.4	131.5	132.3
Ireland	73.7	89.0	87.8	101.1	110.4	111.5
Italy	938.8	1013.0	1037.2	1075.1	1156.6	1126.2
Latvia	23.4	20.4	26.9	29.1	32.2	33.8
Lithuania	37.8	36.3	41.5	38.4	45.9	36.6
Luxembourg	9.8	9.4	11.0	10.6	13.0	11.9
Malta	5.9	5.3	7.1	5.6	8.8	5.7
Netherlands	200.1	214.9	218.8	226.9	245.3	238.0
Poland	420.6	442.1	489.6	506.6	571.1	583.5
Portugal	120.8	127.9	144.3	140.9	175.2	148.0
Czech Republic	125.3	125.3	146.4	146.0	181.4	174.0
Germany	1183.4	1164.1	1236.6	1216.0	1301.0	1310.3
Romania	127.3	130.8	157.1	158.1	205.6	210.8
Slovak Republic	45.1	42.7	57.6	50.9	68.9	62.5
Slovenia	34.9	33.7	39.6	36.2	43.5	36.5
Sweden	150.4	158.7	168.5	171.7	191.1	188.3

Source: TRT

Table 3-5: Forecasted total inland freight demand by country (Gtkm/year)

Country	2020		2030		2050	
	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC
Austria	81.2	70.5	90.2	81.5	102.4	94.7
Belgium	82.3	82.5	103.0	94.0	123.9	120.8
Bulgaria	24.1	23.7	28.2	27.7	33.7	33.8
Cyprus	1.2	1.3	1.3	1.4	1.5	1.4
Denmark	26.8	24.1	30.1	26.3	35.8	29.3
Estonia	6.8	7.8	8.2	8.9	10.3	10.1
Spain	225.9	263.3	278.0	304.2	324.6	359.1
Finland	40.7	51.4	45.8	55.2	54.1	56.7
France	382.0	382.0	476.3	422.3	543.6	477.3
United Kingdom	194.1	208.6	225.0	223.8	264.5	243.9
Greece	32.0	27.8	34.6	30.5	39.6	34.4
Hungary	34.7	35.5	40.4	40.7	46.4	50.5
Ireland	14.0	13.5	18.1	17.6	24.0	27.1
Italy	234.3	223.5	273.4	239.5	308.9	271.6
Latvia	7.0	7.0	8.6	8.1	10.2	10.2
Lithuania	12.6	12.6	14.9	14.8	18.5	17.4
Luxembourg	6.3	5.8	7.4	6.8	9.0	9.0
Malta	0.3	0.4	0.3	0.5	0.3	0.4
Netherlands	126.8	151.4	144.9	165.7	161.1	188.3
Poland	238.6	248.2	280.3	272.7	316.9	314.5
Portugal	29.3	35.2	33.6	37.9	38.9	42.8
Czech Republic	61.2	59.7	71.6	65.5	84.4	79.5
Germany	585.5	598.0	640.4	615.9	687.7	636.1
Romania	70.7	67.9	87.5	81.2	104.1	101.1
Slovak Republic	28.1	26.2	33.5	31.1	37.7	36.3
Slovenia	16.8	17.6	22.2	20.8	27.6	27.3
Sweden	73.3	83.7	83.4	92.5	97.6	105.3

Source: TRT

Table 3-6: Forecasted passenger demand mode split by EU zone (%)

	Mode	2020		2030	
		PRIMES	ASTRA-EC	PRIMES	ASTRA-EC
EU15	Car	73%	74%	71%	73%
	Bus	8%	8%	7%	7%
	Train	8%	9%	9%	9%
	Air	10%	10%	12%	10%
EU12	Car	74%	75%	72%	75%
	Bus	10%	10%	10%	9%
	Train	8%	8%	10%	8%
	Air	7%	7%	9%	8%
EU27	Car	74%	74%	72%	74%
	Bus	8%	8%	8%	7%
	Train	8%	9%	9%	9%
	Air	10%	10%	12%	10%
		2040		2050	
		PRIMES	ASTRA-EC	PRIMES	ASTRA-EC
EU15	Car	70%	72%	69%	70%
	Bus	7%	7%	7%	7%
	Train	10%	10%	10%	10%
	Air	13%	11%	14%	12%
EU12	Car	71%	74%	70%	72%
	Bus	9%	8%	9%	8%
	Train	10%	9%	10%	9%
	Air	10%	9%	11%	10%
EU27	Car	70%	72%	69%	71%
	Bus	8%	7%	8%	7%
	Train	10%	9%	10%	10%
	Air	13%	11%	14%	12%

Source: TRT

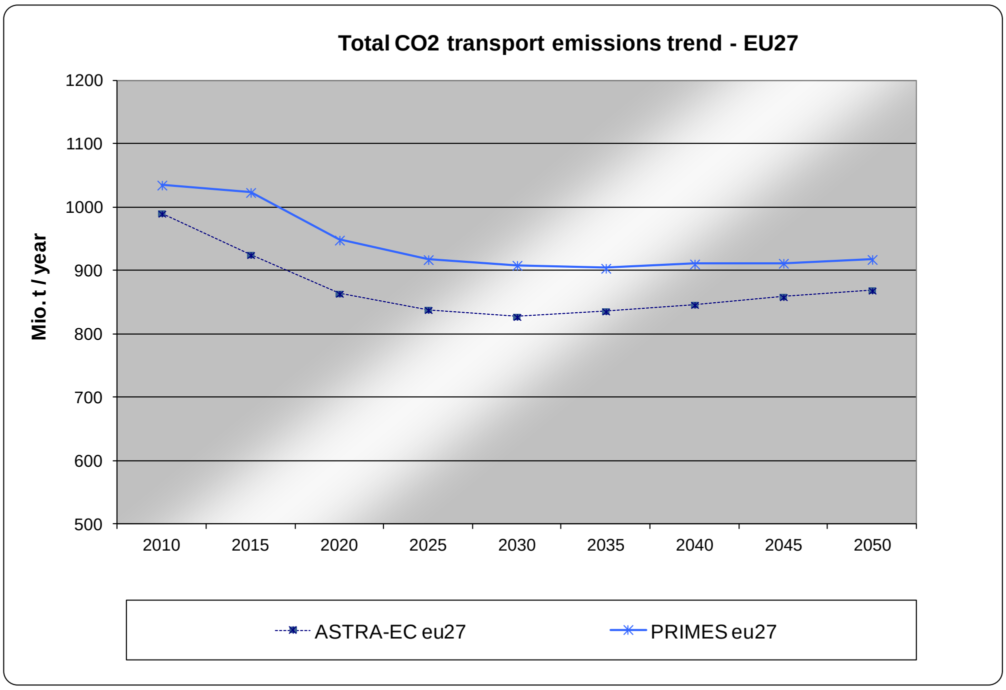
Table 3-7: Forecasted freight demand mode split by EU zone (%)

		2020		2030	
	Mode	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC
EU15	Truck	45%	48%	46%	47%
	Train	8%	9%	9%	9%
	IWW*	4%	4%	4%	4%
	Maritime*	43%	39%	41%	40%
EU12	Truck	46%	47%	47%	47%
	Train	17%	17%	19%	16%
	IWW*	4%	4%	4%	4%
	Maritime*	33%	32%	30%	32%
EU27	Truck	46%	48%	47%	47%
	Train	10%	10%	11%	10%
	IWW*	4%	4%	4%	4%
	Maritime*	41%	38%	39%	38%
		2040		2050	
		PRIMES	ASTRA-EC	PRIMES	ASTRA-EC
EU15	Truck	46%	47%	46%	46%
	Train	9%	9%	9%	9%
	IWW*	4%	4%	4%	4%
	Maritime*	41%	40%	41%	40%
EU12	Truck	48%	48%	48%	49%
	Train	19%	17%	19%	17%
	IWW*	4%	4%	4%	4%
	Maritime*	29%	31%	28%	30%
EU27	Truck	47%	47%	46%	47%
	Train	11%	10%	11%	10%
	IWW*	4%	4%	4%	4%
	Maritime*	39%	38%	39%	38%

* IWW and maritime data is estimated on PRIMES “inland navigation”
Source: TRT

On the environmental side, the comparisons with the reference PRIMES-TREMOVE projections concern CO_2 emissions from transport and consumption of transport fuels.

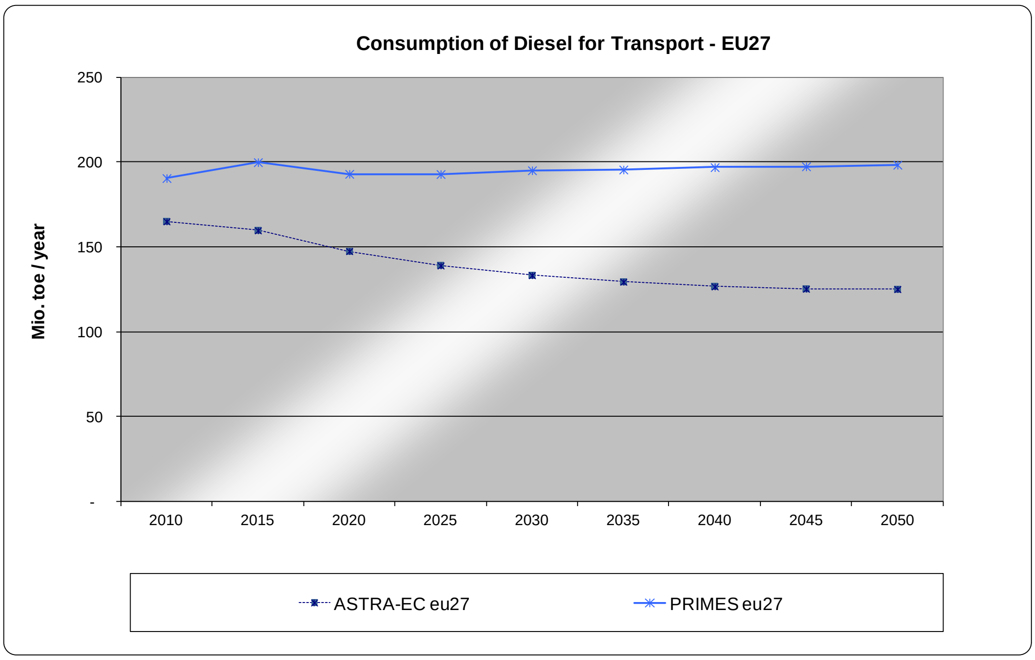
The future trend of CO_2 emissions according ASTRA-EC is basically the same as in the reference scenario (Figure 3-5). ASTRA-EC starts from a lower absolute value in the year 2010 (see section 2.3.1) and continue to estimate less CO_2 emissions from transport for the whole forecasting period. The difference increases in the first five forecasted years, then remains stable and finally decrease but in general is below 10%. The increased difference between 2010 and 2015 and then the progressive reduction seems to show that in ASTRA-EC efficiency improvements comes earlier than in PRIMES-TREMOVE while there is only a small progress in the final part of the simulation.



Source: TRT

Figure 3-5: Forecasted total CO_2 transport emissions (Mio tons/year) in EU27

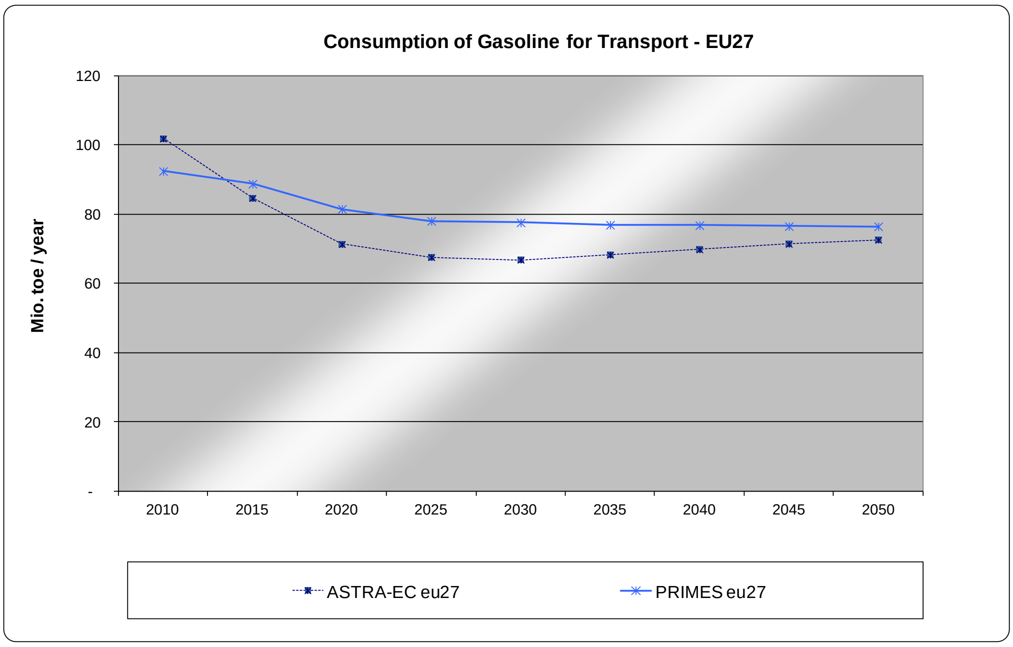
Consumption of diesel is somewhat less satisfying than other trends in comparison to the reference forecasts. While according to PRIMES-TREMOVE the consumption of diesel is basically stable, according to ASTRA-EC a reduction is expected (Figure 3-6), so the two trends are not the same. The reason for this discrepancy is a differing energy efficiency improvement of diesel vehicles (diesel cars, light duty vehicles, heavy duty vehicles, diesel trains) in ASTRA-EC and in PRIMES-TREMOVE. Another driver is a different trend of diesel cars in the car fleet. Studies like GHG-TransPoRD (Schade et al. 2011) proved that energy efficiency potentials are significantly larger for gasoline than for diesel cars. Also a different pace of electrification of railways plays a role but this is a minor impact.



Source: TRT

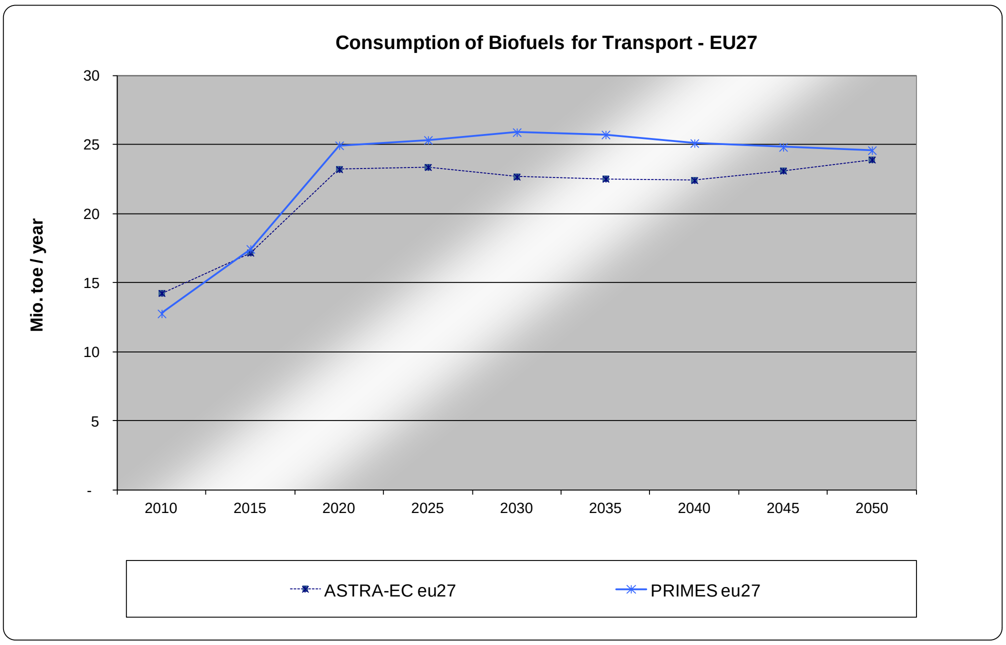
Figure 3-6: Forecasted diesel fuel consumption for transport (Mio Toe/year) in EU27

For other relevant fuel types like gasoline and biofuels the comparison with the reference scenario is more satisfying as shown in Figure 3-7 and Figure 3-8. As noticed already for CO_2 emissions, in ASTRA-EC there is a faster reduction in the initial part of the forecasting period compared to the reference scenario, whereas in the final part the two series tend to get closer. This observation would support the conclusion that in ASTRA-EC efficiency improvements are anticipated. For biofuels, the fast increase until 2020 and then the stabilisation is well reproduced by ASTRA-EC.



Source: TRT

Figure 3-7: Forecasted gasoline fuel consumption for transport (Mio Toe / year) in EU27



Source: TRT

Figure 3-8: Forecasted biofuels consumption for transport (Mio Toe/year) in EU27

3.2.2 Economic and population module

The validation of the Economic module in ASTRA-EC focuses on GDP growth rates. Table 3-8 provides an overview on the indicators that were adjusted towards a Reference scenario. The projections for GDP growth rates as well as for population per country are taken from the PRIMES 2013 Reference Scenario. The DG ECFIN Ageing Report (2012) is the main source of information for exogenous inputs like labour productivity per sector and country and birth rates per country.

Table 3-8: List of data sources used for validating the economic and population module

Module	Variable	Level	Unit	Reference data 2010 - 2050
Economic module	Gross domestic product growth	Country	%	PRIMES 2013 Reference scenario
	Labour productivity growth	Country	%	DG ECFIN – Ageing Report 2012
Population module	Population	Country	Persons	PRIMES 2013 Reference scenario
	Birth rates	Country	Persons	DG ECFIN – Ageing Report 2012

Source: Fraunhofer-ISI

As opposed to statical transport models ASTRA-EC does not simply take an exogenous growth rate for GDP per country until 2050. GDP needs to remain an endogenous indicator driven by changes in the demand and supply side of the economy. Otherwise economic impacts from TPMs can hardly be assessed. Therefore, the validation of GDP needs to be done by adapting the endogenous development of this indicator. This can be done in different ways. The simplest way would be to add a factor that adapts GDP over time. As an alternative to this approach ASTRA-EC offers further ways to adapt the endogenous GDP growth pathway towards a desired GDP projection. Adapting the single components of GDP is the preferable solution. For this purpose, a number of leverages have been implemented in ASTRA-EC. These leverages mainly represent drivers that cannot be modelled. As an example the development of future saving ratios is used as leverage and an exogenous input. According to the model structure, an increase of savings directly leads to a reduced growth of consumption of private households. This results in reduced investment growth and finally dampens the growth of final demand and GDP.

Other leverages in the economic and trade module of ASTRA-EC are as follows:

- The development of average hours worked of a full-time-equivalent employed person. This leverage influences the labour input in the Cobb-Douglas production function and in the following GDP.
- Labour productivity trend per sector are originally derived from the DG ECFIN Ageing Report (2012). In ASTRA-EC the trends have been adapted slightly in order to validate the development of employment per sector which effects potential output.
- Total factor productivity (TFP) is supposed to be influenced by investments, labour productivity and the technical progress represented by improvements of average freight time. As TFP is one of the drivers of potential output, a trend factor representing a decrease of the impact of future investments is considered.
- Another leverage influencing the supply side of the economy is given by the trend of the share of foreign direct investments accounting to capital stock.
- Besides the powerful leverage of saving ratios, a trend factor that limits the impact of consumption and export growth on the growth of investments is implemented in ASTRA-EC.
- Historically, exports grew much stronger in the EU27 compared to other demand side indicators like consumption of private households, government consumption or investments. Hence, a trend factor considering a stronger decoupling of the growth of GDP in regions outside the EU27 has been considered for the validation.
- Finally, an important exogenous input is the share of imported goods and services used for intermediate products.

Not all leverages listed above are adapted during the validation for each EU27+2 country. The decision to change a certain leverage or trend for validating ASTRA-EC between 2010 and 2050 was based on the analysis of the growth of all supply and demand side indicators. For some countries, investment was the major driver of a too strong growth such that limiting the impact of consumption and export growth on investments was the preferred leverage to change. The optimisation of the respective leverages can only be done by a trial and error process. For some countries a whole set of leverages was changed in order to approximate the PRIMES 2013 GDP growth projections.

Table 3-9: Comparison of annual GDP growth from 2010 to 2050 by country

Country	Annual growth 2010-2050		GDP 2050 [bn $€_{2005}$]	
	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC
Austria	1.4%	1.5%	466	468
Belgium	1.6%	1.8%	606	628
Denmark	1.5%	1.6%	377	384
Spain	1.7%	1.8%	1,849	1,959
Finland	1.5%	1.8%	305	336
France	1.6%	1.7%	3,403	3,371
United Kingdom	1.9%	2.0%	3,947	3,974
Germany	0.8%	0.9%	3,315	3,265
Greece	0.9%	1.2%	277	301
Ireland	2.3%	2.6%	403	438
Italy	1.2%	1.3%	2,332	2,417
Netherlands	1.3%	1.5%	931	926
Portugal	1.3%	1.5%	263	288
Sweden	1.8%	2.0%	657	686
Bulgaria	1.5%	1.6%	48	47
Cyprus	1.9%	1.8%	32	32
Czech Republic	1.7%	1.9%	232	258
Estonia	2.1%	2.4%	25	30
Hungary	1.3%	1.6%	147	157
Latvia	1.8%	2.2%	26	28
Lithuania	1.8%	2.2%	45	57
Malta	1.5%	1.5%	10	10
Poland	1.7%	2.0%	605	632
Romania	1.4%	1.6%	157	168
Slovenia	1.4%	1.5%	54	57
Slovak Republic	1.7%	1.8%	94	94
Luxembourg	1.8%	1.8%	68	68

Source: Fraunhofer-ISI

Table 3-9 provides a comparison between average annual GDP growth rates as well as the targeted GDP in real terms in 2050 from PRIMES 2013 and ASTRA-EC. The ASTRA-EC model projections deviate for some countries from the PRIMES projections. These deviations are caused by the different model structures of the PRIMES and the ASTRA-EC model. Even if ASTRA-EC could in principle be made completely in line with the required GDP growth projections, it is not recommendable to do this by 100%. The quality of the ASTRA-EC impact assessment results for transport policy measures would suffer from such a strict adaption of GDP growth rates. According to the basic modelling principles for ASTRA-EC, the development of economic indicators should mainly be determined by the dynamics between the different economic and transport indicators in terms of feedback loops. Setting the leverages in a too strict way would prevent the ASTRA-EC model from allowing a reliable assessment of TPM impacts. Therefore, at least for some EU27 countries (Finland, Ireland and the Baltic States), a stronger deviation from the PRIMES 2013 Reference Scenario needed to be accepted.

Table 3-10: Comparison of annual population growth from 2010 and 2050 by country

Country (EU15)	PRIMES	ASTRA-EC	Country (EU12)	PRIMES	ASTRA-EC
Austria	0.2%	0.2%	Bulgaria	-0.7%	-0.8%
Belgium	0.2%	0.4%	Cyprus	0.7%	1.1%
Denmark	0.1%	0.2%	Czech Republic	0.0%	-0.2%
Spain	0.2%	0.3%	Estonia	-0.3%	-0.6%
Finland	0.0%	0.2%	Hungary	-0.3%	-0.3%
France	0.3%	0.3%	Latvia	-0.7%	-0.8%
United Kingdom	0.5%	0.5%	Lithuania	-0.5%	-0.8%
Germany	-0.4%	-0.4%	Malta	0.0%	-0.2%
Greece	0.0%	0.1%	Poland	-0.3%	-0.3%
Ireland	0.7%	0.7%	Romania	-0.5%	-0.4%
Italy	0.2%	0.2%	Slovenia	0.0%	-0.3%
Netherlands	0.0%	0.1%	Slovak Republic	-0.1%	-0.3%
Portugal	0.2%	0.0%			
Sweden	0.3%	0.5%			
Luxemburg	0.7%	0.9%			

Source: Fraunhofer-ISI

Fitting the ASTRA-EC population projections towards the Reference Scenario is based on changes of total net migration trends and of birth rates and infant mortalities. Table 3-10 shows a comparison between the average annual growth of GDP in the PRIMES Reference Scenario and in ASTRA-EC. The estimated development of migration balances per country is important for the projected final population in 2050. Furthermore, the age structure of the net migration plays a significant role. In ASTRA-EC this age structure is determined by the calibration for the period from 1995 to 2010. Therefore, differences in some countries might occur but are still in an acceptable range of deviation.

3.2.3 Vehicle fleet module

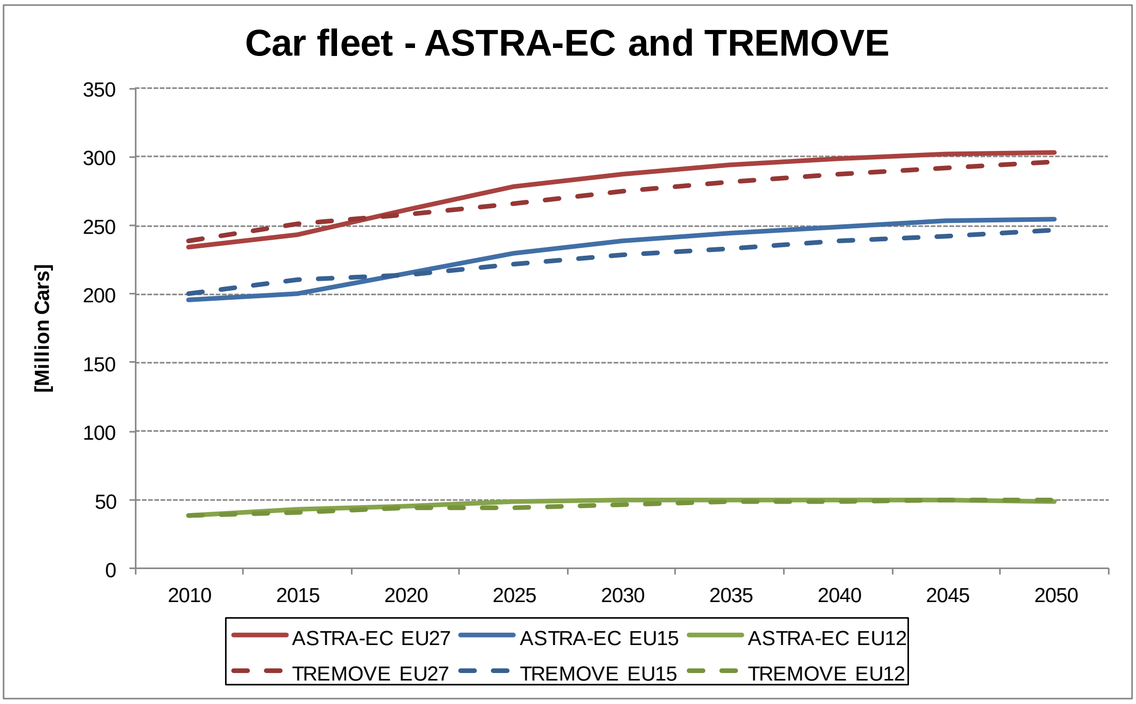
The main source of information for validating vehicle fleet modules has been the 2013 Reference scenario of the PRIMES-TREMOVE model, released in 2013 in terms of trends of vehicle fleet size and motorisation rate from the year 2010 to 2050. The following Table 3-9 summarises the list of variables for the validation of the vehicle fleet modules from the year 2010 to 2050.

Table 3-11: List of data sources used for validating the vehicle fleet module

Module	Variable	Level	Unit	Reference data 2010 - 2050
Vehicle fleet module	Car stock	Country	Cars	PRIMES 2013 Reference scenario
	Truck stock	Country	Trucks	PRIMES 2013 Reference scenario

Source: Fraunhofer-ISI

The validation of the car as well as of the truck fleets strongly depends on the validation of the drivers of the respective fleets. According to the ASTRA-EC model structure, new car registrations depend on the development of income, the population structure, the average car prices, the average fuel prices and the income distribution. Therefore, differences between PRIMES-TREMOVE and ASTRA-EC can occur. Figure 3-9 demonstrates that there are marginal deviations from the ASTRA-EC to the PRIMES-TREMOVE car fleet trend for 2010 to 2050. Despite to the differences in the structure of both models the deviations remain in a reasonable range. The EU27 car fleet estimated by ASTRA-EC is by +2.4% only marginally higher than the PRIMES-TREMOVE fleet. For EU12 the projections are even more in line.



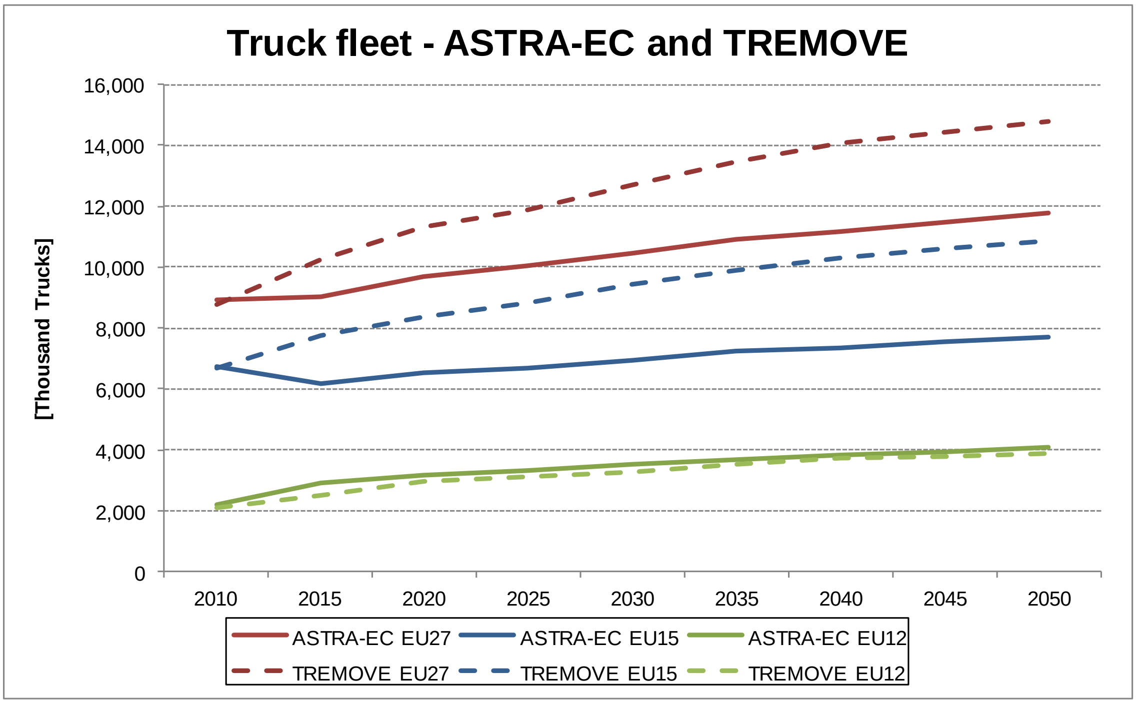
Source: Fraunhofer-ISI

Figure 3-9: Comparison of car fleet trend in TREMOVE and ASTRA-EC

As opposed to the ASTRA-EC car fleet model the development of the truck fleet is mainly driven by the freight transport performance for medium to long distances in terms of vehicle-km. Figure 3-10 compares the development of truck fleets in EU27, EU15 and EU12 calculated by ASTRA-EC and PRIMES-TREMOVE. Especially for EU15 the trends differ significantly. While PRIMES-TREMOVE estimates a growth of EU27 truck fleets by 69% until 2050 (compared with 2010), ASTRA-EC assesses an increase of only 32%.

In order to understand the origin of these differences, a closer look on the evolution of freight transport is necessary. PRIMES-TREMOVE projects a growth of EU27 ton-km on roads of about 55% in this period. The resulting growth of vehicle-km depends on the development of load factors. ASTRA-EC includes a trend which reflects an improvement of average load factors for trucks above 3.5 tons until 2050. This trend is derived from observations from the calibration period but also from continuous improvements of logistics towards better load factors. Therefore, the growth of road freight vehicle-km is in ASTRA-EC by intention lower than the growth of ton-km in the Reference Scenario as opposed to PRIMES-TREMOVE.

ASTRA-EC estimates the freight demand for different distance bands. Due to stronger increase of freight on longer distances, heavy duty vehicle fleets grow stronger than light duty vehicle fleets which differs from PRIMES-TREMOVE.



Source: Fraunhofer-ISI

Figure 3-10: Comparison of truck fleet trend in TREMOVE and ASTRA-EC

4 Reference Scenario

The understanding of the underlying assumptions is crucial for evaluating a model-based scenario evaluation. The main purpose of this section is to frame the policies considered and not considered in the ASSIST Reference Scenario. Therefore, this section begins with a description of the EU policy framework considered in the Reference Scenario. Then, the second subsection analysis the results of the Reference Scenario simulated with ASTRA-EC. Major trends for social, economic, transport and environmental indicators in the Reference Scenario from the year 2010 to the year 2050 are presented. Forecasts for key variables are segmented according to the modular structure in ASTRA-EC as follows:

- Demography,
- Economy,
- Transport,
- Road vehicle fleet and
- Environment.

4.1 Policy framework in the Reference Scenario

The following Table 4-1 lists the European policies implemented in the Reference Scenario. A general rule for the selection of the set of policies for the Reference Scenario was the legislative status and the quantitative approval of the policy. E.g. the revision of the Energy Taxation Directive has not been considered as part of the Reference Scenario because the majority of the MEPs in the European Parliament voted in April 2013 against the proposed ETD from April 2011. Finally approved policies like the regulation on emission standards Euro 5 and Euro 6 are taken into account.

The list below highlights as well those directives or regulations that are not yet implemented in the ASTRA-EC Reference Scenario due to their legislative status.

Table 4-1: Policy content of the Reference scenario

N°	Measures	Legislative reference	ASTRA-EC implementation
General regulatory measures			
1	RES directive	Directive 2009/28/EC	Increase of share of biofuels for all modes, increase of share of BIO car in the fleet
2	GHG Effort Sharing Decision	Decision 406/2009/EC	-
3	EU ETS directive	Directive 2003/87/EC as amended by Directive 2004/101/EC, Directive 2008/101/EC and Directive 2009/29/EC	Increase of air cost
4	Energy Taxation Directive	Directive 2003/96/EC	
5	Biofuels directive	Directive 2003/30/EC	Reduced biofuels taxation
6	Fuel Quality Directive	Directive 2009/30/EC	CO2 emission factor for fuel production
Road transport			
7	Regulation on CO_2 from cars	Regulation No 443/2009	
8a	Labelling regulation for tyres	Regulation No 1222/2009	-
8b	Tyre labelling implementation regulations	Regulations 228/2011 and 1235/2011	-
9	Regulation EURO 5 and 6	Regulation No 715/2007	LDV fleet development
10	Directive on the Promotion of Clean and Energy Efficient Road Transport Vehicles	Directive 2009/33/EC	Policy: not implemented in the Reference scenario
11	Regulation on CO_2 from vans	Regulation (EU) No 510/2011	

12	Regulation Euro VI for heavy duty vehicles	Regulation No 595/2009	HDV fleet development
13	Eurovignette Directive on road infrastructure charging	Directive 2011/76/EU	Eurovignette and motorway tolls as of 2012
14	Regulation on common rules for access to the international road haulage market	Regulation No 1072/2009	Reduction of empty returns for HDV >12t (increased load factor for trucks)
15	Directive concerning social legislation relating to road transport activities	Directive 2009/5/EC	Policy: not implemented in the Reference scenario
Rail transport			
16	Third railway package	Directive 2007/58/EC	Reduction of train passenger cost
17	Directive of the European Parliament and of the Council establishing a single European railway area (Recast)	Directive 2012/34/EU	Policy: not implemented in the Reference scenario
18	Emission standards for diesel trains (UIC Stage IIIA)		Reduced emission factors for diesel train
19	Directive on inland transport of dangerous goods	Directive 2008/68/EC	-
Aviation			
20	ICAO Chapters 3 (emissions)		Air emission factors
21	Single European Sky II	COM(2008) 389 final	Policy: not implemented in the Reference scenario
22	Regulation on ground handling services at Union airports	Council agreement on general approach[1], EP vote on 16 April 2013[2](part of "Better airports package")	-
23	Regulation on noise-related operating restrictions at Union airports	Council agreement on general approach[3], EP vote on 11 December 2012[4] (part of "Better airports package")	-

Maritime			
24	IMO Energy Efficiency Design Index (EEDI)	IMO Resolution MEPC.203(62)	Reduced ship fuel consumption factor
25	Port state control Directive	Directive 2009/16/EC	Decrease of 'other cost' for ship mode
26	Directive amending directive 1999/32/EC as regards the sulphur content of marine fuels	Directive 2012/33/EU	Reduced SO2 ship emission factor
27	Implementation of MARPOL Convention ANNEX VI	2008 amendments - revised Annex VI	Included in SO2 ship emission factors reduction for measure 26.
Financial support			
28	TEN-T guidelines	Decision 884/2004/EC and expected continuation – 2012 Council agreement on revised TEN-T guidelines[5]	Core network completed by 2030 and comprehensive completed by 2050

Source: Elaboration on various sources

4.2 Major trends in the Reference Scenario

4.2.1 Demographic trends

According to the request in ASSIST to follow the demographic development set by the 2013 PRIMES Reference Scenario, the projections by ASTRA-EC do only differ marginally from the PRIMES forecasts. Table 4-2 presents the development of population by country until 2050. Common for all EU27 member states is the fact that birth rates remain according to the 2012 Ageing Report below 2. Hence, a growth of population can only occur under the assumption of a positive migration balance. This assumption is valid for almost all EU27 member states besides Bulgaria and Estonia.

ASTRA-EC assesses an increase of total population in EU27 of 2% or 514 million people until 2050. The climax will be reached until 2030 with about 525 million people. While population in EU25 is expected to increase by about 6% due to optimistic migration trends, EU12 decrease by about 13% until 2050. The strongest increase of population is projected for United Kingdom which will grow up to 76 million people in 2050.

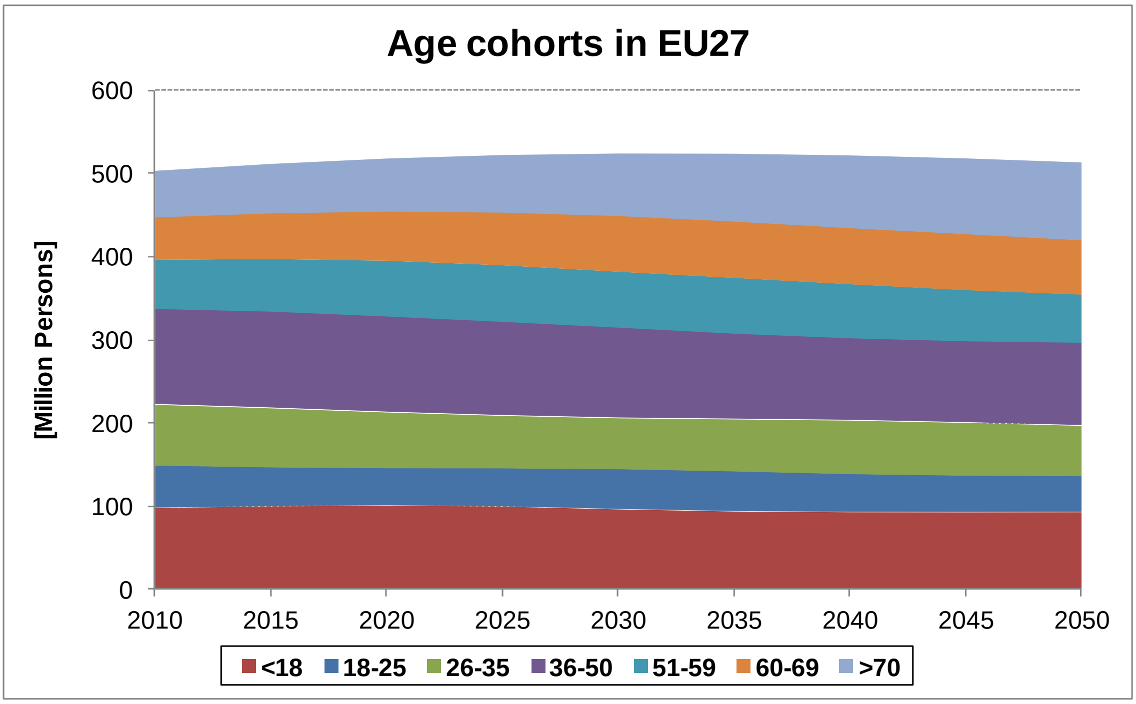
Table 4-2: Population in thousand persons by country

Country	2010	2020	2030	2040	2050
Austria	8,397	8,670	8,901	9,005	8,937
Belgium	10,806	11,454	11,757	11,881	11,872
Denmark	5,553	5,726	5,789	5,810	5,779
Spain	47,265	49,873	51,947	52,201	51,510
Finland	5,355	5,512	5,536	5,443	5,325
France	63,129	66,280	68,261	69,364	70,081
United Kingdom	62,128	66,829	70,661	73,953	76,634
Germany	82,048	81,262	79,073	75,790	71,003
Greece	11,218	11,441	11,475	11,351	11,081
Ireland	4,704	5,393	5,825	6,053	6,213
Italy	60,019	62,512	63,879	64,800	64,680
Netherlands	16,857	17,466	17,446	17,110	16,556
Portugal	10,783	10,952	11,271	11,493	11,521
Sweden	9,330	9,943	10,242	10,416	10,494
Bulgaria	7,833	7,412	6,875	6,274	5,688
Cyprus	811	1,004	1,129	1,220	1,275
Czech Republic	10,580	10,516	10,416	10,170	9,890
Estonia	1,385	1,343	1,280	1,194	1,106
Hungary	10,153	10,095	9,943	9,561	9,086
Latvia	2,379	2,254	2,123	1,952	1,760
Lithuania	3,453	3,273	3,050	2,792	2,521
Malta	401	413	410	395	375
Poland	39,294	39,339	38,573	36,729	34,642
Romania	22,194	21,828	21,109	20,006	18,828
Slovenia	2,106	2,112	2,082	2,004	1,902
Slovak Republic	5,510	5,613	5,517	5,258	4,929
Luxembourg	493	566	616	649	665

Source: Fraunhofer-ISI

Average mobility patterns strongly differ between the age cohorts in the population. Therefore, a closer look towards the expected development of different age cohorts in EU27 is crucial to understand the impacts mainly on passenger transport. Figure 4-1 provides an overview on the estimated ageing trend in the ASSIST Reference Scenario. Today, every 5th person in EU27 is above 60 years old. Even under the optimistic assumption that people migrating towards EU27 are mainly between 15 and 44 years old, the problem of ageing societies becomes clear. In 2050 on average every third inhabitant of EU27 will be above 60 years old. Potential labour force will decrease from 60% to 50% until 2050.

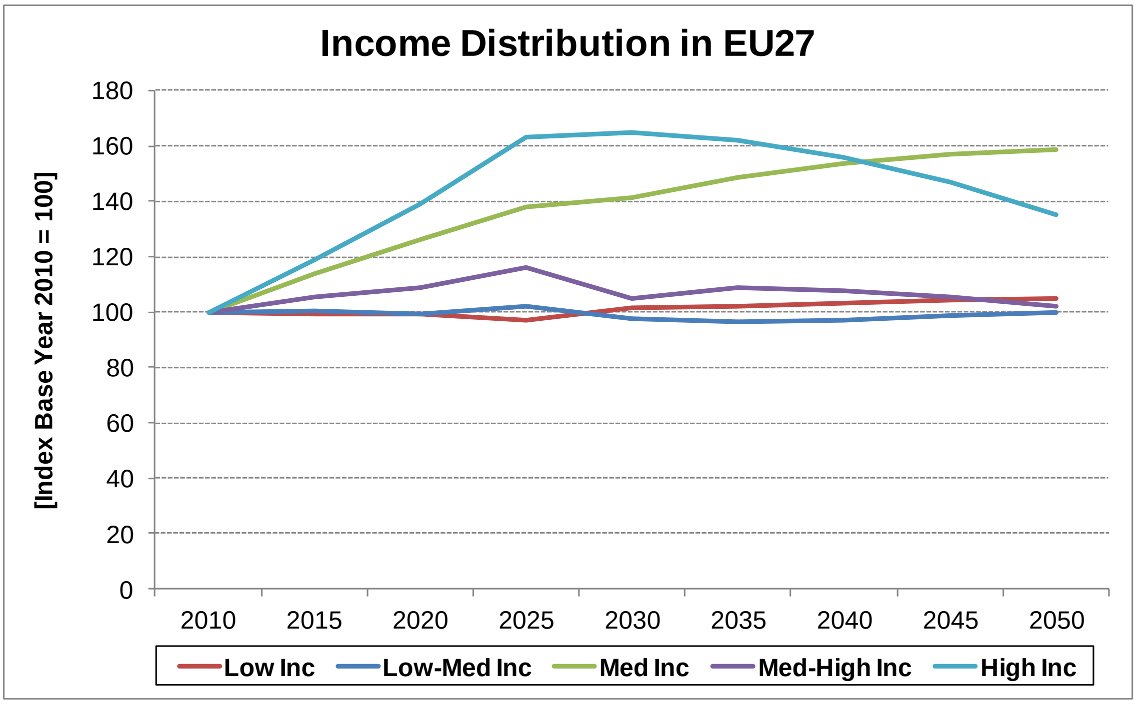
Even if the trend towards higher shares of the group of elderly people on total population is valid for all member states, there are significant differences in EU27. While the share of people above 60 years increases until 2050 up to 41% in Poland, France is assumed to grow only up to 26%.



Source: Fraunhofer-ISI

Figure 4-1: Development of age cohorts in EU27

Another important indicator in terms of mobility patterns is income and its distribution among the population. ASTRA-EC estimates the development of income distribution for all types of income besides capital income. Nevertheless, capital income contributes to total income of households by up to 50% according to Eurostat data. But it is even more unequally distributed such that the influence on mobility patterns of capital income can be considered as marginal. Figure 4-2 illustrates the projected trends for income distribution. ASTRA-EC assesses an increase of the number of persons in high and medium income classes. There are two main drivers of this trend until 2050. The first is coming from a catch-up process in EU12 countries. The second is based on the changing age structure. Based on the outcome of a regression analysis of Eurostat income data, ASTRA-EC assumes a growth of income with growing age of employed persons. The overall ageing process of the European society induces a move towards medium and high income classes. ASTRA-EC considers steady upper income in real terms for all income groups until 2050. This assumption must be taken into account when analysing the ASTRA-EC projections.



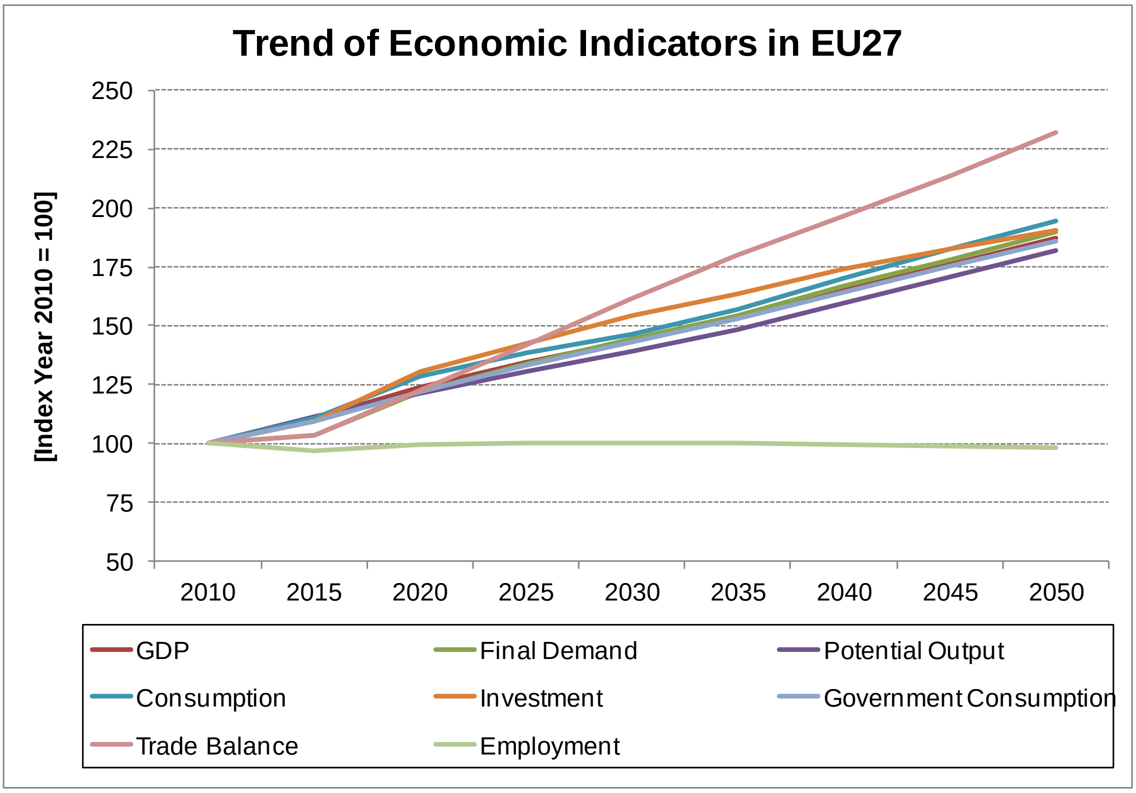
Source: Fraunhofer-ISI

Figure 4-2: Income distribution trend in EU27

4.2.2 Socio-economic trends

The economic development until 2050 simulated with ASTRA-EC is based on the 2012 PRIMES Reference Scenario. During the validation of ASTRA-EC, the average annual growth of GDP has been adapted to the growth of the PRIMES Reference Scenario with some country-specific minor differences. Demand side as well as supply side indicators are linked with the development of GDP. Figure 4-3 presents the estimated development of major socio-economic indicators in EU27 between 2010 and 2050. ASTRA-EC assesses an average growth of GDP in these decades of +1.6% for EU27,

+1.56% for EU15 and +1.85% for EU12. Consumption of private households is expected to increase annually by +1.7%, investments by +1.6% and trade balance by +2.1% in EU27. Despite the economic growth, employment stagnates or even slightly decreases by -2% for the whole period from 2010 to 2050.



Source: Fraunhofer-ISI

Figure 4-3: Trend for major economic indicators in EU27

Table 4-3 provides an overview on the GDP trends in absolute and relative terms per member state until 2050. United Kingdom, Ireland and Sweden are expected to grow strongest in EU15 while ASTRA-EC estimates the highest average growth of GDP for Poland and the Baltic countries.

Table 4-3: GDP in billion $€_{2005}$ and average annual GDP growth in %

Country	GDP in bn $€_{2005}$			Annual Growth in %
	2010	2030	2050	2010-2050
Austria	256.3	363.6	468.3	1.5%
Belgium	311.9	415.4	628.1	1.8%
Denmark	202.1	305.3	383.8	1.6%
Spain	944.5	1,500.4	1,959.0	1.8%
Finland	164.2	250.4	336.2	1.8%
France	1,735.4	2,403.1	3,371.3	1.7%
United Kingdom	1,819.3	2,932.7	3,974.4	2.0%
Germany	2,273.7	2,857.1	3,265.0	0.9%
Greece	189.5	265.9	300.7	1.2%
Ireland	159.9	305.1	438.1	2.6%
Italy	1,419.9	1,957.7	2,417.1	1.3%
Netherlands	517.8	682.3	925.6	1.5%
Portugal	156.3	217.7	287.7	1.5%
Sweden	307.5	458.7	686.5	2.0%
Bulgaria	24.9	36.8	47.4	1.6%
Cyprus	16.0	28.9	32.1	1.8%
Czech Republic	121.2	186.0	257.7	1.9%
Estonia	11.5	22.0	29.7	2.4%
Hungary	82.3	133.9	156.5	1.6%
Latvia	11.7	22.9	28.4	2.2%
Lithuania	23.8	45.5	57.3	2.2%
Malta	5.5	6.6	10.0	1.5%
Poland	290.6	469.1	631.5	2.0%
Romania	88.7	139.3	168.3	1.6%
Slovenia	31.2	47.7	56.9	1.5%
Slovak Republic	45.6	76.5	94.5	1.8%
Luxembourg	34.0	53.1	68.2	1.8%

Source: Fraunhofer-ISI

A comparison between the economic development in EU15 and EU12 in terms of absolute and relative growth of major economic indicators is presented by Table 4-4. The separation of average annual growth in two decades, 2010 to 2030 and 2030 to 2050 shows that the demographic development strongly influences economic growth. While there is a further growth of population expected until 2030, the decreasing population from 2030 to 2050 induces decreasing employment and lower growth of the demand side indicators and finally also GDP.

Table 4-4: Overview on development of major economic indicators

Region	Indicator	Indicators in bn $€_{2005}$ / Mio pers.			Annual Growth in %	
		2010	2030	2050	2010-'30	2030-'50
EU27	GDP	11,245	16,184	21,080	1.8%	1.3%
	Consumption	4,981	7,302	9,705	1.9%	1.4%
	Investment	1,662	2,563	3,172	2.2%	1.1%
	Employment	219.3	219.9	214.7	0.0%	-0.1%
	Trade Balance	1,174	1,898	2,727	2.4%	1.8%
EU15	GDP	10,492	14,969	19,510	1.8%	1.3%
	Consumption	4,634	6,813	9,061	1.9%	1.4%
	Investment	1,537	2,357	2,910	2.2%	1.1%
	Employment	175.2	175.6	173.3	0.0%	-0.1%
	Trade Balance	1,076	1,759	2,496	2.5%	1.8%
EU12	GDP	753	1,215	1,570	2.4%	1.3%
	Consumption	347	490	644	1.7%	1.4%
	Investment	125	206	262	2.5%	1.2%
	Employment	44.1	44.2	41.3	0.0%	-0.3%
	Trade Balance	98	140	231	1.8%	2.5%

Source: Fraunhofer-ISI

4.2.3 Transport system trends

The transport trends in the Reference Scenario are those provided by the PRIMES-TREMOVE model. In the EU27, passenger transport activity is expected to growth until the year 2050 but a descending rate (Table 4-5). In the first half of the forecasting period (i.e. between 2010 and 2030) the expected growth rate is 1.1%. In the second half – between 2030 and 2050 – the expected growth rate falls to 0.7%. Of course, these average rates hide regional differences. As Table 4-5 shows, faster grow is forecasted for EU12 than for EU15 (despite population stagnation in these countries).

Table 4-5: Passenger demand (Gpkm/year for motorised modes) and average growth rates per year in the Reference Scenario

Region	2010	2030	2050	2010/30 per year	2030/50 per year
EU15	5404	6535	7463	1.0%	0.7%
EU12	865	1194	1426	1.6%	0.9%
EU27	6268	7729	8889	1.1%	0.7%

Source: PRIMES-TREMOVE

Different trends by mode of transport are also expected. Rail and air transport are expected to grow more than other modes. Forecasted air growth rates are 2.7% per year until 2030 and 1.6% from 2030 to 2050, i.e. more than twice the average EU27 rate. In EU12 air growth rate is as high as 3.9% per year until 2030. Rail trend is still over the average but more moderate: 1.8% per year until 2030 and 1.1% afterwards. Road modes, car and bus, are instead expected to grow less the average even if car in EU12 countries should grow by 1.4% per year until 2030.

As result of the different growth rates, mode split is changed over time (Table 4-6). Despite remaining largely dominant, car market share should fall from 76% (calculated on motorised modes only) to 69% of demand (calculated in terms of passenger-km). In EU12 the fall should be only slightly lower (from 76% to 70%). Air should become the second mode in the ranking climbing to a share of 14% (11% in EU12). Rail is expected to increase from 8% to 10%. Bus share is stable although with a small decrement.

Table 4-6: Passenger mode split (on passengers-km) in the Reference Scenario

Transport mode	2010	2030	2050
EU15			
Car	76%	71%	69%
Train	8%	9%	10%
Bus	8%	7%	7%
Air	9%	12%	14%
Total	100%	100%	100%
EU12			
Car	76%	72%	70%
Train	8%	10%	10%
Bus	11%	10%	9%
Air	6%	9%	11%
Total	100%	100%	100%
EU27			
Car	76%	72%	69%
Train	8%	9%	10%
Bus	8%	8%	7%
Air	8%	12%	14%
Total	100%	100%	100%

Source: PRIMES-TREMOVE

Freight demand is expected to growth a bit more than passenger's: 1.6% per year until 2030 and 0.7% per year from 2030 to 2050 in the EU27. In the first period freight tonnes-km should grow faster in EU12 (2.0% per year) than in EU15 whereas after 2030 basically no difference is expected (but of course differences exist at the country level).

Unlike the passenger case, growth rates by mode are quite similar especially after the year 2030. Only from 2010 to 2030 rail freight is expected to grow significantly more than other modes (2.2% per year). Therefore, mode split is not changed much with respect to the reference case. Truck should lose some market share (from 48% to 46%) with all the reduction concentrated in EU15.

Table 4-7: Freight demand (Gtkm/year for motorised modes) and average growth rates per year in the Reference Scenario

Region	2010	2030	2050	2010/30 per year	2030/50 per year
EU15	3082	4190	4810	1.5%	0.7%
EU12	570	854	962	2.0%	0.6%
EU27	3652	5044	5772	1.6%	0.7%

Source: TRT elaboration on PRIMES-TREMOVE

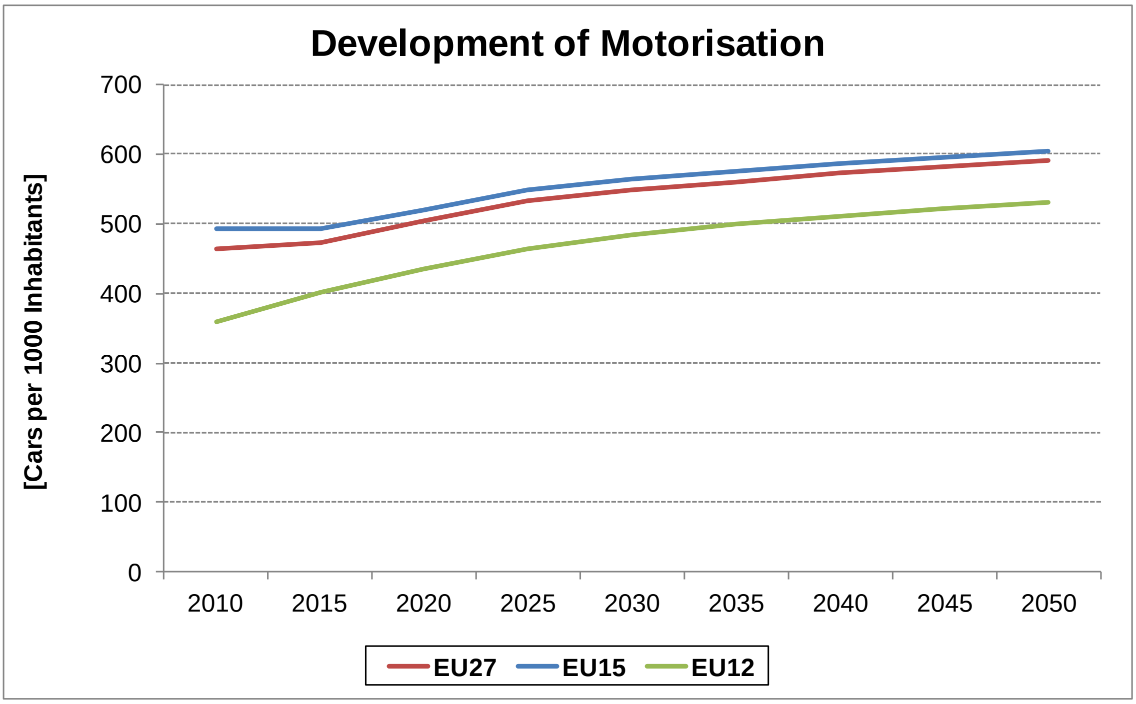
Table 4-8: Freight mode split (on tonnes-km) in the Reference Scenario

Transport mode	2010	2030	2050
EU15			
Truck	48%	46%	46%
Train	8%	9%	9%
Navigation	44%	45%	45%
Total	100%	100%	100%
EU12			
Truck	47%	47%	48%
Train	18%	19%	19%
Navigation	35%	34%	32%
Total	100%	100%	100%
EU27			
Truck	48%	47%	46%
Train	10%	11%	11%
Navigation	43%	43%	43%
Total	100%	100%	100%

Source: TRT elaboration on PRIMES-TREMOVE

4.2.4 Vehicle fleet trends

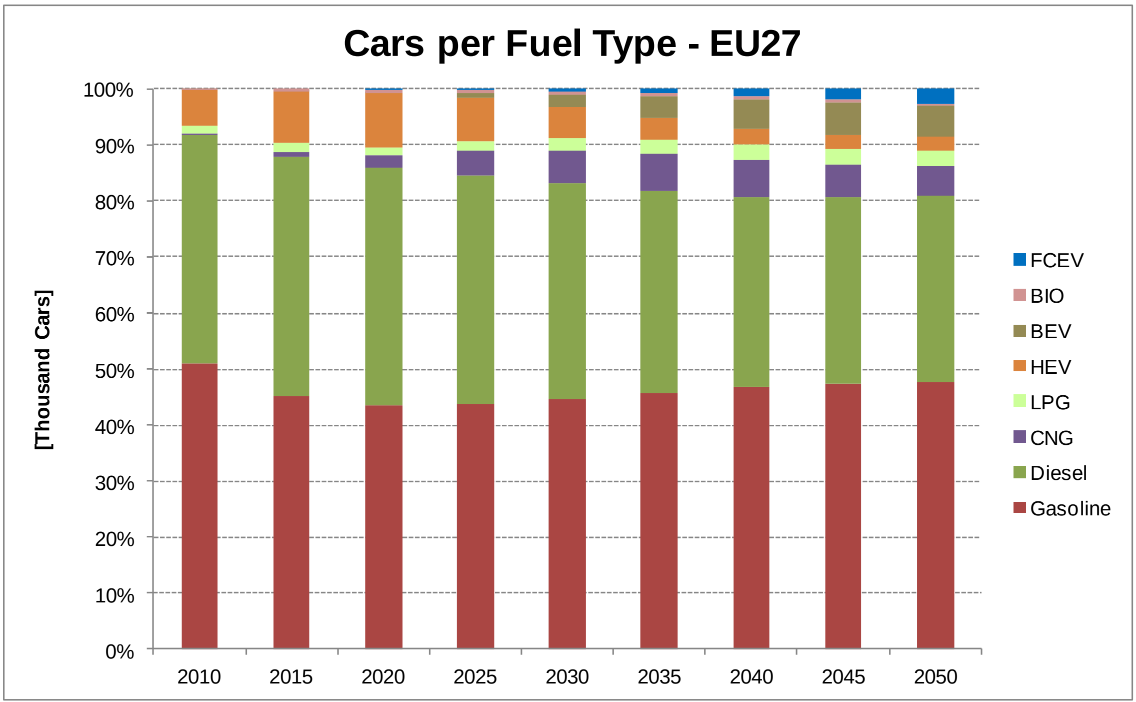
New car registrations and motorisation depend on various socio-economic drivers. In ASTRA-EC, the major driver of motorisation is the development of average income and income distribution. Further drivers are car prices, average fuel prices and the demographic development. Figure 4-4 provides an overview on the estimated motorisation development in EU27, EU15 and EU12. ASTRA-EC assesses a growth of car ownership up to 590 cars per 1000 inhabitants for EU27 in 2050. Motorisation in EU15 is expected to increase to 604 cars per 1000 inhabitants while the motorisation in EU12 achieves 530 cars per 1000 inhabitants. In absolute numbers, about 304 million cars will be registered in Eu27 in 2050. ASTRA-EC simulates the highest car ownership to be in Italy and Austria with 692 cars per 1000 inhabitants.



Source: Fraunhofer-ISI

Figure 4-4: Motorisation trend in EU27, EU15 and EU12

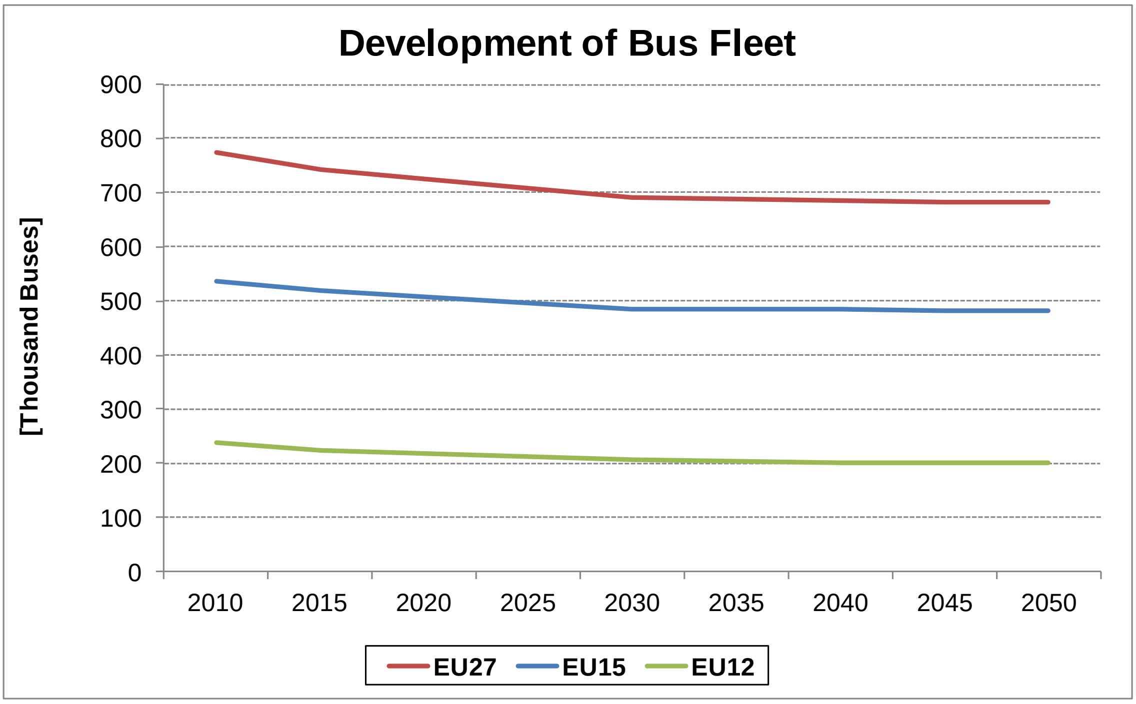
Besides the total stock of cars in EU27, the technological composition and the diffusion of alternative fuel vehicles plays an important role for the assessment of GHG emissions. ASTRA-EC calculates the diffusion based on an adapted Total Cost of Ownership approach considering the influence of filling station infrastructure. Major drivers are car prices as well as fuel, gas or electricity prices. Figure 4-5 shows the estimated share of the fuel technologies on the total EU27 car fleet. About 80% of the car stock will still be based on the conventional diesel and gasoline technology. The main driver for this development is a combination out of moderate fuel and energy price growth in the and already high fuel efficiency potential of conventional diesel and gasoline cars in the Reference Scenario. Diesel fuel price is supposed to increase until 2050 by on average +59% compared with 2010, gasoline fuel prices only +55%. Under the current development of passenger and freight transport all over the world and the projections of oil supply e.g. by the World Energy Outlook 2013, this trend can be considered as optimistic. Fuel efficiency technologies for fossil fuel cars contribute to a slowed down diffusion of electrified vehicles (EVs). Furthermore, the ASSIST Reference Scenario does not take into account additional incentives for these cars such that the speed of diffusion remains low.



Source: Fraunhofer-ISI

Figure 4-5: Projection of technological composition of car fleet in EU27

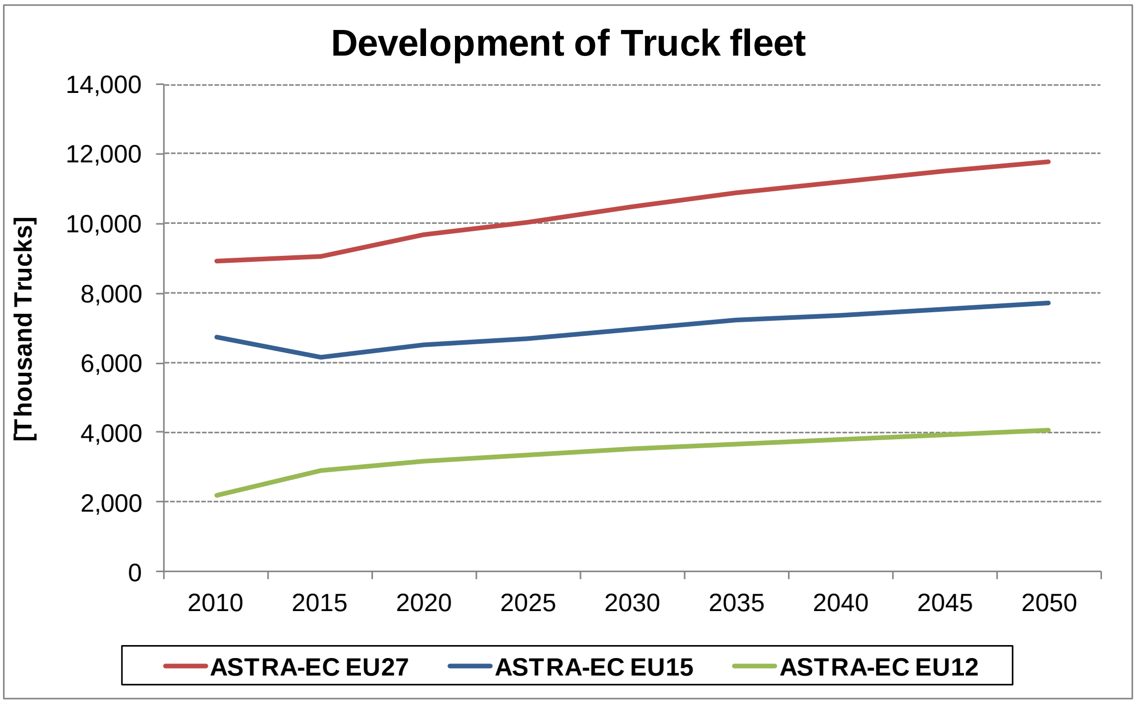
As opposed to the development of car ownership, the commercial vehicle fleets and the bus fleet development depends directly on the trend of vehicle-km. Hence, the passenger transport performance for bus mode and the freight transport performance on roads are directly reflected by the development of bus, LDV and HDV stock. Figure 4-6 shows the projected trend of bus stock in EU27, EU15 and EU12. Due to decreasing passenger-km for bus, the number of registered busses is expected to decline by -11% in EU27 between 2010 and 2050. For EU12, the decline is by -15% even stronger than in EU15 where the number of registered busses decrease by -10%.



Source: Fraunhofer-ISI

Figure 4-6: Bus fleet forecast in EU27, EU15 and EU12

Following the growing road freight transport demand, ASTRA-EC projects a growth of the number of trucks registered in EU27 from 2010 to 2050 of about 2.9 million trucks or by +32% in relative terms. The growth of the EU12 truck fleet is significantly higher than for the EU15 fleet. ASTRA-EC estimates an increase of the EU12 truck fleet of +86% between 2010 and 2050. For EU15, the growth is by +15% less strong.



Source: Fraunhofer-ISI

Figure 4-7: Truck fleet forecast in EU27, EU15 and EU12

4.2.5 Environmental trends

In the PRIMES-TREMOVE scenario fuel consumption is slightly increasing in the forecasting period with some significant differences between fuel types as shown in Table 4-9.

Table 4-9: Fuel consumption (Mtoe/year) and average growth rates per year in the Reference Scenario

Region	2010	2030	2050	2010/30 per year	2030/50 per year
EU15					
Diesel	165	164	166	0.0%	0.1%
Gasoline	80	65	64	-1.0%	-0.1%
Kerosene	47	54	56	0.7%	0.1%
Biofuels	11	22	21	3.4%	-0.3%
EU12					
Diesel	25	31	33	1.1%	0.2%
Gasoline	12	12	12	0.0%	0.0%
Kerosene	2	4	5	2.5%	1.2%
Biofuels	2	4	4	4.7%	-0.2%
EU27					
Diesel	191	195	198	0.1%	0.1%
Gasoline	92	78	76	-0.9%	-0.1%
Kerosene	49	58	60	0.8%	0.2%
Biofuels	13	26	25	3.6%	-0.3%

Source: TRT elaboration on PRIMES-TREMOVE

Diesel is expected to remain the dominant transport fuel and its consumption should be slightly increasing at an average pace of 0.1% per year in EU27. This growth is mainly driven by fuel consumption in EU12 countries until the year 2030 (1.1% per year). Instead, the faster growth is expected for biofuels, whose consumption is forecasted to increase by 3.6% per year until the year 2030, while after this date their consumption is expected to remain basically stable. Also kerosene consumption grows faster than diesel’s in the Reference Scenario, because of the air demand trend. Gasoline is the only fuel type for which a decrement is expected throughout the whole simulation period. Only in EU12 the consumption of gasoline is forecasted to be stable.

PRIMES-TREMOVE provides reference projections for CO_2 emissions of road transport, rail transport and aviation, while data for navigation is not available (Table 4-10).

Table 4-10: CO_2 emissions from transport (Mio Tons/year) and average growth rates per year in the reference scenario

Region	2010	2030	2050	2010/30 per year	2030/50 per year
EU15					
Road	575.5	485.3	493.9	-0.8%	0.1%
Rail	6.7	4.3	1.0	-2.2%	-7.0%
Aviation	142.9	165.0	169.0	0.7%	0.1%
EU12					
Road	117.7	123.1	126.9	0.2%	0.1%
Rail	1.9	1.6	0.6	-1.0%	-5.1%
Aviation	6.5	10.7	13.5	2.5%	1.2%
EU27					
Road	693.3	608.4	620.8	-0.7%	0.1%
Rail	8.6	5.9	1.6	-1.9%	-6.4%
Aviation	149.4	175.8	182.5	0.8%	0.2%

Source: TRT elaboration on PRIMES-TREMOVE

Despite transport activity is expected to increase, both for passengers and for rail, CO_2 emissions are decreasing for road and rail (in EU12 only for rail). Most of this discrepancy has to be explained by efficiency improvement. Indeed, as mentioned above, diesel consumption is stable and gasoline consumption is even decreasing despite more demand. Only for aviation, the traffic growth is too high to be compensated by the improved efficiency of aircrafts. Considering the sum of the three modes, CO_2 emissions from transport are forecasted to be just a bit below the 2010 level (804 Mio Tons compared to 851 Mio Tons), which means that in the reference scenario the transport sector is quite far away the White Paper target for CO_2 reduction.

5 Application of ASTRA-EC for policy analysis

The ASTRA-EC model is able to simulate the impacts of a number of the 61 TPMs selected for analysis in the ASSIST project. Deliverable D4.2 provides an overview on the list of 26 TPMs that can be assessed with ASTRA-EC. For the purpose of this deliverable six TPMs were selected covering the most important categories of transport policies defined in the 2011 Transport White Paper.

This chapter provides an assessment of the major transport, economic, social, technological and environmental impacts of the selected TPMs. For this purpose, the results are mainly presented in terms of percentage changes of the most important indicators for each impact category. For specific policies like Electromobility Road heading towards a technological shift in rolling stock the absolute changes of car fleets are described additionally.

After the description of the quantitative impact assessment result based on ASTRA-EC, a further section elaborates on the validation of the ASTRA-EC model reactions for each TPM. Panteia not being part of the core ASTRA-EC developing team worked on this validation in order to provide the complementary validation from the user perspective.

5.1 Assessment results for selected TPMs

In the following sections, selected key modelled impacts for a sample of TPMs are reported and commented. We have selected a transport measure for each of the main policy domains. The policy analysed are:

- Pricing - Internalisation of external costs for specific modes of transport (road, rail, iww, ports, airports)
- Taxation - Energy Taxation
- Internal markets - EU-wide common job quality and working conditions for truck drivers
- Efficiency standards - CO_2 emission limits for HDV, LDV, cars etc
- Transport planning - City logistic
- Research and Innovation - Electromobility Road

5.1.1 Pricing – Internalisation of external costs

This policy consists of the introduction of charges to internalise the external costs generated by transport modes. Two different simulations have been made to show impacts estimated by ASTRA-EC. In one simulation all the passenger modes and only the passenger modes have been charged, in the other scenario the internalisation charge was applied to freight modes only.

It might be useful to remind that in ASTRA-EC is it supposed that the internalisation charge for road modes is not limited to some part of the network (e.g. the motorway network) but is supposed to be levied on the whole network. In other words the entire transport activity is charged. Furthermore, it is assumed that the charge to non road modes is entirely passed to user tariffs.

The charges used for the tests are based on the external costs reported by CE Delft, (2011)[2]. The values are reported in Table 5-1 and Table 5-2 for passenger and, respectively, freight. They depend on assumptions for load factors for passenger and freight modes as the original values are calculated for passenger-km and ton-km.

Table 5-1: Internalisation charges for passenger modes in Euro/vkm

Indicator	Urban	Non-urban
Car	0.1245	0.072
Bus	0.546	0.312
Passenger train	8.1	5.4
Air	-	4.845

Source: TRT elaboration on CE Delft (2011)

Table 5-2: Internalisation charges for freight modes in Euro/vkm

Indicator	Urban	Non-urban
Truck	0.25	0.39
Freight train	-	3.3
Inland navigation	-	15
Maritime (short sea shipping)	-	96

[2] CE Delft, (2011) : External Costs of Transport in Europe, Update Study for 2008

A selection of results obtained by the application of ASTRA-EC for the simulation of the internalisation of passenger transport external costs is shown in Table 5-3.

The measure does not change significantly the overall personal mobility. In the medium term there is a slight reduction of total passenger-km but in the long term there is no difference with respect to the reference scenario. Indeed, mobility of passengers is affected but the response is mainly in terms of mode shift. Car and air lose mode share, the latter more than the former in relative terms despite in absolute term car is supposed to lose nearly 320 billion passenger-km whereas air loss is of 180 billion passenger-km. Bus and passenger train benefit of the mode shift, in particular rail passenger transport demand is estimated to increase by one quarter with respect to the reference scenario.

Table 5-3: Key impacts for EU27 of TPM Internalisation of passenger external costs – variations with respect to the reference scenario

Indicator	Var% 2030	Var % 2050
Passenger transport performance (passenger-km)	-0.2%	0.0%
Car mode share	-5.4%	-5.2%
Passenger train mode share	24.0%	23.3%
Air mode share	-16.7%	-17.2%
Revenues by road charge	872.0%	791.5%
Average transport expenditure low income	69.8%	66.3%
Average transport expenditure medium income	61.5%	59.3%
Average transport expenditure high income	55.7%	54.0%
GDP without charge recycling	-2.2%	-3.4%
GDP with charge recycling	0.2%	-0.4%
Employment without charge recycling	-0.6%	-0.6%
Employment with charge recycling	0.0%	-0.2%
CO_2 emissions from transport	-4.5%	-5.1%

Source: ASTRA-EC model

The revenues from charging are substantial. Road charge revenues (which already exist in the reference case) are incremented by a factor 8: in absolute terms the increment amount to nearly 300-350 billion Euro per year since 2020. Of course, the counterpart is an increment of the expenditure for transport of households. The size of this increment is more than 50% and it is higher in relative terms for individuals belonging to the lower income group (despite in absolute terms the expenditure grows much more for the higher income group: nearly 1.500 Euro per individual in the year 2050 compared to 700 Euro of the lower income group. The discrepancy in the ranking based on relative and absolute values depends on the expenditure in the reference case, which is significantly larger for the higher income group such as the increment is relatively lower.

The economic impact heavily depends on the assumptions regarding the destination of the revenues. If no assumptions are made and it is supposed that revenues enter in the public budget (e.g. to reduce debt) the economic growth is negatively affected and GDP is 2% lower in the medium term and 3.5% lower in the longer term in comparison to the reference scenario (i.e.: GDP still grows but a slightly lower pace). If the assumption is made that revenues are used to reduce direct taxes, this recycling offset the negative impact of the taxation and the GDP is basically unchanged.

The impact on the employment is of course strictly correlated to the impact on economic growth: it is negative (despite not largely negative) if no use of revenues is assumed while it is negligible if the reduction of direct taxes is simulated.

From an environmental point of view there is a positive effect. CO_2 emissions are 5% lower than in the reference case thanks to the mode shift. Other externalities like air pollutant emissions, accidents and congestion are as well positively influenced. The reduction would be somewhat larger in the variant without recycling of the revenues, but it can be said that the internalisation of passenger external costs provides a more balanced field for the competing modes, but does not help much to reduce externalities.

The main outcomes of the simulation of the internalisation of freight external costs are summarised in Table 5-4.

As for passengers, the overall transport activity is not really affected by this measure. Indeed, total tonnes-km are even slightly higher. This increment is mainly the result of some mode shift from road towards rail and maritime, whose average distances are generally higher because e.g. of feederage to/from terminals. In relative terms the increment of rail freight demand with respect to the reference case is much larger than maritime's but in absolute terms they gain more or less the same amount of demand.

Again, a significant amount of money is raised through the internalisation charges. The increment of revenues from road charges is above four times the reference case value.

Table 5-4: Key impacts for EU27 of TPM Internalisation of freight external costs – variations with respect to the reference scenario

Indicator	Var% 2030	Var % 2050
Freight transport performance (tonnes-km)	0.5%	0.6%
Truck mode share	-3.5%	-3.5%
Freight train mode share	+10.4%	+10.0%
Maritime mode share	+2.4%	+2.4%
Revenues by road charge	+456.8%	+416.6%
GDP without charge recycling	-0.7%	-0.9%
GDP with charge recycling	1.0%	1.4%
Employment without charge recycling	-0.2%	-0.1%
Employment with charge recycling	0.3%	0.1%
CO_2 emissions from transport	-0.5%	-0.4%

Source: ASTRA-EC model

Like for passengers, the economic effect of the internalisation depends on the assumption made regarding the use of revenues. Without any specific use, the economic growth is slightly reduced. The negative effect is smaller than in the case of passenger cost internalisation. The reason is that when passenger modes are charged, disposable income is directly reduced and so is private consumption and, in turn, aggregate demand. Instead, when freight modes are charged, disposable income is only indirectly affected. There is however a negative impact on Total Factor Productivity.

If it is supposed that revenues are used to reduce direct taxes there is positive impact on the economic growth in comparison to the reference case. Basically the reduction of direct taxes increases disposable income and the consequent growth of aggregate demand more than offset the reduction of Total Factor Productivity.

The effect on employment follows those on the economic growth, therefore there is either a small reduction or a small increment depending on the assumption of revenues use.

CO_2 emissions are reduced but in marginal quantity since the mode shift from road is small and total tonnes-km are slightly higher. Again, internalisation of external costs does not mean reduction of external costs.

5.1.2 Taxation – Energy Taxation

The principle of the TPM Energy Taxation (ET) is to harmonise fuel and energy taxes in the EU among all member states by setting minimum tax rates. These minimum tax rates are based on the carbon intensity and the energy intensity of the fuel or energy type. According to the proposal of the European Commission from April 2011 (COM2011 169/3), the CO_2 component was set by 20 € per ton in addition to 9.6 € per GJoule of energy. Table 5-5 shows the resulting minimum tax rates for the major transport-related fuel and energy types. While most EU member states already have higher tax rates for gasoline and some countries also for diesel, CNG taxes[3] rise significantly due to the proposed minimum rates in the ET. The second fuel type that will be strongly influenced by the ET due the tax increase is kerosene. As concerns kerosene, the ET can be considered as a valuable policy measure to achieve the target of reducing emissions. The resulting strong growth of CNG tax rates will most probably have an opposite impact which is confirmed by the impact assessment with ASTRA-EC.

Table 5-5: Minimum tax rates per fuel type in Euro/litre

Fuel type	Minimum tax rate	Unit
Gasoline	0.36	Euro/Litre
Diesel	0.39	Euro/Litre
LPG	0.2706	Euro/Litre
CNG	0.4601	Euro/kg
Electricity	0.00054	Euro/kWh
Kerosene	0.392	Euro/Litre

Source: Fraunhofer-ISI based on COM2011 169/3

According to the proposal from 2011 the Energy Taxation is supposed to start in 2018 after a phasing in. ASTRA-EC simulates the impact without phasing in. ASTRA-EC chooses the maximum of the country-specific and the defined tax rate for each fuel type. The Energy Taxation initiates several changes in the transport, the economic, the trade and in the vehicle fleet modules of ASTRA-EC. At first, modal split and distribution of trips are influenced by changing prices mainly for road and air mode. The

[3] Tax rates are converted into € per kg via the specific energy density of 43 MJ/kg

second major change of consumer behaviour takes place in the choice of fuel technology at the stage of car purchasers. Furthermore, car-ownership changes as the change of tax rates leads to changing average fuel prices. ASTRA-EC offers two options for the simulation of the ET.

- In the first option, ASTRA-EC does not refund additional revenues by the government induced by the ET. They are only accounted for reducing government debts;
- In the second option, a mechanism in ASTRA-EC allows to refund 90% of all additional ET revenues by reducing direct taxes. This directly impacts consumption of private households.

Table 5-6 presents the impact assessment results for the TPM Energy Taxation in terms of percentage changes of major indicators compared to the Reference Scenario. All changes besides those for GDP and Employment are only provided for the ET simulation with a refunding of tax revenues. ASTRA-EC assesses a marginal reduction of total passenger transport performance and freight transport performance for EU27 until 2050. In total the ET is expected to induce 8.5 billion passenger-km and about 11.4 billion tonnes-km less in EU27 until 2050. In relative terms, this means only a reduction compared to the Reference Scenario of -0.09% respectively -0.19%.

Zooming into the impacts on passenger transport performance for the different transport modes, the increase of car model share by about +0.7% compared with the Reference Scenario in 2050 seems to be contradictory. The marginal growth of passenger-km by car is caused by a modal shift from air to road. Strong growth of average ticket prices due to the minimum tax rate for kerosene causes a reduction of air modal share of -6.5% until 2050. Rail mode gains most out of the ET but partially also car mode. The modal share of car rises slightly from 67.3% in the ASSIST Reference Scenario up to 67.7% in the ET Scenario with 90% refunding.

The ET leads to changing average transport expenditures for consumers of different income groups in EU27. Persons belonging to the highest income group have to face by +5.2% the strongest change of average transport expenditures. The ET affects as well persons in low income groups but by +3.4% less severe than for medium and high income groups.

Major economic impacts are initiated by changing new car registrations, transport expenditure, impacts of higher transport costs on exports and on the supply chain. Refunding the additional tax revenues by 90% via reduction of direct taxes can compensate the loss of GDP to a certain degree but cannot completely avoid negative impacts on GDP. In comparison with the Reference Scenario, GDP is by -0.4% in

EU27 in 2050 lower. Without refunding, GDP is expected to be by -0.7% below the level of the ASSIST Reference Scenario. As regards employment, the overall negative effect of rising fuel and energy prices leads to a reduction of employment of -0.1% in 2050. In absolute terms this means about 225 thousand jobs less in 2050 in the Scenario including a refunding of revenues.

Table 5-6: Key impacts for EU27 of TPM Energy Taxation – variations with respect to the reference scenario

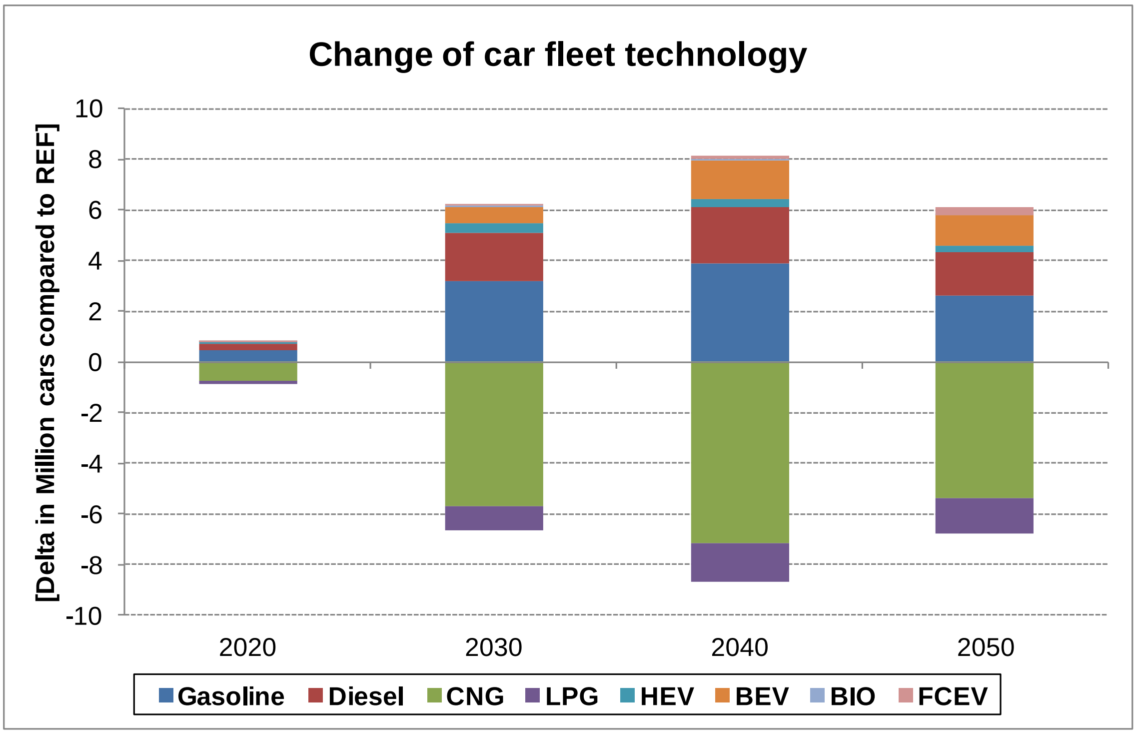
Indicator	Var% 2030	Var % 2050
Passenger transport performance (passenger-km)	-0.08%	-0.09%
Freight transport performance (tonnes-km)	-0.16%	-0.19%
Car mode share	0.4%	0.7%
Passenger train mode share	1.9%	1.8%
Air mode share	-6.1%	-6.5%
Average transport expenditure low income	3.4%	3.4%
Average transport expenditure medium income	4.3%	4.4%
Average transport expenditure high income	5.2%	5.2%
GDP without tax refunding	-0.4%	-0.7%
GDP with tax refunding	-0.2%	-0.4%
Employment without tax funding	-0.1%	-0.2%
Employment with tax funding	-0.1%	-0.1%
CO_2 emissions from transport	-1.1%	-1.2%

Source: ASTRA-EC model

The environmental impact of the TPM is only slightly positive even if the proposed high minimum tax rate for CNG prevents CNG from achieving a higher share in the EU27 car fleets. ASTRA-EC projects about -1.2% less CO_2 emissions (tank-to-wheel) in EU27 in 2050 than in the ASSIST Reference Scenario. The first reason for the lower level of CO_2 emissions initiated by the ET is the resulting marginal decrease of passenger and freight transport performance. The stronger impact comes from a technological shift from LPG and CNG towards efficient ICE cars propelled with gasoline and towards electrified vehicles (HEV, BEV, FCEV).

Figure 5-1 illustrates this shift. ASTRA-EC calculates significantly smaller CNG and LPG car fleets until 2050. About 6.8 million CNG and LPG cars are mainly substituted by gasoline (+2.5 million), Battery Electric Vehicles (+1.2 million), diesel cars (+1.8

million) and Hybrid Electric Vehicles respectively Fuel Cell Electric Vehicles (+0.2 million respectively +0.3 million). In the case of LPG which causes higher CO_2 emissions than an average diesel car this shift is positive. The strong decrease of CNG is under the perspective of climate targets questionable as CNG cars emit on average less CO_2 than diesel and gasoline cars.



Source: ASTRA-EC model

Figure 5-1: Change of fuel technology in EU27 car fleets in the TPM Energy Taxation compared with REF

5.1.3 Internal Markets – EU-wide common job quality and working conditions for truck drivers

The transport policy measure related to the introduction of quality working conditions for truck drivers is implemented in ASTRA-EC by assuming that labour cost in the road freight sector is slightly increased (+3%) and travel time for long distance trucks is 15% longer (as result of more restrictive conditions on resting time).

Some key impacts of this measure are summarised in Table 5-7. Total tonnes-km for freight transport are a bit higher, again because there is some mode shift towards rail and maritime, which imply larger distances. The mode shift is however small: road freight share is reduced by less than 2% (in relative terms, e.g. in the year 2050 truck share is 51.8% of total tonnes-km instead of 52.2%).

The average expenditure per tonne transported by road is generally increased, given the assumption that labour cost is increased. The increment is different country by country and in a few cases is even negative. The reason is that this expenditure is computed ex-post as ratio between total expenditure and tonnes transported. A different transport pattern (e.g. reduction of average distances, larger modal shift on some routes than on others) gives rise to a different expenditure, which is generally higher than in the reference case, but usually not as high as the increase of cost per vehicle-km.

Table 5-7: Key impacts for EU27 of TPM EU-wide common job quality and working conditions for truck drivers – variations with respect to the reference scenario

Indicator	Var% 2030	Var % 2050
Freight transport performance (tonnes-km)	0.2%	0.1%
Road freight mode share	-1.7%	-1.8%
Road freight transport expenditure per tonne(1)	-0.3%/+1.2%	-0.5%/+1.2%
GDP	-1.0%	-1.4%
Employment	-0.2%	-0.2%
CO_2 emissions from transport	-0.3%	-0.3%

(1) The impact depends on the specific country.
Source: ASTRA-EC model

The measure has a slight negative impact on the economic growth. GDP is 1% lower than in the reference scenario at the year 2030 and 1.4% lower at the year 2050. In terms of average growth rate over the simulated period, these differences are negligible. The negative effect of the measure derives from the role of freight transport generalised cost (i.e. including travel time) in the Total Factor Productivity, namely, a higher generalised cost is translated in a slower development of Total Factor Productivity. As a consequence of the small reduction of the economic growth, employment is also a bit reduced with respect to the reference scenario.

The impact of the measure in environmental terms is somewhat positive as transport CO_2 emissions are lower than in the reference case. The reduction is basically a consequence of the lower road freight transport activity. Since the mode shift from trucks is small, also the difference in terms of emissions is minor.

5.1.4 Efficiency Standards – CO_2 limits for cars, LDVs and HDVs

This measure corresponds to set restrictive limits on CO_2 emissions from new road vehicles (cars and trucks). With respect to the CO_2 emissions limits already assumed in the reference scenario, this measure implies the application of further limitations, namely:

- for new cars 70 g/CO_2 in 2030 (-56% compared with the 2007 fleet average of 158.7g/km).
- for new vans 110 g/CO_2 in 2030 (-46% compared with the 2007 fleet average of 203 g/km).
- for new heavy duty vehicles a reduction of 25% compared with the 2007 fleet average CO_2 emissions.

Table 5-8 provides the main impacts of this measure according to the simulation made with ASTRA-EC.

As a whole, transport demand is not changed much by this policy. Freight performance is basically the same as in the reference scenario; the tiny decrement is explained by some mode shift to road, whose average travel distance is generally lower. The mode share of trucks is just slightly increased (at the year 2050 the share is 51% compared to 50.7% of the reference case) as results of the improved fuel economy which is also translated in lower transport costs.

Also passenger demand is not significantly changed. There is a minor increment which can be explained by a shift from air to the more energy efficient (and therefore cheaper) cars. Indeed, the simulation suggests that the mode share of car could become 3% higher than in the reference scenario at the horizon of the 2050. This would mean confirming the current mode share (70% at the EU27 level) while in the reference scenario car is expected to lose some market share.

Table 5-8: Key impacts for EU27 of CO_2 limits for cars, LDVs and HDVs – variations with respect to the reference scenario

Indicator	Var% 2030	Var % 2050
Freight transport performance (tonnes-km)	-0.1%	-0.1%
Road freight mode share	0.3%	0.6%
Passenger transport performance (pass-km)	0.1%	0.2%
Car mode share	0.7%	3.3%
GDP	0.1%	0.2%
Employment	0.0%	0.1%
CO_2 transport emissions	-6.0%	-14.2%

Source: ASTRA-EC model

The economic impact of the measure is very small but positive. The introduction of tighter limits induces some faster renewal of the fleet, which means higher consumption and investment.

The slight progress on the economic side corresponds also to some positive effect on the employment at least in the longer term.

Not surprisingly, the most significant effect is by far the environmental one. The renewal of the road vehicle fleet brings about a reduction of CO_2 transport emissions up to 14% with respect to the reference scenario in the longer term. Taking into account that already in the reference case the CO_2 transport emissions are expected to decrease in the future, compared to the 2010 level, the impact of this measure would be that in the year 2050 transport would emit nearly 25% less CO_2 than in the year 2010.

5.1.5 Transport Planning – City logistics

The policy aims at reducing the traffic of duty vehicles within cities and metropolitan areas by means of the implementation of technical and planning measures. In ASTRA-EC it is assumed that these measures can increase the average load factor of light duty vehicles used for urban freight distribution up to 15%. At the same time, it is assumed that also heavy duty vehicles are used more efficiently (since they are not used for local distribution) and their load factor is increased by 1%.

The major impacts of this measure are summarised in Table 5-9.

In terms of total freight transport, the measure is neutral: both in the medium and in the long term the total number of tonnes-km is unchanged in comparison to the reference scenario. Instead, road freight traffic is significantly lower: some 8% of road vehicle-km less than in the reference case are simulated. This is of course a direct consequence of the assumption on the load factor of duty vehicles.

A more efficient use of road freight vehicles has also a positive effect on their competitiveness: transport cost per tonne-km is reduced. That's the reason why the mode share of road freight transport is slightly higher than in the reference scenario. The difference is however so tiny (+0.2% which means that the mode share of trucks grows from 50.7% to 50.8% in the year 2050) which can well be considered negligible. As a matter of fact, the improved efficiency of truck loads does not generate a loss of demand for non-road modes. The reason is that most of the improvement concern light duty vehicles, which do not have competitors for urban distribution and already in the reference case own the 100% of the market share in urban areas.

Table 5-9: Key impacts for EU27 of TPM City logistics – variations with respect to the reference scenario

Indicator	Var% 2030	Var % 2050
Freight transport performance (tonnes-km)	0.0%	0.0%
Road freight traffic (vehicle-km)	-8.2%	-8.1%
Road freight mode share	+0.2%	+0.2%
GDP	0.0%	0.0%
Employment	0.0%	0.0%
CO_2 emissions from transport	-1.1%	-1.0%
$PM_{2.5}$ emissions from transport	-1.1%	-1.3%

Source: ASTRA-EC model

Cost savings for freight transport on roads are induced by the TPM. Nevertheless, the economic and social impact of the measure is very small: neither GDP nor employment are significantly affected by the improvements of city logistics.

Some benefit is provided on the environmental side. Both greenhouse gas emissions and polluting emissions (the table reports particulate matters emissions) are diminished by some 1%. Since the measure is especially focused on the urban freight distribution, most of the reduction is expected take place in urban areas where the environmental improvement will be therefore more significant than just the average 1%.

5.1.6 Research and Innovation – Electromobility road

The TPM 'Electromobility Road' aims at fostering electrified vehicles (EV). This especially means the support of R&D leading to an increase of efficiency, safety and reliability of vehicles with electronic propulsion. An implementation of this measure is expected to increase the number of EVs. The speed of diffusion of EVs mainly depends on the evolution of battery system technology, of battery system costs, of the charging infrastructure and of course of the alternative fuel technologies.

In order to simulate the TPM a number of impacts are initiated in ASTRA-EC. ASTRA-EC assumes additional investments in R&D in EU27 to vary between 1.5 and 2.5 billion $Euro_{2005}$ per year. These investments are supposed to induce an improvement of the learning rate up to 10% such average prices of BEV reduce significantly until 2050. Another important factor is the charging infrastructure which is expected to double compared to the Reference Scenario until 2050. Finally, ASTRA-EC expects a reduction of the so-called residual disutility of BEV and HEV due to promotion measures for and improved safety and reliability of EVs. The lower residual disutility improves the total use of EVs compared to other fuel technologies such that the speed of diffusion of BEV and HEV increases in ASTRA-EC. Due to a higher speed of diffusion, the stronger decrease of car prices for BEV and HEV is supposed to reinforce the diffusion of BEV and HEV.

Table 5-10 highlights the impacts of the TPM Electromobility Road in terms of changes of key indicators compared with the Reference Scenario. The impacts of the TPM are multi-fold. Additional investments in R&D induce a general push on the demand side of the economy and finally on GDP. According to the ASTRA-EC model structure R&D investments on battery system technology in the electronics and the chemicals sector influence technical progress stronger than investments in other sectors like for example construction.

The differing technological composition of car fleets initiates further changes in the passenger transport model of ASTRA-EC. Trip distribution and modal split depend on generalised costs per mode. In the case of cars the costs considered are not total costs of ownership but so-called perceived costs. They consist of costs of operation, therefore, mainly on fuel costs. This is the main reason why despite higher purchase prices for BEV and HEV the modal share of cars increases in this TPM. The average perceived costs among the whole car fleet decreases with the number of EVs because they have a significant fuel or energy cost advantage compared with ICE propelled with diesel or gasoline.

ASTRA-EC estimates an increase of total passenger-km of +0.2% in EU27 until 2050 or in absolute terms a growth of 19 billion pkm. Car modal share is expected to be by +3.6% higher in 2050 than in the Reference Scenario due to lower average perceived costs. A modal shift from rail and air towards car is projected by ASTRA-EC. The modal share of car in terms of pkm increases from 67.2% up to 69.7% while rail modal share declines from 9.6% down to 8.3%. Decreasing average transport expenditures compared with the Reference Scenario Lower are the result for all income groups.

The economic impact of the transport policy measure is overall positive. Additional R&D investment and slightly increasing car-ownership let GDP grow by 0.7% until 2050 in comparison with the Reference Scenario. Employment benefits slightly as well from the TPM. ASTRA-EC estimates additional 320 thousand new jobs in EU27 until 2050 to be created due to the TPM.

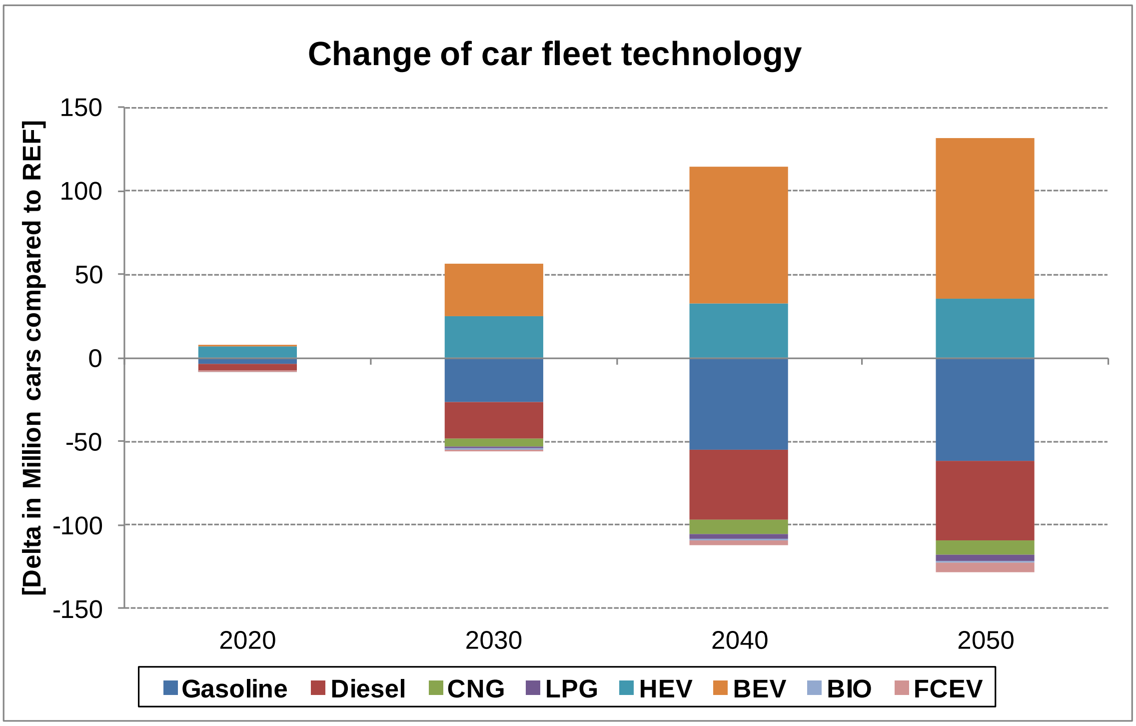
Table 5-10: Key impacts for EU27 of TPM Electromobility Road– variations with respect to the reference scenario

Indicator	Var% 2030	Var % 2050
Passenger transport performance (passenger-km)	0.1%	0.2%
Freight transport performance (tonnes-km)	0.0%	0.1%
Car mode share	0.7%	3.6%
Passenger train mode share	-2.9%	-12.8%
Air mode share	-0.6%	-3.3%
Average transport expenditure low income	-3.8%	-11.5%
Average transport expenditure medium income	-3.2%	-10.0%
Average transport expenditure high income	-2.7%	-8.6%
GDP	0.2%	0.7%
Employment	0.0%	0.1%
CO_2 emissions from transport	-4.1%	-12.3%

Source: ASTRA-EC model

Despite a larger passenger transport performance, total transport-related CO_2 emissions (tank-to-wheel) decrease by -12.3% until 2050. In absolute terms, 109 Mton of CO_2 could be saved in 2050.

Figure 5-2 demonstrates the impacts of the TPM on the structure of the EU27 vehicle fleet until 2050. Filling gaps in the charging infrastructure, improving safety and reliability of battery systems and decreasing purchaser prices for BEV and HEV induce an accelerated diffusion of EVs up to 2050. Every second car in the projected EU27 car fleet in 2050 will be an EV (BEV plus HEV). Even if ASTRA-EC does not take into a revolutionary breakthrough of battery technology like for example the lithium-air technology, the limited range of BEV is not supposed to prevent car purchasers from choosing a BEV.



Source: ASTRA-EC model

Figure 5-2: Impact of Electromobility Road on fuel technology in EU27 car fleets compared with REF

5.2 Validation of ASTRA-EC model reaction

The validation process compares the Reference Scenario results to the policy scenarios results in order to

- assess whether the right parameters are triggered and how (does the policy affect the expected parameters and how, in a positive or negative way) and
- to what extent these are reactive (relative difference between scenario and reference results).

For the validation process of the model reactions, six TPMs were tested:

- Pricing - Internalisation of external costs for specific modes of transport (road, rail, iww, ports, airports)
    - Apply a charge on specific freight modes to internalise external costs: truck, train, IWW and maritime, in short external cost freight scenario
    - Apply a charge on specific passenger modes to internalise external costs: car, bus, train and air, in short external cost passenger scenario
- Taxation - Energy Taxation
- Internal markets - EU-wide common job quality and working conditions for truck drivers
- Efficiency standards - CO_2 emission limits for HDV, LDV, cars etc
- Transport planning - City logistics
- Research and Innovation - Electromobility Road

Due to the extent of results, the model was validated in EU output and for national output. In this way, one can observe the differences –if any- in the EU trends and assess the reliability of the results. In the case of an in-depth, country-level validation, the results might not be so reliable due to the large extent of assumptions and the boundary conditions.

5.2.1 Internalisation of external costs

Expected impact for freight

The impact of internalisation of external costs for freight transport expands the Eurovignette policy to the whole transport network increasing the user costs for goods transportation depending on the mode. The additional costs for water transport are lower than those applied to road and rail (air freight is not included in ASTRA-EC); while road costs are expected to increase, by 2050, on average by 35%[4], rail and water are expected to increased – on average – by 11% and 16% respectively. Hence, in the modal split it is expected that these modes will attract demand at a quicker pace than the reference. The policy however, is not expected to have an impact on GDP nor on the EU trade figures. The reason is that freight transport costs have only an indirect impact on economic growth and their increment is limited enough to result not harmful for EU external trade. The employment is also expected to follow the reference trend.

The policy is applied from 2015 on and is a constant cost factor per mode.

Comparison to ASTRA-EC results

The table below summarises the findings for this scenario

Table 5-11: Scenario outcomes of internalisation of external costs (freight)

Scenario name \ 2010-2050 relative change	GDP	Employment	Freight demand	CO_2 emissions
Reference	+1.6% annual change	-0.1% annual change	+1% annual change	-0.3% annual change
External costs freight expected	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
External costs freight Results	+1.6% annual change	-0.1% annual change	+1% annual change	-0.3% annual change

Source: ASTRA-EC

4 This number ranges from 25-57% depending on the country

The results of this TPM model run do not deviate from the expected results. For the economic output variables, the results are the same, showing that the policy does not anticipate any significant economic change. The total freight demand growth does also not change between the scenarios as a consequence of the similar economic growth. Regarding the environmental output, the CO_2 emissions should decrease. The change here is insignificant as the model does not anticipate a shift towards low-emission technologies. Hence, the decrease in the emission level is mainly due to the modal choice effect, i.e. shift from road to rail and maritime and from a more ‘unconsolidated cargo transport’ to container transport.

The comparative figures for the modes show this shift in transport behaviour: from a 49.7% (2050 value), the road share decreases by -2%, to 47.9%. At the same time the rail and maritime transport shares grow by +1% each reaching 10.6% and 37.7% respectively.

Expected impact for passenger transport

The impact of internalisation of external costs for passenger transport is similar to the expected impact for freight. Here, the modes of interest are car, bus, rail, air and slow. In slow modes there are no additional costs. For each other mode constant costs are defined and are applied from 2015 and on. Due to these costs, a shift is expected from road to other modes. Depending on the shift, changes should occur also to the CO_2 emissions (i.e. a faster decreasing trend).

Similarly to the freight scenario, the economy is not expected to change significantly.

Comparison to ASTRA-EC results

The table below summarises the findings for this scenario

Table 5-12: Scenario outcomes of internalisation of external costs (passenger)

Scenario name \ 2010-2050 relative change	GDP	Employment	Passenger demand	CO_2 emissions
Reference	+1.6% annual change	-0.1% annual change	+0.8% annual change	-0.3% annual change
External costs passengers expected	Similar to Reference	Similar to Reference	Similar to Reference	Decreased compared to Reference
External costs passengers Results	+1.5% annual change	-0.1% annual change	+0.8% annual change	-0.5% annual change

Source: ASTRA-EC

There are marginal differences in GDP and employment stemming from the effects of costs on household expenditures (less income available for non-transport consumption). The level of these differences is insignificant, producing similar results to the freight scenario. The CO_2 emissions output depicts a relative change, which is explained through the modal shift from cars to rail, buses and non-motorised modes. The car share is expected to decrease by 4%, in 2050, reaching 64% of the total demand, as the constant higher costs will have an impact on the generalised costs which are applied to the passenger modal split.

This decrease in road share also affects the CO2 output which decreases at a faster pace (-0.5% pa instead of -0.3%).

5.2.2 Energy Taxation

Expected impact

The TPM Energy Taxation is applied on the model using minimum tax rates for all fuel types. The specific scenario also simulates a tax refund, i.e. a percentage of the levied tax is returned to the fuel consumers. The results are expected to depict insignificant changes compared to the reference scenario not only because part of the taxes are refunded to private households via lower direct taxes but also because the selected minimum tax levels are surpassed already by several countries. Based on the modeling assumptions, the impact of the taxation on gasoline and diesel is minor while the strongest effect is observed for CNG (with a small allocated share on road transport).

As the taxation effects are expected to be minimal, the model also does not anticipate any significant socioeconomic changes. The impact of the taxation on the transport emissions should be marginal as the projected changes in the modal split are limited. The results of this run are influenced by two elements: the limited penetration of alternative fuels (in order to substitute diesel or gasoline) and the tax refunds. Hence, if only a taxation scenario was applied or the scenario would be combined with alternative fuels market uptake the results would be significantly different.

Comparison to ASTRA-EC results

The actual results of the simulation are very close to the anticipated ones. Due to the set assumptions the model behaves similarly to the Reference Scenario. The discrepancies between the economic indicators are not significant: The same applies also for the total demand (passenger and freight) and the modal distribution.

This TPM affects the CO_2 emission, which is decreasing by -0.4% p.a., 0.1% more than the reference. However this difference is marginal and demonstrates on top of the effect of tax refunds, the limited uptake of non-conventional fuels by 2050.

Table 5-13: Scenario outcomes for energy taxation TPM

Scenario name \ 2010-2050 relative change	GDP	Employment	Passenger demand	Freight demand	CO_2 emissions
Reference	+1.6% annual change	-0.1% annual change	+0.8% annual change	+1% annual change	-0.3% annual change
Energy Taxation expected	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
Energy Taxation Results	+1.6% annual change	-0.2% annual change	+0.8% annual change	+1% annual change	-0.4% annual change

Source: ASTRA-EC

5.2.3 Job quality truck drivers

Expected impact

The implementation of this TPM has a direct impact on the travel cost and travel time of the trucks and specifically the application of an average increment of 15% on travel time and of 3% on drivers' labour costs. This change in time and costs is expected to have an impact on the road share, while the rest of the output parameters should not anticipate any deviations from the reference scenario, including the total freight demand.

Comparison to ASTRA-EC results

The table below demonstrates in a nutshell the outcomes of the validation for this scenario:

Table 5-14: Scenario outcomes for truck drivers job quality

Scenario name \ 2010-2050 relative change	GDP	Employment	Freight demand	CO_2 emissions
Reference	+1.6% annual change	-0.1% annual change	+1% annual change	-0.31% annual change
Job quality trucks expected	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
Job quality trucks Results	+1.6% annual change	-0.1% annual change	+1% annual change	-0.32% annual change

Source: ASTRA-EC

The results of the comparison are similar to the expected ones; the economic and environmental values are almost the same, and so is the total freight demand (see table above). The only difference is in the road demand, which grows by +0.79% pa, instead of +0.84% pa (reference growth rate 2010-2050) and share of the modal split, from 50% to 49%. The shifted demand is allocated mainly to rail, which is reasonable given the distance and the commodities served by road. Due to the scenario input in terms of costs and time, the scenario does not demonstrate any significant deviations from the reference scenario.

5.2.4 CO_2 emission limits

Expected impact

The CO_2 emission limits are applied for road vehicles from 2030 and on for new cars, new LDVs and new HDVs. The implementation of this TPM has a strong impact on the fuel consumption and consequently on the CO_2 emissions as it affects all modelled types of road vehicles.

As this TPM applies a standard, the road vehicle stock is expected to remain as it is, however with lower energy consumption per km. This means that the total demand or the modal split are not affected by this TPM. This is reasonable as the fuel efficiency is an incremental technological change on the engine hence the costs are assumed not to escalate.

Finally, the economic output should remain similar to the reference scenario as the trade factors or the private consumption factors are not expected to be modified in this scenario.

Comparison to ASTRA-EC results

The scenario output is similar to the reference expect from the CO_2 emissions. These, due to fuel efficiency decrease at a faster pace of 0.7% annually, instead of 0.3%. This result confirms that the application of fuel efficiency TPM on road transport could have positive changes on the CO_2 emissions.

Table 5-15: Scenario outcomes for CO_2 emission limits

Scenario name \ 2010-2050 relative change	GDP	Employment	Passenger demand	Freight demand	CO_2 emissions
Reference	+1.6% annual change	-0.1% annual change	+0.8% annual change	+1% annual change	-0.3% annual change
CO2 limits expected	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference	Decreased compared to Reference
CO2 limits Results	+1.6% annual change	-0.1% annual change	+0.8% annual change	+1% annual change	-0.7% annual change

Source: ASTRA-EC

In terms of modal split, the road transport, as more efficient increases marginally its share from 68% to 70% by 2050. The other indicators (transport, economic) remain the same as the fuel efficiency does not have an impact on trade figures and does not drive the passenger demand.

5.2.5 City logistics

Expected impact

The implementation of this TPM is expressed via the increment of the load factors of HDVs and LDVs by 1% and 15% respectively. Due to the scenario definition, there should be no changes in the economic factors as the change in load factors should also be translated in terms of efficiency of the road vehicle stock. The scenario could produce an improvement in CO_2 emissions; however, the applied factors do not suggest a significant change. Finally, this scenario is not expected to affect the total freight demand.

Comparison to ASTRA-EC results

Based on the scenario run, the outputs for the economic variables (GDP, employment) demonstrate no change. The same does the total freight demand. The scenario also does not depict any change in the road share as the total tons transported by road remain the same. The increment in average load factors is depicted in the output in vehicles-km. These are decreased by circa 1% for HDVs and 13% for LDVs, linking directly the load factors to the vehicle demand.

Another slight difference is observed for the CO_2 emissions, which are decreased by 0.33% annually instead of 0.31%, due to the road vehicle efficiency.

Table 5-16: Scenario outcomes for city logistics

Scenario name \ 2010-2050 relative change	GDP	Employment	Freight demand	CO2 emissions
Reference	+1.6% annual change	-0.1% annual change	+1% annual change	-0.31% annual change
City logistics expected	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
City logistics Results	+1.6% annual change	-0.1% annual change	+1% annual change	-0.33% annual change

Source: ASTRA-EC

In total the results of the logistics model do not present significant differences from the reference scenario. Indeed the main impact of this measure is improving load factor for light duty vehicles which operate mainly at local level where they are already monopolist. So, even with a lower unitary cost (cost per tkm) thanks to the higher average load, there is basically no demand which can be attracted by road transport.

5.2.6 Electromobility road

Expected impacts

The promotion of electric road vehicles could be, on the first sight, expected to have negative impact on the passenger road mileage due to the limited travel range of EVs. Taking into account that even today's low range of BEVs suits to the majority of daily trips, the implication of less annual mileages is not valid such that even an increase of pkm by car could be the expected result.

With regard to freight vehicles, the impact is marginal as the scenario assumes that the implementation of the policy regards only city logistics, therefore the limited range does not play an important role. The service and comfort is also negative affected mainly due to the necessary charging times.

The economic impact on alternative vehicle road costs is overall expected to be positive as it is defined only for the operational costs and due to additional investment in R&D.

The impact of the eMobility on competitiveness, and consequently on employment, is positive as the adoption of innovative vehicles creates new business opportunities; at the same time, the anticipated effects should be rather limited. The strongest impact is expected on emissions, which should decrease considerably. As a consequence, eMobility is expected to have positive effects on health as the air pollution and noise emissions especially in urban areas. The effects of the scenario are expected to take effect in 2015.

Comparison to ASTRA-EC results

The eMobility scenario outputs were compared to the expected outcomes. Even though the scenario did not anticipate any major changes in its results on aggregate level. The table below depicts the annual growth rates for the specific set of output variables and compares the expected change with the scenario results. As it can be seen below, the variables do not deviate significantly from the expected output.

Table 5-17: Scenario outcomes of eMobility

Scenario name \ 2010-2050 relative change	GDP	Employment	Passenger demand	Freight demand	CO_2 emissions
Reference	+1.6% annual change	-0.1% annual change	+0.8% annual change	+1% annual change	-0.31% annual change
eMobility (expected)	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference	Decreased compared to Reference
eMobility Results	+1.6% annual change	-0.1% annual change	+0.8% annual change	+1% annual change	-0.63% annual change

Source: ASTRA-EC

More specifically, the total demand figures for transport demand do not change between the reference and the eMobility scenario as the trade in EU is not influenced by this TPM; this is also reflected in the GDP growth, which is almost the same in the two scenarios. The observed employment decreases but with a slightly slower pace (instead of -0.05% pa, -0.04 pa).

The car passenger demand (pkm) increases, compared to the reference scenario, by 3.8% by 2050, while the freight demand does not change. This is expected as the model allocates decreased operational costs for EVs, shifting passenger demand to road but also public transport demand to private. This is why public transport (bus) demand decreases by 9.9% by 2050.

For freight transport this is not the case as due to the range limitation, the long-distance travel is not covered by the EVs. In terms of freight modal split, the road share decreases marginally, and shifts the demand to rail and maritime transport; air and rail lose modal share in the passenger modal split.

The emissions represent the most significant change, a decrease of 12.3% by 2050. This is because the eMobility scenario assumes a continuous penetration of EVs (economies of scale for the technology and learning rate of 10%). A share of 50% of total road vehicles will be reached by 2050.

5.3 Impacts of future challenges: Shortage of fossil fuels

The ASTRA-EC model can also be used to assess the impact of changes in exogenous conditions like the external challenges addressed in the Deliverable D3.1 of ASSIST. Here the example of shortage of fossil fuels is considered. This scenario is simulated in ASTRA-EC by assuming that fuel prices become progressively higher than in the reference scenario. Table 5-18 reports the increment of user cost per litre for the fossil fuel types and for the biodiesel. An increment of the biodiesel price simulates a shortage of supply also for this alternative fuel.

The price increments applied in the scenario are not huge: in the last 15 years in some countries the pump price of gasoline and diesel has increased more than the amount assumed in the scenario. For instance the assumed gasoline price in the year 2050 is around 2.5 Euro/litre (in Euro2005) while for diesel the simulated price is nearly 3 Euro/litre (still in the year 2050).

Table 5-18: Increased user fuel prices in the fossil fuel shortage scenario with respect to the reference scenario

Fuel type	Var% 2030	Var % 2050
Gasoline	21%	44%
Diesel	47%	96%
LPG	7%	15%
CNG	17%	28%
Biodiesel	18%	25%

Source: TRT

Table 5-19 summarises some key impacts in this scenario according to the ASTRA-EC model.

Total transport activity is not much affected. Total passenger-km are only slightly reduced whereas total tonne-km are even slightly increased. The mode shift effect already mentioned above explains this outcome. As mentioned above the energy price increment simulated is not above growths experienced in the past and model results looks realistic in showing that overall demand is not significantly affected in the long term.

Of course however some mode shift occurs. Car share is reduced up to 3% in the year 2050 (from 68% to 66%) while truck share is lowered by nearly 5% from 46% to 44%. For passenger and freight, most of the demand lost by private road modes is shifted on rail, whose mode share in the year 2050 grows to 11% for passengers (instead of 9%) and 12% for freight (instead of 10%).

Another impact on car mobility is a faster renewal of the fleet. Conventional cars (gasoline and diesel) lose some of their market share, replaced by innovative cars (especially electric cars).

Table 5-19: Key impacts for EU27 of fossil fuel shortage – variations with respect to the reference scenario

Indicator	Var% 2030	Var % 2050
Passenger transport performance (passenger-km)	-0.3%	-0.2%
Car mode share	-2.0%	-2.8%
Passenger train mode share	11.7%	18.1%
Air mode share	-2.5%	-7.3%
Freight transport performance (freight-km)	0.7%	1.1%
Truck mode share	-1.9%	-4.7%
Freight train mode share	5.9%	13.8%
Gasoline + Diesel cars market share	-2.9%	-5.3%
Fuel tax revenues	-3.8%	-9.3%
Average transport expenditure low income	11.7%	19.4%
Average transport expenditure medium income	11.4%	19.4%
Average transport expenditure high income	11.2%	19.7%
GDP	-0.4%	-1.1%
Employment	-0.2%	-0.6%
CO2 emissions from transport	-3.9%	-8.5%

Source: ASTRA-EC model

Since less conventional cars are used, there is a loss of fuel tax revenues. This loss is moderate in the year 2030 (-3.5%) and a bit larger in 2050: -9.0% which amounts to more the 15 billion Euro at the EU27 level.

Personal mobility gets more expensive. The average expenditure for transport is about 11% higher in the year 2030 and nearly 20% higher in the year 2050. This is of course much less than the assumed increase for fossil fuel prices because of mode shift and of the fleet renewal. No significant differences are found for the three income groups.

GDP is negatively affected although only slightly and so it is employment. The negative impact is driven by the reduction of income for non-transport consumption and by the lower Total Factor Productivity because of the higher transport costs.

Finally, CO_2 emissions are reduced thanks to the mode shift to non-road modes whose unitary emissions are lower but also thanks to more efficient road vehicles.

6 Conclusions

One of the main objectives of this deliverable was to describe how key indicators in the ASTRA-EC model were fit to validated data source for the historical time period from 1995 to 2010 and reference projections from 2010 to 2050. The deliverable provides a comprehensive overview on the chosen approach and the quality of the calibration and validation. ASTRA-EC calculates each indicator in every year between 1995 and 2050. Even if the calibration cannot of a System Dynamics model cannot only concentrate on one single point of time but on a whole time series a high quality of calibration could be achieved. This implies that deviations between statistical data for 1995 to 2010 and calculated ASTRA-EC indicators are common but are in a marginal and acceptable range of altitude.

The second task described in this deliverable is the matching of key indicator development in ASTRA-EC from 2010 to 2050 with projections from the 2013 Reference Scenario from PRIMES-TREMOVE. In principle, ASTRA-EC does not require many exogenous inputs in terms of trends. It should be considered that the ASTRA-EC model is a tool to provide endogenous forecasts sensitive to key determinants. Therefore the target of the model is to provide realistic long-term average growth rates rather than point estimations at a given year. ASTRA-EC could be successfully adapted towards the main projections from PRIMES-TREMOVE. Nevertheless, the internal consistency of reference trends are a prerequisite such that some trends like the truck fleet development differ from the modelled reference trends in PRIMES-TREMOVE.

Another objective of the deliverable consisted of the application of ASTRA-EC for policy analysis. Therefore, the ASTRA-EC Reference Scenario trends are elaborated before the report shows the application of ASTRA-EC for a selected number of transport policy measures. Six measures from different types of transport policy categories were selected. As a summary, ASTRA-EC could provide detailed impact assessment results for a number of social, economic, transport and environmental indicators. The degree of a quantitative assessment of social impacts is limited due to the characteristics of most social impacts. They occur mainly on local level whereas ASTRA-EC is a macro-level model. Given these restrictions, ASTRA-EC simulated impacts of TPMs on labour market and could give an indication about the influence of a policy on mobility expenditures for different income groups.

The integrated structure of ASTRA-EC proved to be helpful in assessing impacts of TPMs that occur on second or third level. Another type of impact often not considered is rebound effect. The model structure allows identifying these rebounds and thus enables a more realistic and comprehensive assessment of impacts. As an example the measure Electromobility Road lead to an accelerated diffusion of battery and hybrid electric vehicles. Even if the purchase prices are at least nowadays significantly higher than for conventional cars, the measure induces lower costs of operation for cars on average. Hence, modal share of cars increases which is under consideration of the climate impact an undesired impact. Another example is the TPM Energy Taxation. Setting minimum tax rates for different fuels and for energy as proposed by the European Commission in 2011 will impact the technical composition of the vehicle fleets but differently as expected. Especially CNG, LPG and diesel cars are facing higher fuel costs but costs for gasoline remain in most countries such that gasoline cars reach a higher share than in the Reference Scenario.

In order to validate the impact assessment results expected results were documented ex-post. These expectations were then confronted with ASTRA-EC assessment results. For the differences between expected and actual modelling results, an analysis of the origins of these differences is made. Finally, ASTRA-EC was applied to test for the implications of one of the major future challenges, scarcity of fossil fuels.

7 References

Bossel H. (1994): *Modellbildung und Simulation – Konzepte, Verfahren und Modelle zum Verhalten dynamischer Systeme*. 2nd edition, Vieweg, Brunswick, Germany.

EC DG ECFIN (2012): *Ageing Report 2012*. European Commission, Brussels, Belgium.

EC (2013): *EU Energy, Transport and GHG Emissions. Trends to 2050 – Reference Scenario 2013.* European Commission Directorate-General for Climate Action and Directorate-General for Mobility and Transport. Brussels, Belgium.

Fermi F., Fiorello D., Krail M., Schade W. (2013): *Description of the ASTRA-EC model and of the user interface*. Deliverable D4.2 of ASSIST (Assessing the social and economic impacts of past and future sustainable transport policy in Europe). Project co-funded by European Commission 7th RTD Programme. Fraunhofer-ISI, Karlsruhe, Germany

Krail M. (2009): *System-Based Analysis of Income Distribution Impacts on Mobility Behaviour*. Dissertation at the University of Karlsruhe (TH), Nomos-Verlag, Baden-Baden, Germany.

Schade W. (2005): *Strategic Sustainability Analysis: Concept and application for the assessment of European Transport Policy*. Nomos Verlag, Baden-Baden, Germany.

Schade W., Akkermans L., Fiorello D., Jopson A., Köhler J., Krail M., Moizo A., Schade B., Shepherd S., Sievers L., Tercero L., vanHerle K., Weiss C., Wiesenthal T. (2011): Bottom-up quantifications of selected measures to reduce GHG emissions of transport for the time horizons 2020 and 2050: Cost assessment of GHG mitigation measures of transport. Deliverable D3.1 of GHG-TransPoRD (Reducing greenhouse-gas emissions of transport beyond 2020: linking R&D, transport policies and reduction targets). Project cofounded by European Commission 7th RTD Programme. Fraunhofer-ISI, Karlsruhe, Germany.

Annex 1: Key indicators for the ASTRA-EC calibration

Calibration indicators by country

The following tables provide further information about the calibration of key indicators in ASTRA-EC. While the majority of tables and figures in the main text are on aggregate EU27, EU15 or EU12 level, the attached tables and figures are on country level.

Table : Passenger demand mode split by country (%): year 2000

Country	Car		Bus		Train	
	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC
Austria	76%	75%	10%	10%	14%	16%
Belgium	83%	83%	10%	10%	7%	7%
Bulgaria	59%	61%	32%	30%	9%	10%
Cyprus	78%	81%	22%	19%	0%	0%
Denmark	82%	81%	9%	9%	9%	10%
Estonia	69%	68%	27%	28%	4%	4%
Spain	80%	81%	13%	12%	7%	6%
Finland	83%	83%	11%	11%	6%	6%
France	85%	85%	5%	6%	10%	9%
United Kingdom	87%	86%	7%	8%	6%	7%
Greece	72%	71%	25%	26%	4%	3%
Hungary	60%	62%	24%	22%	16%	16%
Ireland	84%	85%	13%	12%	3%	3%
Italy	83%	82%	11%	11%	6%	7%
Latvia	78%	78%	16%	15%	7%	7%
Lithuania	89%	85%	9%	12%	2%	3%
Luxembourg	85%	85%	9%	9%	5%	6%
Malta	80%	77%	20%	22%	0%	0%
Netherlands	84%	81%	7%	8%	10%	11%
Poland	71%	73%	15%	15%	14%	12%
Portugal	81%	79%	14%	14%	5%	7%
Czech Republic	67%	67%	17%	18%	16%	16%
Germany	84%	85%	7%	7%	9%	9%
Romania	63%	60%	15%	18%	22%	23%
Slovak Republic	66%	57%	26%	31%	9%	12%
Slovenia	83%	82%	14%	15%	3%	3%
Sweden	82%	83%	8%	8%	9%	9%

Source: TRT

Table: Passenger demand mode split by country (%): year 2005

Country	Car		Bus		Train	
	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC
Austria	76%	76%	10%	9%	14%	14%
Belgium	80%	82%	13%	10%	7%	7%
Bulgaria	68%	62%	27%	29%	5%	9%
Cyprus	79%	82%	21%	18%	0%	0%
Denmark	81%	81%	10%	9%	10%	10%
Estonia	77%	70%	21%	27%	2%	4%
Spain	81%	82%	13%	12%	7%	6%
Finland	84%	85%	10%	10%	5%	5%
France	84%	84%	5%	5%	10%	10%
United Kingdom	87%	86%	6%	7%	7%	7%
Greece	77%	73%	20%	24%	3%	3%
Hungary	62%	64%	22%	21%	15%	15%
Ireland	83%	86%	13%	11%	4%	2%
Italy	81%	83%	12%	11%	7%	6%
Latvia	75%	83%	18%	12%	7%	5%
Lithuania	89%	87%	9%	10%	1%	3%
Luxembourg	86%	85%	11%	9%	4%	6%
Malta	80%	79%	20%	21%	0%	0%
Netherlands	84%	83%	7%	7%	9%	10%
Poland	79%	82%	12%	10%	9%	9%
Portugal	84%	81%	11%	13%	5%	6%
Czech Republic	69%	70%	16%	16%	15%	15%
Germany	84%	85%	7%	6%	9%	9%
Romania	70%	66%	14%	15%	17%	19%
Slovak Republic	70%	65%	23%	26%	7%	9%
Slovenia	85%	84%	12%	13%	3%	3%
Sweden	83%	85%	7%	6%	9%	9%

Source: TRT

Table: Passenger demand mode split by country (%): year 2010

Country	Car		Bus		Train	
	Eurostat	**ASTRA-EC**	**Eurostat**	**ASTRA-EC**	**Eurostat**	**ASTRA-EC**
Austria	75%	77%	10%	9%	15%	14%
Belgium	78%	81%	14%	11%	8%	8%
Bulgaria	77%	68%	18%	24%	5%	7%
Cyprus	82%	83%	18%	17%	0%	0%
Denmark	80%	82%	10%	9%	10%	10%
Estonia	81%	76%	17%	21%	3%	3%
Spain	81%	81%	12%	12%	7%	6%
Finland	84%	86%	10%	10%	6%	5%
France	83%	82%	6%	6%	11%	12%
United Kingdom	85%	86%	6%	6%	9%	8%
Greece	80%	74%	17%	23%	2%	3%
Hungary	67%	68%	20%	19%	13%	14%
Ireland	84%	87%	13%	11%	3%	2%
Italy	82%	83%	12%	11%	6%	6%
Latvia	85%	85%	10%	10%	5%	5%
Lithuania	91%	87%	8%	10%	1%	3%
Luxembourg	83%	84%	12%	9%	4%	6%
Malta	81%	81%	19%	19%	0%	0%
Netherlands	83%	84%	7%	7%	10%	9%
Poland	87%	86%	6%	7%	7%	7%
Portugal	84%	81%	11%	13%	5%	6%
Czech Republic	66%	70%	18%	16%	16%	14%
Germany	85%	84%	6%	6%	9%	9%
Romania	75%	72%	12%	12%	13%	16%
Slovak Republic	77%	76%	15%	18%	7%	7%
Slovenia	87%	86%	11%	12%	3%	2%
Sweden	82%	86%	7%	6%	11%	9%

Source: TRT

Table: Freight demand mode split by country (%): year 2000

Country	Truck		IWW		Train	
	Eurostat	**ASTRA-EC**	**Eurostat**	**ASTRA-EC**	**Eurostat**	**ASTRA-EC**
Austria	63%	63%	5%	5%	32%	32%
Belgium	81%	78%	9%	12%	10%	10%
Bulgaria	48%	40%	8%	8%	44%	51%
Cyprus	100%	100%	0%	0%	0%	0%
Denmark	92%	94%	0%	0%	8%	6%
Estonia	50%	54%	0%	0%	50%	46%
Spain	93%	92%	0%	0%	7%	8%
Finland	81%	81%	0%	0%	19%	19%
France	78%	81%	3%	3%	19%	16%
United Kingdom	90%	90%	0%	0%	10%	9%
Greece	99%	99%	0%	0%	1%	1%
Hungary	68%	69%	4%	4%	28%	27%
Ireland	96%	94%	0%	0%	4%	6%
Italy	90%	90%	0%	0%	10%	10%
Latvia	86%	85%	0%	0%	14%	15%
Lithuania	62%	64%	0%	0%	38%	36%
Luxembourg	85%	88%	6%	5%	9%	8%
Malta	100%	100%	0%	0%	0%	0%
Netherlands	63%	59%	34%	38%	4%	3%
Poland	52%	42%	1%	1%	47%	57%
Portugal	94%	94%	0%	0%	6%	6%
Czech Republic	62%	58%	0%	0%	37%	42%
Germany	67%	67%	15%	14%	18%	19%
Romania	40%	40%	9%	9%	51%	51%
Slovak Republic	53%	49%	7%	6%	40%	46%
Slovenia	58%	57%	0%	0%	42%	43%
Sweden	67%	67%	0%	0%	33%	33%

Source: TRT

Table: Freight demand mode split by country (%): year 2005

Country	Truck		IWW		Train	
	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC
Austria	61%	61%	3%	3%	36%	35%
Belgium	78%	75%	11%	15%	11%	10%
Bulgaria	63%	52%	11%	10%	26%	38%
Cyprus	100%	100%	0%	0%	0%	0%
Denmark	92%	93%	0%	0%	8%	7%
Estonia	51%	55%	0%	0%	49%	45%
Spain	95%	95%	0%	0%	5%	5%
Finland	82%	82%	0%	0%	18%	18%
France	83%	84%	3%	3%	14%	13%
United Kingdom	89%	90%	0%	0%	11%	10%
Greece	98%	99%	0%	0%	2%	1%
Hungary	68%	67%	7%	7%	24%	25%
Ireland	98%	95%	0%	0%	2%	5%
Italy	91%	91%	0%	0%	9%	9%
Latvia	86%	90%	0%	0%	14%	10%
Lithuania	64%	64%	0%	0%	36%	36%
Luxembourg	88%	88%	5%	4%	6%	8%
Malta	100%	100%	0%	0%	0%	0%
Netherlands	62%	55%	33%	42%	5%	3%
Poland	61%	57%	0%	0%	38%	43%
Portugal	93%	93%	0%	0%	7%	7%
Czech Republic	67%	64%	0%	0%	33%	35%
Germany	68%	68%	13%	13%	19%	19%
Romania	62%	55%	13%	16%	25%	29%
Slovak Republic	65%	57%	4%	4%	32%	39%
Slovenia	67%	60%	0%	0%	33%	40%
Sweden	68%	67%	0%	0%	32%	33%

Source: TRT

Table: Freight demand mode split by country (%): year 2010

Country	Truck		IWW		Train	
	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC
Austria	61%	60%	4%	4%	34%	36%
Belgium	78%	75%	13%	15%	10%	10%
Bulgaria	57%	54%	30%	24%	13%	23%
Cyprus	100%	100%	0%	0%	0%	0%
Denmark	89%	90%	0%	0%	11%	10%
Estonia	51%	56%	0%	0%	49%	44%
Spain	95%	96%	0%	0%	5%	4%
Finland	80%	81%	0%	0%	20%	18%
France	87%	86%	3%	3%	10%	11%
United Kingdom	89%	89%	0%	0%	11%	11%
Greece	98%	98%	0%	0%	2%	2%
Hungary	71%	70%	7%	8%	21%	21%
Ireland	99%	96%	0%	0%	1%	4%
Italy	91%	92%	0%	0%	9%	8%
Latvia	87%	90%	0%	0%	13%	10%
Lithuania	60%	65%	0%	0%	40%	35%
Luxembourg	90%	86%	7%	5%	4%	9%
Malta	100%	100%	0%	0%	0%	0%
Netherlands	55%	59%	39%	37%	6%	4%
Poland	74%	71%	0%	0%	26%	29%
Portugal	91%	93%	0%	0%	9%	7%
Czech Republic	74%	68%	0%	0%	26%	32%
Germany	68%	69%	12%	12%	20%	19%
Romania	43%	51%	31%	24%	25%	25%
Slovak Republic	70%	64%	5%	4%	25%	32%
Slovenia	71%	66%	0%	0%	29%	34%
Sweden	65%	67%	0%	0%	35%	33%

Source: TRT

Table: CO2 transport emissions by country (Mio Tons / year)

Country	2000		2005		2010	
	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC	Eurostat	ASTRA-EC
Austria	20.4	17.7	26.5	18.0	24.2	18.0
Belgium	27.4	23.3	29.2	22.6	30.7	21.2
Bulgaria	5.8	6.8	7.7	7.2	8.1	7.8
Cyprus	2.5	3.8	2.9	4.5	3.2	5.2
Denmark	14.0	11.9	15.3	11.2	15.1	10.2
Estonia	1.8	2.2	2.2	2.3	2.3	2.4
Spain	94.2	81.7	110.4	92.5	101.2	91.4
Finland	12.7	16.2	13.8	15.8	13.9	15.4
France	150.4	162.1	155.0	169.6	146.6	162.0
United Kingdom	152.2	131.0	158.8	132.4	145.8	121.9
Greece	20.0	21.2	22.7	21.8	22.7	20.1
Hungary	9.7	9.8	12.5	10.0	12.5	10.3
Ireland	13.1	10.7	15.6	14.0	13.6	13.1
Italy	123.5	134.9	130.6	140.3	122.1	132.1
Latvia	2.4	2.4	3.2	2.8	3.6	2.9
Lithuania	3.3	4.1	4.3	4.6	4.5	5.4
Luxembourg	6.0	1.9	8.2	1.9	7.7	1.8
Malta	0.7	1.4	0.8	1.5	0.9	1.4
Netherlands	41.7	31.0	45.0	31.5	44.6	31.7
Poland	28.5	39.2	35.7	44.9	49.2	57.6
Portugal	21.2	19.6	21.9	21.2	21.3	19.8
Czech Republic	13.2	14.4	18.9	15.4	18.3	15.7
Germany	198.0	177.0	180.1	180.1	174.6	174.5
Romania	8.7	11.3	12.6	13.0	14.6	13.7
Slovak Republic	4.3	5.8	6.4	6.0	6.8	6.5
Slovenia	3.9	5.0	4.5	5.2	5.3	5.4
Sweden	20.6	22.3	22.5	22.9	21.8	22.1

Source: TRT

Annex 2: Additional indicators for the ASTRA-EC validation

Validation indicators by country

The following additional tables provide a detailed comparison between trends for some key indicators calculated with ASTRA-EC and those from the 2013 Reference Scenario calculated with PRIMES-TREMOVE for the period 2010 to 2050.

Table: Trend of total passenger demand by mode by country: average yearly growth rate.

	Mode	2010 - 2020		2020 - 2030		2030 - 2050	
		PRIMES	ASTRA-EC	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC
AT	Car	0.7%	1.0%	0.7%	1.0%	0.6%	0.2%
	Bus	0.9%	1.3%	0.7%	0.5%	0.5%	0.4%
	Train	1.5%	2.0%	1.1%	0.9%	0.8%	0.5%
	Air	3.3%	2.4%	3.0%	2.0%	1.4%	1.1%
BE	Car	0.6%	1.2%	1.0%	0.7%	0.9%	0.3%
	Bus	1.0%	2.0%	0.9%	0.7%	0.8%	0.5%
	Train	1.6%	2.2%	2.1%	-0.1%	1.1%	0.8%
	Air	2.4%	1.9%	2.8%	0.7%	1.9%	0.9%
DK	Car	0.4%	1.1%	0.5%	1.2%	0.4%	0.7%
	Bus	0.7%	1.2%	0.8%	0.4%	0.8%	-0.2%
	Train	1.0%	0.8%	1.1%	0.3%	1.1%	-0.3%
	Air	2.8%	2.1%	2.9%	2.6%	1.8%	1.7%
ES	Car	0.6%	0.8%	2.6%	1.7%	0.8%	0.4%
	Bus	0.8%	1.0%	1.4%	0.1%	0.8%	0.7%
	Train	2.9%	2.7%	4.3%	2.5%	1.3%	2.0%
	Air	2.2%	1.5%	2.6%	2.4%	1.7%	2.4%
FI	Car	0.6%	1.1%	0.3%	0.5%	0.3%	0.5%
	Bus	0.6%	0.6%	0.3%	-0.1%	0.3%	0.2%
	Train	1.4%	1.3%	1.1%	0.7%	0.7%	1.1%
	Air	2.7%	1.7%	3.1%	0.9%	1.8%	1.2%
FR	Car	0.5%	0.6%	1.0%	0.7%	0.6%	0.7%
	Bus	1.1%	1.7%	1.1%	0.5%	0.7%	1.1%
	Train	1.1%	1.7%	2.2%	0.8%	1.5%	1.6%
	Air	2.2%	1.2%	2.2%	0.8%	1.3%	1.9%
UK	Car	0.7%	1.1%	0.9%	0.9%	0.6%	0.6%
	Bus	0.8%	1.9%	1.0%	0.0%	0.6%	1.1%
	Train	1.3%	2.8%	1.2%	0.5%	0.7%	0.8%

	Air	1.8%	1.2%	2.7%	0.7%	1.5%	0.8%
DE	Car	0.3%	0.4%	0.1%	0.2%	0.0%	0.1%
	Bus	0.7%	0.7%	0.4%	0.3%	0.3%	0.0%
	Train	2.0%	2.2%	1.6%	2.1%	1.0%	1.4%
	Air	2.6%	1.1%	2.4%	0.5%	1.0%	1.6%
EL	Car	0.2%	1.7%	0.4%	1.7%	0.4%	0.4%
	Bus	0.5%	0.8%	0.5%	-1.7%	0.3%	-0.4%
	Train	0.9%	1.5%	1.4%	-1.6%	1.4%	-1.0%
	Air	3.0%	3.6%	3.3%	2.0%	1.7%	1.0%
IE	Car	1.1%	2.1%	1.7%	1.4%	1.1%	0.6%
	Bus	0.5%	0.4%	1.3%	-0.5%	0.9%	-0.8%
	Train	0.9%	1.7%	1.3%	1.3%	0.9%	-0.3%
	Air	2.4%	2.1%	2.4%	1.6%	1.6%	0.6%
IT	Car	0.2%	0.6%	0.8%	0.6%	0.4%	0.1%
	Bus	0.2%	1.5%	0.7%	0.3%	0.4%	0.5%
	Train	0.9%	1.7%	2.1%	1.1%	0.9%	1.0%
	Air	2.9%	1.5%	2.5%	0.8%	1.5%	0.8%
NL	Car	0.4%	0.9%	0.6%	0.7%	0.3%	0.3%
	Bus	0.9%	1.2%	0.6%	-0.4%	0.7%	-0.4%
	Train	1.3%	1.7%	1.4%	-0.2%	1.1%	-0.3%
	Air	2.5%	1.5%	2.8%	0.8%	1.5%	0.5%
PT	Car	0.1%	1.0%	1.5%	1.1%	0.7%	0.1%
	Bus	0.1%	1.3%	1.8%	0.1%	0.9%	0.5%
	Train	1.1%	2.2%	3.7%	0.3%	1.5%	0.6%
	Air	2.3%	2.5%	2.4%	1.3%	1.8%	0.5%
SE	Car	0.8%	1.0%	0.8%	0.9%	0.4%	0.6%
	Bus	1.4%	2.0%	0.8%	0.0%	0.5%	0.2%
	Train	1.3%	3.6%	1.1%	0.2%	0.7%	-0.2%
	Air	2.8%	1.8%	3.1%	0.8%	1.8%	0.4%
BG	Car	0.4%	3.0%	0.4%	0.9%	0.2%	0.2%
	Bus	0.6%	-1.9%	0.6%	-0.9%	0.4%	0.6%
	Train	2.4%	-0.6%	1.4%	0.3%	0.6%	0.9%

	Air	4.5%	4.9%	3.8%	1.6%	2.3%	1.7%
CY	Car	0.9%	2.9%	1.6%	1.5%	0.7%	0.4%
	Bus	1.0%	2.6%	0.9%	0.0%	0.5%	0.1%
	Train	0.0%	7.7%	0.0%	1.9%	0.0%	-0.6%
	Air	4.0%	3.2%	3.5%	1.3%	1.3%	0.2%
CZ	Car	1.4%	1.1%	1.4%	1.6%	1.0%	0.7%
	Bus	1.3%	1.2%	1.0%	0.9%	0.7%	0.7%
	Train	2.1%	2.0%	1.6%	1.4%	1.1%	1.2%
	Air	3.4%	3.0%	3.4%	2.8%	1.8%	1.6%
EE	Car	1.1%	1.6%	1.1%	1.5%	0.5%	0.4%
	Bus	1.2%	-1.9%	0.8%	0.7%	0.4%	1.0%
	Train	2.3%	-0.8%	2.3%	4.8%	1.4%	3.1%
	Air	4.1%	-0.3%	4.3%	8.2%	2.9%	3.7%
HU	Car	0.7%	1.7%	1.9%	0.9%	0.8%	0.5%
	Bus	0.7%	1.2%	1.0%	0.3%	0.5%	0.4%
	Train	1.2%	2.2%	2.3%	0.1%	1.1%	1.0%
	Air	3.9%	4.0%	3.8%	1.3%	2.4%	1.9%
LV	Car	0.7%	1.5%	0.8%	2.4%	0.4%	0.3%
	Bus	1.0%	-0.9%	1.2%	4.6%	0.7%	1.0%
	Train	2.2%	0.4%	2.4%	6.6%	1.6%	1.6%
	Air	4.5%	2.4%	4.6%	11.2%	2.8%	2.3%
LT	Car	0.9%	1.3%	0.7%	0.7%	0.2%	-0.1%
	Bus	0.8%	-1.3%	0.7%	-1.6%	0.2%	-2.2%
	Train	2.1%	1.1%	2.5%	0.1%	1.5%	-1.0%
	Air	4.5%	2.0%	4.2%	1.3%	3.0%	-0.1%
MT	Car	0.3%	2.1%	0.3%	0.3%	0.4%	-0.3%
	Bus	0.3%	-1.0%	0.2%	0.8%	0.2%	0.7%
	Train	0.0%	1.8%	0.0%	1.0%	0.0%	0.0%
	Air	3.7%	0.6%	3.1%	0.9%	1.5%	0.3%
PL	Car	1.8%	2.0%	1.3%	1.4%	0.7%	0.5%
	Bus	0.1%	0.2%	0.7%	-0.5%	0.4%	0.4%
	Train	2.6%	1.5%	4.0%	1.0%	1.1%	1.7%

	Air	4.0%	3.3%	3.6%	2.7%	2.4%	2.9%
RO	Car	1.6%	1.9%	1.9%	2.0%	1.1%	1.2%
	Bus	1.3%	-0.7%	1.2%	0.7%	1.0%	1.1%
	Train	2.7%	0.3%	2.4%	1.3%	1.7%	1.4%
	Air	5.3%	3.8%	4.7%	4.3%	2.7%	3.7%
SI	Car	1.3%	0.9%	1.1%	1.0%	0.4%	0.1%
	Bus	0.7%	0.7%	0.5%	-1.3%	0.2%	-0.8%
	Train	5.3%	1.6%	4.6%	-0.4%	1.1%	0.1%
	Air	3.8%	2.1%	3.3%	1.0%	2.3%	0.1%
SK	Car	2.0%	1.1%	2.3%	1.8%	0.7%	0.9%
	Bus	2.1%	-1.2%	2.4%	0.1%	0.7%	0.5%
	Train	2.4%	1.1%	3.1%	3.6%	1.1%	2.1%
	Air	4.7%	1.4%	3.6%	4.4%	2.8%	2.7%
LU	Car	1.5%	2.1%	0.9%	1.3%	0.7%	0.7%
	Bus	1.4%	2.9%	1.1%	0.8%	0.7%	0.7%
	Train	1.7%	2.6%	1.5%	0.1%	1.0%	-0.4%
	Air	2.5%	2.0%	2.7%	0.8%	1.8%	0.3%

Source: TRT

Table: Trend of total freight demand by mode by country: average yearly growth rate.

	Mode	2010 - 2020		2020 - 2030		2030 - 2050	
		PRIMES	ASTRA-EC	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC
AT	Truck	4.7%	2.1%	1.0%	1.7%	0.5%	0.7%
	Train	1.2%	1.7%	1.3%	1.2%	1.0%	0.9%
	IWW	1.4%	2.1%	0.9%	0.8%	0.7%	0.5%
	Maritime	--	--	--	--	--	--
BE	Truck	2.5%	1.4%	2.1%	1.2%	0.9%	1.3%
	Train	3.7%	3.4%	3.0%	1.9%	1.0%	1.4%
	IWW	1.5%	0.0%	2.4%	1.6%	1.0%	1.1%
	Maritime	1.5%	0.9%	0.6%	0.9%	0.6%	0.8%
DK	Truck	2.6%	0.4%	1.1%	0.7%	0.8%	0.5%
	Train	1.7%	3.6%	1.8%	2.2%	1.1%	0.9%
	IWW	--	--	--	--	--	--
	Maritime	2.4%	2.6%	1.0%	0.8%	1.0%	0.6%
ES	Truck	1.0%	2.1%	2.1%	1.4%	0.8%	0.8%
	Train	2.1%	0.8%	2.8%	1.6%	0.8%	0.6%
	IWW	--	--	--	--	--	--
	Maritime	2.9%	3.1%	1.0%	1.5%	1.0%	1.1%
FI	Truck	1.1%	2.2%	1.1%	0.6%	0.8%	0.0%
	Train	2.0%	1.9%	1.6%	1.3%	1.1%	0.6%
	IWW	1.3%	1.1%	1.2%	0.3%	0.9%	0.0%
	Maritime	2.9%	1.1%	1.0%	1.1%	1.0%	0.8%
FR	Truck	2.0%	2.0%	2.0%	0.8%	0.7%	0.6%
	Train	4.6%	3.4%	4.1%	2.4%	0.8%	0.8%
	IWW	1.1%	1.7%	1.2%	1.4%	0.4%	0.9%
	Maritime	2.9%	2.1%	0.3%	0.6%	0.3%	0.5%
UK	Truck	1.1%	1.6%	1.5%	0.7%	0.8%	0.4%
	Train	1.5%	1.8%	1.6%	0.9%	0.9%	0.8%
	IWW	1.1%	-0.3%	1.0%	0.4%	0.2%	0.0%

	Maritime	2.7%	1.0%	0.9%	0.9%	0.9%	0.7%
DE	Truck	0.6%	0.6%	0.7%	0.0%	0.3%	-0.1%
	Train	1.7%	1.8%	1.5%	0.9%	0.5%	0.5%
	IWW	0.9%	0.4%	0.9%	1.0%	0.4%	0.7%
	Maritime	2.9%	1.3%	0.7%	0.8%	0.7%	0.6%
EL	Truck	0.5%	0.5%	0.8%	0.9%	0.7%	0.6%
	Train	0.6%	1.3%	1.0%	0.8%	0.9%	0.5%
	IWW	--	--	--	--	--	--
	Maritime	2.9%	1.3%	1.0%	0.5%	1.0%	0.5%
IE	Truck	2.8%	-0.1%	2.6%	2.8%	1.4%	2.2%
	Train	1.4%	0.3%	1.3%	1.1%	0.9%	1.4%
	IWW	--	--	--	--	--	--
	Maritime	2.9%	3.3%	1.0%	1.0%	1.0%	0.8%
IT	Truck	1.2%	-0.4%	1.5%	0.7%	0.6%	0.7%
	Train	1.4%	0.2%	1.7%	1.0%	0.7%	0.1%
	IWW	0.9%	1.0%	1.2%	0.5%	0.5%	0.4%
	Maritime	1.3%	0.3%	0.4%	0.6%	0.4%	0.1%
NL	Truck	2.4%	2.2%	1.1%	0.6%	0.5%	0.4%
	Train	2.2%	3.4%	1.9%	1.2%	0.6%	0.6%
	IWW	1.5%	0.5%	1.6%	1.4%	0.6%	1.0%
	Maritime	2.5%	4.7%	1.0%	1.1%	1.0%	0.8%
PT	Truck	0.9%	1.5%	1.3%	0.7%	0.7%	0.6%
	Train	1.6%	1.7%	2.2%	0.8%	0.8%	0.7%
	IWW	--	--	--	--	--	--
	Maritime	2.2%	1.4%	0.9%	0.9%	0.9%	0.8%
SE	Truck	1.0%	0.7%	0.7%	0.9%	0.7%	0.6%
	Train	1.5%	1.0%	2.2%	1.2%	0.9%	0.7%
	IWW	--	--	--	--	--	--
	Maritime	2.4%	2.9%	1.0%	1.7%	1.0%	0.8%
BG	Truck	1.1%	2.7%	1.2%	1.7%	0.9%	1.2%
	Train	2.7%	1.9%	2.7%	1.7%	0.9%	1.4%
	IWW	2.4%	4.0%	1.6%	1.2%	0.9%	0.2%

	Maritime	4.9%	1.6%	0.0%	0.6%	0.0%	0.7%
CY	Truck	0.7%	3.3%	1.2%	0.3%	0.8%	0.0%
	Train	--	--	--	--	--	--
	IWW	--	--	--	--	--	--
	Maritime	4.9%	3.9%	0.0%	0.2%	0.0%	0.2%
CZ	Truck	1.5%	1.7%	1.4%	1.0%	0.8%	1.0%
	Train	2.1%	1.2%	2.0%	0.9%	0.9%	0.9%
	IWW	1.9%	0.1%	1.9%	0.5%	1.0%	0.1%
	Maritime	--	--	--	--	--	--
EE	Truck	1.3%	2.3%	1.4%	1.2%	1.1%	0.6%
	Train	2.5%	2.1%	2.3%	1.3%	1.1%	0.7%
	IWW	--	--	--	--	--	--
	Maritime	1.0%	1.1%	0.8%	0.4%	0.6%	0.5%
HU	Truck	0.5%	0.8%	1.3%	1.4%	0.7%	1.2%
	Train	1.7%	1.0%	1.9%	1.4%	0.8%	0.9%
	IWW	1.3%	3.0%	1.9%	1.2%	0.6%	0.7%
	Maritime	--	-0.5%	--	0.7%	--	0.7%
LV	Truck	1.7%	1.7%	2.1%	1.7%	0.9%	1.2%
	Train	1.7%	1.6%	2.2%	0.3%	1.0%	0.7%
	IWW	--	--	--	--	--	--
	Maritime	1.9%	1.9%	1.3%	2.2%	0.6%	0.3%
LT	Truck	1.3%	2.1%	1.6%	1.9%	1.0%	1.1%
	Train	2.1%	1.5%	1.9%	0.8%	1.2%	0.3%
	IWW	0.9%	5.8%	1.9%	1.1%	1.1%	0.0%
	Maritime	4.7%	2.6%	0.0%	0.3%	0.0%	-0.2%
MT	Truck	0.9%	0.8%	1.0%	0.2%	0.6%	-0.1%
	Train	--	--	--	--	--	--
	IWW	--	--	--	--	--	--
	Maritime	4.9%	1.1%	0.0%	0.1%	0.0%	0.3%
PL	Truck	2.9%	4.6%	1.4%	1.0%	0.6%	0.7%
	Train	1.9%	1.1%	2.3%	0.8%	0.7%	0.8%
	IWW	2.9%	1.4%	3.1%	0.6%	0.7%	0.6%

	Maritime	3.7%	0.7%	0.0%	0.4%	0.0%	0.1%
RO	Truck	6.1%	2.6%	2.3%	1.8%	0.8%	1.1%
	Train	3.4%	2.5%	2.3%	1.5%	1.0%	1.5%
	IWW	2.6%	3.6%	1.8%	2.1%	0.8%	0.8%
	Maritime	4.9%	3.0%	0.0%	2.3%	0.0%	0.9%
SI	Truck	3.5%	3.9%	2.4%	1.6%	1.1%	1.4%
	Train	5.2%	2.8%	3.8%	1.9%	1.1%	1.4%
	IWW	--	--	--	--	--	--
	Maritime	3.8%	3.2%	0.0%	0.7%	0.0%	0.9%
SK	Truck	1.7%	1.0%	1.6%	1.8%	0.5%	0.8%
	Train	3.2%	0.0%	2.3%	1.7%	0.7%	0.8%
	IWW	1.5%	1.6%	1.3%	0.6%	0.5%	0.4%
	Maritime	--	--	--	--	--	--
LU	Truck	1.7%	-1.0%	1.7%	1.6%	1.0%	1.5%
	Train	3.8%	2.0%	2.2%	1.6%	1.4%	1.1%
	IWW	1.1%	0.3%	1.0%	1.0%	0.9%	0.7%
	Maritime	-15.1%	-2.5%	1.0%	1.0%	1.0%	1.0%

Source: TRT

Table: CO_2 transport emissions by country: average yearly growth rate

Country	2010 - 2020		2020 - 2030		2030 - 2050	
	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC
Austria	-0.4%	-0.7%	0.7%	0.1%	0.0%	0.1%
Belgium	1.0%	-1.3%	-0.1%	-0.1%	-0.5%	0.3%
Bulgaria	0.6%	0.3%	0.1%	0.0%	-0.4%	0.5%
Cyprus	0.1%	2.2%	-0.4%	0.5%	-0.3%	0.3%
Denmark	0.9%	-1.6%	0.5%	-0.1%	-0.2%	-0.4%
Estonia	0.6%	-0.5%	0.1%	0.6%	-0.1%	0.7%
Spain	0.6%	-1.8%	-0.8%	0.6%	-0.3%	0.8%
Finland	0.8%	-1.0%	0.8%	-0.3%	0.0%	-0.1%
France	1.1%	-1.3%	0.8%	-0.7%	0.0%	0.4%
United Kingdom	1.2%	-1.2%	0.4%	-0.7%	-0.1%	0.2%
Greece	1.0%	-0.5%	0.6%	0.7%	-0.1%	0.5%
Hungary	0.6%	-0.9%	-0.3%	-0.3%	-0.2%	0.6%
Ireland	0.0%	-1.3%	-0.6%	1.3%	-0.7%	0.6%
Italy	0.7%	-2.1%	0.2%	-0.7%	-0.1%	0.0%
Latvia	0.1%	-1.3%	-0.7%	1.1%	-0.3%	1.1%
Lithuania	0.3%	-1.9%	0.2%	-0.2%	-0.2%	0.2%
Luxembourg	0.6%	-1.4%	-0.2%	0.2%	-0.4%	0.7%
Malta	-0.1%	-1.1%	-0.3%	0.0%	-0.2%	0.4%
Netherlands	0.7%	-2.0%	0.5%	-0.8%	0.0%	-0.8%
Poland	-1.1%	0.6%	0.0%	-0.3%	-0.1%	0.4%
Portugal	0.6%	-0.8%	0.0%	-0.5%	-0.3%	0.1%
Czech Republic	0.0%	-1.0%	-0.2%	0.1%	-0.2%	0.5%
Germany	2.3%	-1.9%	2.2%	-1.1%	0.7%	-0.1%
Romania	-1.2%	-0.7%	-0.5%	0.4%	-0.4%	1.0%
Slovak Republic	-0.7%	-1.7%	-0.4%	0.1%	-0.1%	0.2%
Slovenia	-0.4%	-1.2%	-0.6%	-1.1%	-0.3%	-0.2%
Sweden	0.9%	-1.7%	0.8%	-0.5%	-0.2%	0.1%

Source: TRT

Table: Car fleet by country: 1000 cars

Country	2030		2050	
	PRIMES	ASTRA-EC	PRIMES	ASTRA-EC
Austria	4,967	5,790	5,449	6,184
Belgium	6,284	6,312	7,317	7,139
Denmark	2,480	2,544	2,818	2,792
Spain	26,791	28,481	30,021	30,743
Finland	3,183	3,588	3,333	3,267
France	37,588	38,877	41,641	40,030
United Kingdom	36,757	44,323	42,572	44,645
Germany	42,270	42,397	42,055	44,073
Greece	5,902	5,071	6,162	7,146
Ireland	2,560	2,714	3,168	3,291
Italy	40,760	39,494	42,734	44,738
Netherlands	8,178	8,296	8,375	9,104
Portugal	4,854	4,987	5,211	5,539
Sweden	5,382	5,047	5,700	5,755
Bulgaria	2,975	2,580	3,006	2,777
Cyprus	547	801	670	857
Czech Republic	5,268	5,716	6,304	4,835
Estonia	675	858	664	789
Hungary	3,739	4,569	4,378	4,548
Latvia	729	1,137	778	1,131
Lithuania	1,774	1,655	1,606	1,654
Malta	235	245	244	217
Poland	20,710	21,348	20,211	20,533
Romania	6,130	6,425	7,737	7,493
Slovenia	1,285	1,306	1,296	992
Slovak Republic	2,312	3,074	2,608	2,955
Luxembourg	418	387	481	435

Source: Fraunhofer-ISI