# Development of the Future Rail Freight System to Reduce the Occurrences and Impact of Derailment

# D-RAIL

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## D2.1
## Rail Freight Forecast to 2050

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Dissemination Level

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# Executive Summary

The “Development of the Future Rail Freight System to Reduce the Occurrences and Impact of Derailment” (D-RAIL) project is aimed at identifying root causes of derailment for freight vehicles, based on freight traffic and other parameters such as the range in loads, speed and maintenance quality. The project also investigates how combined or independent minor incidents could cause a derailment. Analysis is extended to include the expected future freight demand up to 2050 and advancements such as heavier axle loads, new vehicle designs, longer trains and faster speeds. Based on a set of alarm limits, D-RAIL assesses current technologies and indicates the requirements for future monitoring systems.

Work Package (WP2) of the D-RAIL project aims to evaluate current and future trends of the railway freight system considering current and intended European Rail Policy and emerging technologies and operations. More specifically, this WP assesses future trends, up to 2050, of freight movement and loading looking at both the logistical and economic aspects. Then, based on freight projections, specifies rolling stock breakdown in terms of type, model and operational conditions. Finally, it explores a variety of interventions in rail operations from the costs and benefit perspective.

This deliverable (D2.1) is the first step of the WP2 analysis and focuses on describing the future levels of rail freight demand for three scenarios: the Reference scenario with no change from the current rail system in infrastructure, policies and other trends, and two White Paper scenarios (High and Low), which describe how rail demand will develop through implementation of the White Paper guidelines assuming both a full and partial modal shift to rail. The scenario parameters were identified through the study of existing reports on rail developments then the White Paper policy options were applied to the Reference scenario as meta-models deriving the freight demand for all three scenarios.

Results were analysed from the demand, modal split and commodity perspective. Specifically, the Reference and Low scenarios demonstrate similar results in terms of growth and modal split as the Low scenario increases demand up to 2050 by less than 20%. The High scenario results are quite differentiated as additional demand almost doubles the 2050 Reference values. Finally, the rail sector experiences a commodity shift from the road demand (mainly foodstuffs, building and transport materials).

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# Glossary

| Abbreviation/Acronym | Definition |
|---|---|
| 3PL | Third Party Logistics |
| 4PL | Fourth Party Logistics |
| CER | Community of European Railway and Infrastructure companies |
| CLECAT | Comité de Liaison Européen des Commissionaires et Auxiliaires de Transport du Marché Commun (european association for forwarding, transport, logistics and customs services |
| DG-ECFIN | Directorate-General for Economic and Financial Affairs study |
| EC | European Commission |
| EIA | European Intermodal Association |
| ELA | Ecological Landscaping Association |
| ERTMS | European Rail Traffic Management System |
| ESC | European Shipper Council |
| EU | European Union |
| EU12 | The countries of Bulgaria (BG), Czech Republic (CZ), Estonia (EE), Hungary (HU), Lithuania (LT), Latvia (LV), Poland (PL), Romania (RO), Slovenia (SI), Slovakia (SK), Cyprus (CY), Malta (ML) |
| EU15 | The countries of Austria (AT), Belgium (BE), Germany (DE), Denmark (DK), Spain (ES), Finland (FI), France (FR), Greece (GR), Ireland (IE), Italy (IT), Luxembourg (LU), Netherlands (NL), Portugal (PT), Sweden (SE), United Kingdom (UK) |
| EU27 | The total of EU12 and EU15 countries |
| GDP | Gross Domestic Product |
| ITS | Intelligent Transport Systems |
| NSTR | Nomenclature for the Transport Statistics, Revised (Nomenclature uniforme des marchandises pour les Statistiques de Transport, Revisée) |
| NUTS | Nomenclature of Units for Territorial Statistics |
| REF | Reference Scenario |
| UIC | International Union of Railways |
| WP | Work Package |
| WPSc | White Paper Scenario |

# 1. **Introduction**

The D-RAIL project aims to reduce freight derailments in the future in two ways; firstly, by improving understanding of derailment causes and, secondly by increasing the accuracy of the measuring methods and systems parameters in anticipating derailments. The focus of D-RAIL lies in the underlying causes of derailment as well as in cases where multiple factors coincide to result in derailment even when all system parameters are within tolerance ranges, for example, higher than usual speed combined with a slight track twist.

WP2 evaluates trends in future railway freight systems up to 2050. The evaluation considers past, current and future European rail policies and strategies for freight and their likely impact on future operations and technologies. Future trends are assessed to support future derailment scenarios based on the impact analysis from WP1, and to ensure that selected approaches embrace the future freight vision.

Specifically, task 2.1 provides insight on how the future rail market may develop (in terms of commodities, types of wagons, operational patterns, etc.). In this way, it will serve as input to perform long-term analyses of costs and benefits in reducing or even preventing derailments, or mitigating their impact (which constitutes the main outcome of this WP).

**Methodology**
The objective of this report (D2.1) is to provide a rail freight forecast up to 2050. This is conducted in two stages: the study of on-going or finished reports and the actual modelling part, followed by the synthesis of the intermediate results.

As a first step, a number of EU funded on-going and completed research projects were reviewed, in order to integrate them into the study. Research projects, indicated in the DoW, included projects with a much broader foresight such as SPECTRUM SUSTRAIL, MARATHON, REORIENT, TREND, RETRACK and CREAM, as well as visioning exercises such as:

- TRANSVisions (Transport visions 2030-2050),
- TEN_CONNECT (Alternative Trans-European Transport Networks 2030),
- FREIGHTVISION (Vision and action plans for European freight transport until 2050),
- PASHMINA (Paradigm Shift Modelling and Innovative Approaches),
- INDICSER (Indicators for evaluating international performance in service sectors),
- USTIR (User driven stimulation of radical new technological steps in surface transport),
- GHG-TRANSPORD (Reducing greenhouse-gas emissions of transport beyond 2020: linking R&D, transport policies and reduction targets),
- ENCI-LOWCARB (European network engaging civil society in low carbon scenarios),
- PACT (Pathways for carbon transitions),
- MONITOR (Monitoring system on the development of global air transport),
- OPEN (EU: One planet economy network: Europe).

In addition, the projects TPT.2010-1 (Global challenges over a long term perspective: 2030-2050) and TPT.2010-3 (Exploring future transport paradigms beyond 2050), were reviewed for possible cooperation and synergy, without, however, bearing any significant input to the present study.

The second step of the study was to synthesise the results of the aforementioned broader foresight studies and visioning exercises into rail freight scenarios leading up to 2050, focusing on the particular characteristics of the various freight sectors and the proportion of goods likely to be carried by rail. The likely scenarios included concepts such as steady state, modal shift, new train configurations (e.g. from SPECTRUM, SUSTRAIL and MARATHON) with additional consideration given to various wild card outcomes. Two techniques were used to validate the synthesis results: the *backcasting* method, where desired results were first defined so as to identify policies which would lead the current situation to the desired situation, and the *foresight* method, where an industry sector group (UIC, CER, EIA, ESC, CLECAT, ELA) was selected to validate the synthesis during a workshop for *futures-planning-networking*.

Finally, the TRANS-TOOLS model was applied for analysis of the transport demand. Given the long term time horizon of the project (up to 2050), model results will be primarily used as input for meta-analysis models which will, where possible, combine the TRANS-TOOLS results with the findings of the relevant studies and exercises mentioned previously.

The overview of the studies and their synthesis are described in sections 2 to 3 of this report. More specifically, section 2 assesses past and on-going studies based on their relevance to D-RAIL. Then, section 3 elaborates on the main scenario trends, namely economic development, transport and logistics sector development, and rail sector development. The different scenarios together with modelling methodologies are discussed in section 4 with outcomes of the various scenarios for 2050 analysed in section 5. Conclusions are drawn and presented in section 6.

# 2. Overview of past and on-going studies

The overview of past and on-going studies under task 2.1 involved literature reviews of all projects listed in the Description of Work (DOW) for the D-RAIL project and was enhanced by projects additional to the list. Based on the availability of published online materials and their relevance to D-RAIL, the projects were grouped into three categories:

- The projects **relevant** to D-RAIL, which included information regarding both rail freight forecasting and future rolling stock breakdown.
- The projects **partly relevant** to D-RAIL, where information included either forecasting or freight forecasting of future rolling stock breakdown and,,
- The projects **not relevant** to D-RAIL, where there was no direct or indirect information related to forecasting or rail freight forecasting and future rolling stock breakdown

## *2.1. Most relevant projects*

The following projects were considered to be most relevant and to contain valuable information for the entire derailment subject and in particular for the rail freight forecasting and the future rolling stock breakdown. Each project is summarised in the context of the primary WP with the subject and scope, a short summary of the main results, assumptions (e.g. GDP growth, policies etc) and the outcomes relevant to D-RAIL briefly described.

### 2.1.1. NEWOPERA[1]

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|---|---|
| **Main work package** | Encouraging modal shift and decongesting transport corridors. |
| **Website** | http://www.newopera.org/newopera |
| **Partners** | Consorzio TRAIN, F&L, Alstom Transport, NESTEAR, TRANSFESA, RAIL4CHEM, Ansaldobreda, LKW-Walter, CEMAT, STORA ENSO, Rail Traction Company, Bombardier transportation, Porto Di Genova, GYSEV, SIEMENS TS, KOMBIVERKEHR, BD NETZ, RFF, UNIFE< SO.GE.MAR, ERMEWA, DHL, VW Transport, Port du Havre, RFI. |
| **Subject and scope** | Development of Rail Freight Networks. |
| **Project Status** | Completed. |
| **Summary of project results** | Results over Europe-wide investigation of optimised rail freight networks and new capacity |
| **Assumptions for forecasting** | Need for detailed analysis of growth forecasts underlying demands for new capacity and infrastructure. |
| **Project outcomes relevant to D-RAIL** | Relevant in terms of identifying the constraints of rail freight performance and the options for development at a technical, operational and policy level. This was a high profile and very large project that was in full development when it was overrun by the major economic downturn. There has been little tangible evidence of the implementation of any of the outputs of the project and there was some scepticism about some of the findings and projections (e.g. twin stack container operation). As a result, forecasts developed for this project will need to be treated with some reservation. |

[1] NEWOPERA (2005-2009). Retrieved 24th April 2012 from http://www.newopera.org/

### 2.1.2. CREAM

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| **Main work package** | New business models for rail freight supported by the main national incumbent rail freight operators. |
| **Website** | http://www.cream-project.eu/home/index.php |
| **Partners** | HaCon (Project Coordinator), BDZ, CFR Marfa, Lokomotion, MÁV Cargo, OSE, Keyrail, RCA, DB Schenker, Railion NL (until 12/2007), RTC, TCDD, SZ, MZ, ICA (until 12/2009), Kombiverkehr, TRW (until 04/2009), DB Intermodal, Balnak, Ökombi (since 10/2007), OZV (since 1/2008), Ekol (since 10/2008), IFB (since 05/2009), Knorr-Bremse (until 08/2008), HaCon, Eureka (since 09/2008), Voith (since 03/2009), KombiConsult, NTUA, OTB TU Delft, UIC |
| **Subject and scope** | Innovative supply chains using rail, inter-modal and IT. CREAM will lead to an increase in rail freight transport on this important East-West freight corridor and thereby contribute to the EU transport policy goals. |
| **Project Status** | Completed. |
| **Summary of project results** | Project focuses on rail based supply chains using rail and multi-modal transports. Focus on quality and cross border issues plus interoperability. Telematics and remote sensors plus semi-trailer systems were considered. |
| **Assumptions for forecasting** | Forecasts used for business cases to be reviewed. The inclusion of trailers as part of the inter-modal component is relevant (See SAIL) as this is projected to be a growing part of total international freight traffic by all modes of transport within Europe. This could be significant for rail if an increasing component of the wagon fleet is made up of vehicles with a capability to carry trailers and containers. |
| **Project outcomes relevant to D-RAIL** | The extent to which the rail freight solutions generate more volume for environmental friendly transport.<br>Regarding the fleet, CREAM investigates the effects of the solutions on transit times, weight, punctuality etc. |

### 2.1.3. TIGER

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| **Main work package** | Encouraging modal shift and decongesting transport corridors. |
| **Website** | http://www.tigerproject.eu/ |
| **Partners** | Consorzio TRAIN, HaCon, New Opera, Rivalta Terminal Europa, DUSS, ELOG, Eurogate, Genoa Port Authority, Hafen Hamburg marketing, Interporto Bologna, Italcontainer, Kombiverkehr, Liguria region, RFI, Sogemar, Terminal San Giorgio, Tecnicas Terriroriales y Urbanas, Trenitalia Cargo, UNIFE |
| **Subject and scope** | European Inter-modal Rail solution to EU ports and road congestion. |
| **Project Status** | Completed. |
| **Summary of project results** | Development of concepts on longer, faster and heavier trains between ports and major terminals. Ship to train concept demonstrated in TIGER demo. |
| **Assumptions for forecasting** | Need for project review to identify underpinning rationale for new long train concepts. |
| **Project outcomes relevant to D-RAIL** | The focus on longer, heavier and faster trains is relevant for D-RAIL if this model forms an increasing component of total rail freight traffic activity. There are technical, operational, commercial and management aspects that flow from such developments. The impact on infrastructure and the incidence of derailments attributable to bigger trains could be significant. |

### 2.1.4. MARATHON

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| **Main work package** | Follow on from Tiger with big train technologies using line capacity more efficiently. |
| **Website** | http://www.marathon-project.eu/ |
| **Partners** | ALSTOM, Cerontech, DÁppolonia, Faiveley Transport Italia, FS Logistica, New Opera, Reseau ferre de France epic, Kungliga Tekniska Hoegskolan KTH, Schweizer Electronic, SNCF |
| **Subject and scope** | Technical, commercial, IT and operational specifications being developed. |
| **Project Status** | Ongoing. |
| **Summary of project results** | See Business case output as basis of forecast uptake of new systems and methods of operation. |
| **Assumptions for forecasting** | To be reviewed. The impact of the economic downturn needs to be measured against any forecasts or projections made to underpin the use of the new train operating model and associated control mechanisms. |
| **Project (expected) outcomes relevant to D-RAIL** | With regard to the rolling stock breakdown, MARATHON investigates the integration of rolling stock technologies combined with innovative operating patterns in order to provide freight services based on longer heavier and faster trains. In addition, MARATHON evaluates railway freight services based on:<br>- Simulation of train circulation<br>- Freight traffic simulation<br>- Sustainability aspects |

### 2.1.5. RETRACK

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| **Main work package** | Research to develop and demonstrate (under WP1 to WP8) a pan-European rail freight service across five countries ran by new entrants. Service provision is wholly by new commercial operators with no participation by the national rail freight incumbents |
| **Website** | http://www.retrack.eu/index.php |
| **Partners** | Archicom, CER, Deltarail, ERSA, LTE, NEA, NewRail, Servtrans, TCI Roehling, TNO, TOI, Transpetrol, Wagener & Herbst |
| **Subject and scope** | The operation of a pilot rail freight service for over two years and subsequent evaluation. |
| **Project Status** | Ongoing. However the relevant part for D-RAIL has been completed. |
| **Summary of project results** | RETRACK pilot rail freight service was developed and operated by new entrants, initially with grain commodity and traffic forecasts overtaken by revision of product and service profile. |
| **Assumptions for forecasting** | Initial market forecast and projections (under WP1) available but not relevant to actual services operation as the service was changed to respond to the prevailing market condition. The project was launched in the middle of a major international economic downturn. Traffic forecasts and commodity flows were severely undermined by the economic downturn. Direct contact with potential shippers proved a more robust mechanism in determining future traffic demand. The project is due to move into a commercial format in mid- 2012. No forecasts based on the actual train operations have been developed. |
| **Project outcomes relevant to D-RAIL** | Relevant to D-RAIL in view of operational experience gained and impact of service disruption from derailment incidents. The use of mixed train formations with various wagon types, sizes and capabilities suggests a real relevance given the spread of ownership, management and maintenance profiles of the rolling stock and the long international route operated. |

### 2.1.6. SPECTRUM

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| **Main work package** | The aim of this WP is to fulfil one or more demonstrators in order to validate the critical technologies associated with the innovative high performance freight train design that was developed in WP3. |
| **Website** | http://www.spectrumrail.info/ |
| **Partners** | Faiveley, innovatrain, EIA, FloraHolland, Kockums, Green Cargo, i.log, Universita Degli di Napoli, Gruppo Clas, Manchester Metropolitan University, MARLO, NEA, NetworkRail, NewRail, P&G, Railistics, TCDD, TFK, TNO, Trafikverket |
| **Subject and scope** | Technical, commercial and operational research to develop new rail freight concepts for low density high value cargo. |
| **Project Status** | On-going. |
| **Summary of project results** | The project commenced in May 2011 and the research on the logistics and market analysis (under WP1) is nearing completion and the conceptual design (under WP2) of the new freight service concept has just started (April 2012). The research findings (in WP1) suggest that up to 12% of road freight transport could potentially be shifted to rail freight transport although this represents a growth in rail freight of 178%. Nevertheless the transport of LDHV goods by rail is considered a suitable target market. |
| **Assumptions for forecasting** | No indications yet on market studies/market application. |
| **Project outcomes relevant to D-RAIL** | The SPECTRUM project is relevant to the D-RAIL project as it involves new technologies which may be relevant to D-RAIL. The project is at an early stage and thus the findings of the project were not available for rail freight forecasting for D-RAIL project. |

### 2.1.7. SAIL

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| **Main work package** | Main work package was focused on the potential to carry an increased volume of road trailers on trains and to overcome some of the problems associated with securing a greater volume of cargo using inter-modal options based on trailers.<br>Technical and operational aspects were reviewed together with a focus on the integration of road and rail components to make best use of resources and capabilities. |
| **Website** | http://www.transport-research.info/web/projects/project_details.cfm?id=6965 (not the original site project) |
| **Partners** | Ewals, TFK, RTWH, Kombiwaggon, Kombiverkehr, Koegel, DUSS, ICM, Gattaned, Hupac Intermodal, CEMAT, Trelleborgs, Hupac Intermodal |
| **Subject and scope** | The project intended to improve the intermodal transportation of semi-trailers in Europe and to increase the percentage of semi-trailers transported by rail. |
| **Project Status** | Completed. |
| **Summary of project results** | A clear overview of the potential and limits for the use of semi-trailers in intermodal transport chains in Europe and partly in Third Countries and recommendations on technical, organisational and operational standardised solutions to enhance and ease the use of semi-trailers in intermodal transport. |
| **Assumptions for forecasting** | The SAIL project was established as a means of restoring losses from rail. The project was developed before the major economic down turn and any projections will need to be treated with care. |
| **Project outcomes relevant to D-RAIL** | Relevant to D-RAIL if a larger component of both domestic and international rail freight is made using faster and potentially longer and heavier trains. |

## 2.2. Partly relevant projects

The following projects were considered partly relevant for forecasting or freight forecasting and are also partly relevant for a future rolling stock breakdown. All projects have been completed.

### 2.2.1. TRANSVISIONS

TRANSVISIONS was a project set to encourage modal shift in a more sustainable network. Its goal was to assist the DG TREN in carrying out mid- and long-term analysis of a several policies with a view to provide data for the debate on transport policies.

TRANS-TOOLS can provide reasonably accurate results up to 2030 but any projection this far forward is inevitably vulnerable. After 2030, the projections are calculated using meta-models up to 2050. Meta-models, being essentially different from conventional transport forecast models, do not include complex equilibrium algorithms and sophisticated statistical calibrations. These are still aggregated demand forecasts and, projecting so far forward, they are very vulnerable to major result swings emanating from minor input fluctuations

### 2.2.2. TEN-CONNECT

This project was set to forecast traffic flow, identify corridors and research policies for eliminating bottlenecks in those corridors. The study improved the Commission's TRANS-TOOLS model and carried out an analysis of transport networks in the EU, expanding the current network with an inventory of the main roads in the Eastern part of the EU. Using TRANS-TOOLS, a sequential state-of-the-art transport model, however, had all the "usual" limitations for transport modelling. Uncertainty increased as future scenarios significantly changed compared to base year (for this reason updating the input data from 2000 to 2005 was significant).

The study is relevant to rail demand forecasting up to 2030 however major changes in the economic climate since the completion of the project prevent this project from being the basis for estimating future demand.

### 2.2.3. FREIGHTVISION

The FREIGHTVISION project focussed on the long term policy developments in transport and energy. It built around scenarios on GHG reduction, fossil fuel dependency reduction, accident and congestion reduction. This project is potentially relevant to D-RAIL demand forecasting but the following aspects require consideration: the 2050 estimate based upon extrapolation seems high as the newer EU27 membership states are modelled to show a considerable rise is GDP without this necessarily being credible. An additional limitation is that no future network expansions in transportation network developments are assumed. More specifically, the global map of Europe is considered as a closed system in the model. This could under-estimate any longer-term developments in very long distance rail freight. The potential development of links between Europe and the Far East and the financial crisis of 2008 were not taken entirely into account either. As a result, all these limitations may contribute to devalue the input parameters and, hence, render results less relevant for D-RAIL.

### 2.2.4. High Oil Price (HOP)

This was an EU funded project within the 6th RTD Programme[2]. The projects aim was to conduct research on the macro-economic impact of high oil prices in Europe. It provides quantitative estimates of the impact of high oil prices on the EU-27 economy for the period 2008 - 2050. The analysis is based on an integrated modelling approach that combines the POLES model for the assessment of trends in worldwide energy supply and demand under various assumptions on oil prices, and the ASTRA model, which is used to estimate the reactions of all economic sectors to high oil prices in the EU-27. A set of scenarios are designed to allow the investigation of relationships between high-energy prices and consequences on the macro-economic variables such as GDP and employment. These HOP scenarios (reflecting high oil prices) will be compared to the baseline scenario in the current D-RAIL freight forecast. Providing an overall projection with moderate oil prices is not necessarily the

[2] Fiorello D., Martino A., Schade W., Walz R., Schade B., Wiesenthal T. (2008): High Oil Prices: Quantification of direct and indirect impacts for the EU - Summary.

most likely or the most probable development, but it serves as a projection with a more optimistic assumption on oil resources which leads to a moderate increase of oil prices.

## 2.3. Not relevant projects

After careful consideration, the following projects were identified as not relevant to forecasting or rail freight forecasting and future rolling stock breakdown:

- BESTUFS
- Co-Act
- F-Man
- LIBERTIN
- RAILSERV
- BESTUFS II
- ISTU
- REORIENT
- TREND
- USTIR
- INDICSER
- PASHMINA
- GHG-TRANSPORD
- ENCI-LowCarb

## 2.4. White Paper of Transport[3]

In addition to the line-up of studies and projects relating the rail freight, it is important to refer to the White Paper of Transport, published in 2011 by the European Commission, as this contributes significantly to the present study by defining the basis on which two of the future scenarios are built.

More specifically, the White Paper identifies targets concerning rail freight transport in the later future (long-term analysis). The results can be seen as one scenario or trend. In detail, for distances more than 300 kilometres, the white paper assumes a 30% shift from road demand by 2030 and a 50% shift by 2050 to rail and other modes with all relevant changes taking effect from 2020. Hence, the effects of the implementation of these policies are expected to be demonstrated from 2030 and beyond.

[3] WHITE PAPER (EC, 2011) Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system

# 3. **Main trends and assumptions of D-RAIL**

Trends are classified according to scope in general and are sector-specific in a nested hierarchy. Apart from the general (exogenous) trends defined for the whole system, sector-specific trends include those in the transport and logistics sector and specifically for the rail sector. As a result it is possible to describe sufficiently the relations between general trends and sector specific trends, as well as relationships between different levels of sector-specific trends.

The identified trends serve as input to two different **scenarios** in the form of a consistent set of variables which describe the future development of the system. The first is the **reference** scenario which describes the evolution of uncertain parameters outlined in the following section. The second follows the trends of the **White Paper** described in section 2.4. Each scenario provides a coherent outlook of the economy, population and implemented policies which influence the economy or transport and impacts the model used in forecasting transport flows- in this case, TRANS-TOOLS.

**Framework for model assumptions**
This section identifies the parameters for the two scenarios which provide key assumptions for calculating the demand projections up to 2050. Table 3.1 lists the parameters according to two criteria and their corresponding uncertainty and relevance rates. The parameters which are remotely connected (low relevance) to DRAIL are ignored. On the other hand, parameters with high relevance define the major assumptions of the scenarios. It is important to note the difference between the two scenarios in relation to the model assumptions: for the Reference scenario, both low and high uncertainty variables provide input to the model, while for the White Paper scenario only the variables of high relevance and high impact are considered. The sections below describe in detail the attributes of each of the mentioned variables.

**Table 3.1 Framework for model assumptions**

| **Uncertainty/ Relevance** | **Low uncertainty** | **High uncertainty** |
|---|---|---|
| **Low relevance** | Ignored<br>A. General trends<br><br>B. Transport trends<br><br>C. Rail trends | Ignored<br>e.g. Carbon intensity, non EU GDP growth, oil dependency, … |
| **High relevance** | Embedded in **REF**<br><br>A. General trends<br>Population (ageing, household structure)<br>Urbanization<br>Motorization<br><br>B. Transport trends<br>Liberalisation of transport market<br>C. Rail trends | Embedded in both **REF** and **White Paper Sc**<br>A. General trends<br>Oil prices<br>Economic growth (GDP, GPD per capita)<br><br>B. Transport trends<br>Technological breakthroughs<br><br>C. Rail trends |

The evaluation framework is also differentiated by level of hierarchy. It should be noted that transport trends as well as rail trends are not part of the scenario formulation but serve as indexes for clarification on the system dynamics.

## *3.1. Main Assumptions*

This section presents the general macroeconomic trends defined as the most representative, in terms of uncertainty and relevance, to the scope of the project (i.e. - reducing derailments and their effects), for the scenario formulation in Chapter 4. The exogenous parameters under examination are economic growth, in the form of GDP, oil prices and demographical developments (population). GDP has a strong impact on transport as higher GDP leads to higher transport demand and vice versa. In addition, lower economic growth may lead to shifts to different, more efficient technologies, fuels or

processes by transport users. Population and its relative features are also expected to have a strong positive effect (consequently increasing the demand) on transport. Table 3.2 below shows the projections of the iTREN project for GDP which will be used also for D-RAIL.

**Table 3.2 The GDP trends of the iTREN 2030[4] scenario for the EU-27**

| Measure\ Time | 2005 | 2030 |
|---|---|---|
| GDP (billion Euros) | 10,573 | 15,772 |

Source: iTREN-2030, based on projections from the EC

### 3.1.1. GDP

Currently, transport accounts for 4.6% of EU Gross Domestic Product (GDP) with an additional 1.7% coming from the manufacture of transport equipment. On average GDP in Europe is expected to grow up to 2030 and 2050. The initial high growth for the EU (predicted prior to the 2008 economic crisis) is actually lower and this has resulted in a number of years showing a decline in GDP.

Making projections from the post-1990 acceleration phase to the future, the EC DG-ECFIN study[5] has provided simulations for alternative global relocation patterns, from the perspective of the EU, up until 2050. The forecasts assume a convergence of membership states towards a lower growth in GDP than has been experienced for the last 5 decades. The long term forecasts for EU15 indicate, on average, a growth in GDP of 1.3 % per annum up to 2050, which is similar to the long term trends of the iTREN model.

Exports to large and emerging economies such as Russia, China, India and several countries in South America, contribute to an expected stable GDP growth. The aging of the population in Europe is not yet demonstrated in the available work force[6] though plans exist for dealing with this in the form of increasing productivity with IT and general technology. Furthermore, it is expected that exports (products or expertise) in the agricultural sector will go up, leading to a higher GDP. The figure below (figure 3.1) shows the Eurostat GDP values for EU15 and EU12 separately.

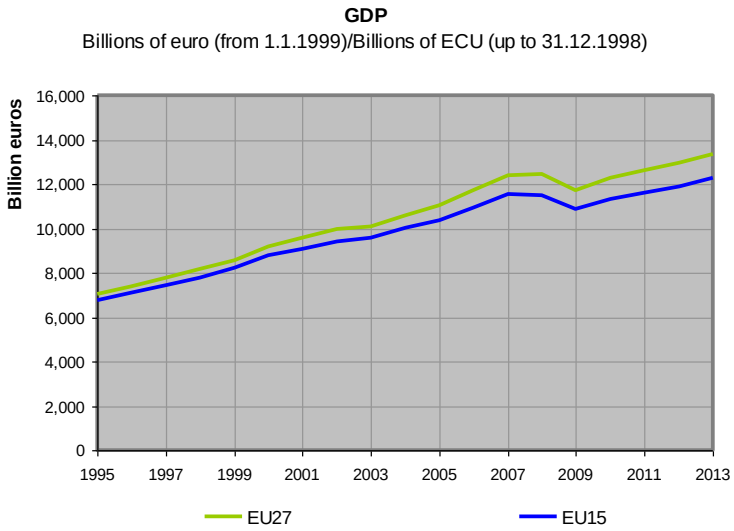


**Figure 3.1 GDP current prices**

*Source: Eurostat database*

[4] TML (2009) iTREN-2030. The iTREN-2030 reference scenario until 2030, Deliverable D4
[5] EC (2006). This study has investigated the effect of ageing and globalisation on the economic development in EU25.
[6] EU-27 employment and unemployment levels stable, Latest labour market trends - third-quarter 2010 data1

### 3.1.2. Oil prices

Oil prices play a principal role in European transport as the transport sector depends almost exclusively (96%) on oil products, while it accounts for almost three quarters of the total oil consumption (EC, 2011). However in the rail sector the influence of oil prices in the future is likely to be lower due to reduced energy consumption (compared to other modes) and an increase in electrical energy usage. Oil prices are highly unstable as they are dependent on numerous factors within and outside the energy sector (see Figure 3.2 below). Their impact is high on passenger and freight demand as well as on the engagement of new technologies. While oil prices are a significant factor, issues also exist over the security of long term supplies which need to be considered. Recent developments in the identification of large volumes of oil and gas that can be recovered through the use of new extraction technologies may have a significant impact on oil prices and concerns over the guarantee of supplies, particularly from the major traditional sources of crude oil.

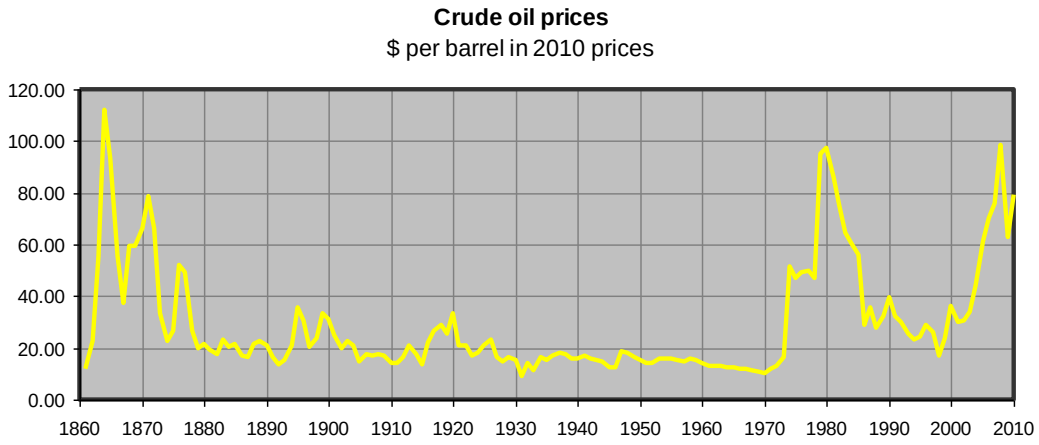


**Figure 3.2 Crude oil prices in $ (2010 values) – Source: BP Historical Data**

### 3.1.3. Population

Figure 3.3 shows population trends for three groups of EU countries up until 2050. The overall EU27 population will not increase significantly by 2050 (0.1% pa), but there is a population shift between the EU12 and EU15 groups over the 2010-2050 time period. In particular, Eurostat expects the EU12 population to decrease with a rate of 0.25% pa, while the EU15 population should increase by 0.2% annually. This inter-Europe migration flow should be taken into consideration also as demand shifts to specific regions.

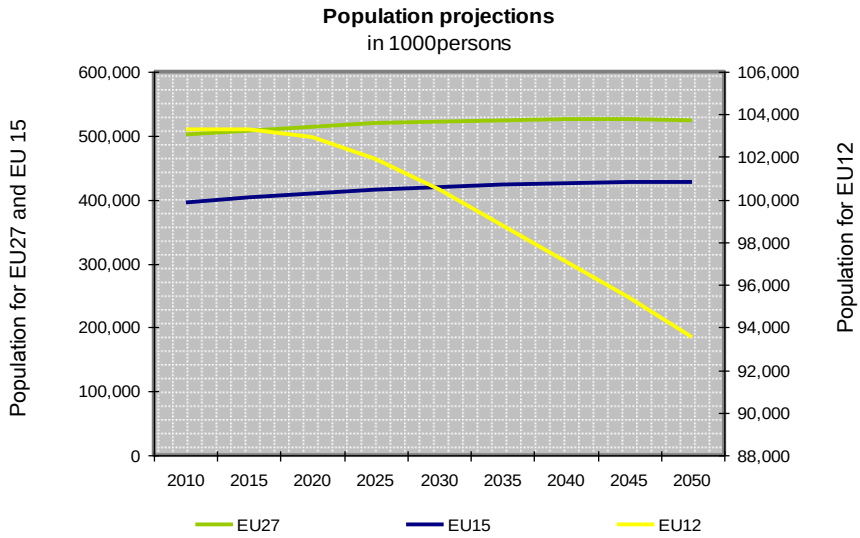


**Figure 3.3 Population projection - Source: EUROSTAT**

The European demographic factor is expected to decline even with immigration / migration included[7], mainly as a result of population ageing[8]. This situation, combined with a steadily increasing GDP, resulting in an increased GDP per head, together with sustained efforts to maintain the rising education levels for young and older people, will create the opportunity for increased individualisation.

An effect of this increased individualisation is to tailor products to specific consumer demand, whether or not through standardized sub-modules or not. As these products better match the needs of customers, the value of these "on the road" products increases and can be identified as working capital.

Household structure is an important driver in the overall mobility of the population. A household is a typical unit owning a car(s) or *having access* to a car(s), with members of that household sharing the car(s). The general tendency has been a decrease in family unit size, and UN projections[9] envisage a further decrease in average household size in the EU27 from 2.4 in 2005 to 2.1 in 2030. These figures indicate that, irrespective of an almost constant total population, there will be an increase in number of households. If the current trend in household car ownership continues then an increase in car fleet is anticipated.

### 3.1.4. Other trends

**Urbanisation**
The long and on-going trend of (sub) urbanisation is expected to continue leading to more congestion, other costs and pollutant emissions. The European Commission Urbanisation strategy[10] lays emphasis on the uptake of non-conventional technologies and a shift to public transport as well as other non-fuel consuming modes of transportation (cycling, walking). For that reason, the EC has committed to provide additional support in terms of policy measures.

**Environmental effects**
Environmental issues are having an increased impact on policy and transport decisions, leading to progressively tighter regulations on emissions, due to population increase and modern life on the environment, landscape, biodiversity, and mankind's own lifestyle and expectations. In order to maintain mobility, considered as one of the basic necessities in modern society, it is important to ensure that the mobility is sustainable and that it does not inflict lasting damage to the environment.

The broad impact of development in new technology has resulted in the combining of basic research/development areas. Though research and development are on-going processes, the resulting applications often occur in jumps and certain thresholds (legal, financial, macro-technological) need to be overcome before applications are available to and generally accepted. Next to this there needs to be an appeal to the likely end users.

**Technological change**
Development of new technologies is a huge factor for a more sustainable exploitation of the world's resources and in creating more efficient solutions especially in the agricultural sector and chemical industries. The technology presently being developed is, in many cases, aimed at facilitating a sustainable development using the latest applications. In terms of energy production some forms of

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[7] WHITE PAPER, Together for Health: A Strategic Approach for the EU 2008-2013 http://ec.europa.eu/health-eu/doc/whitepaper_en.pdf
[8] According to EC (2006), population ageing is the result of the combined effect of low birth rates and increasing longevity. As mentioned in Eurostat population projections (published on the International Day of Older Persons 29 September 2006) by 2050 the number of people in the EU aged 65+ will grow by 70% and the 80+ age group will grow by 170%.
[9] TRANSPLUS (2003a) Review of current practices for promoting participation in the urban planning process. Deliverable D5.1 of the TRANSPLUS project.
[10] 2011 WP "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system".
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52011DC0144:EN:NOT

renewable energy, including hydro, wind or bio fuels are now reliable sources of electricity and have been integrated, to some extent, into national power grids in many areas of the world. Rail has the massive modal advantage of being able to draw electrical power from a diverse mixture of generation inputs.

The on-going process of computerisation has been beneficial in the past with optimal route planning, satellite navigation, and load exchanges for minimising empty hauls. It is expected that more benefits and efficiency will arise from newer information technologies. Furthermore, computerisation combined with globalisation and the integration of Europe ensures that any new revolutionary and applicable technology can be deployed as quickly as possible. Although the technological developments are an additional tool in achieving sustainability they are not sufficiently developed to meet current European goals. Additionally, the policy measures and guidelines of the White Paper for Transport (2011 – see reference 9), need to be considered.

## *3.2. Further system parameters*

This section describes other elements of the system with regard to the policy targets and the outcomes of interest which will be assumed for the two scenarios. Even though these input from these elements do not contribute directly to the scenario formulation, they constitute a major part of the system and, hence, should be examined thoroughly.

### 3.2.1. Transport and Logistics

This section focuses on freight transport trends, with reference to passenger transport trends when considering transport capacity of the rail infrastructure network.

**General description**

The nature of goods production is shifting from the current primary and secondary sector (i.e. raw materials and manufactured materials) towards the tertiary (i.e. finished consumer goods), and this also holds true for the transport sector. Notably the emergence of 3PLs and 4PLs is a partial consequence of this development. The transport activity itself is also surrounded with increasing services provided (i.e. value added logistics). This last tertiary sector is expected to account for more than 70 % of the total economic activity in 2030. There is less bulk to be carried, and more general cargo. With the general decline of primary industries (such as the steel industry) and the building industry the total transport volume will continue to consist of less coal, ore, petroleum products and fewer minerals. For example in Germany, between 1998 and 2007, the share of these goods in total inland transport volume decreased from almost 63% to less than 51%. The shortened product life cycle (compared to 1970) has led to higher transport activity and the shift towards the tertiary and general technology sector can only increase activity.

Higher value goods which tend to require a greater level of customer service together with inventory stock costs are important drivers in the choice of transport mode. The following aspects, in relation to customer service for instance, consist of the following drivers:

1. Lead time of transport
2. Predictability and routinely high levels of reliability and consistency
3. Security
4. Responsiveness
5. Flexibility
6. Managerial competence

- **Lead time of transport**, the time taken for a product to reach a customer. There are several factors which increase the lead time and include congestion on all networks (rail, road and ports). Fuel efficiency for road transport can lead to longer lead times as lower speeds are used to increase efficiency. The same holds true for dense urban areas where speeds are kept low due to congestion and interaction with passenger traffic. At the present rate of development some alternative fuel sources struggle to maintain the current speeds or power, especially when the time needed to recharge (electrical) is taken into account. The shift from raw materials to finished, high tech, goods does mean that the cargo weight decreases and this, together with fuel efficiency increases, should translate into decreased lead times. A good example of this is the occurring change in transporting goods from China to Europe across land by rail through Asia and Russia

into Europe rather than by sea. The shift westwards in production and manufacturing centres in China makes this alternative transport mode more attractive in terms of decreasing lead times particularly if long cross border services can be provided that satisfy requirements on transit time and cost savings.

- **Predictability,** the quality of maintaining previously agreed transporting agreements. One of the primary reasons why the road modality is chosen is its predictability. Water transport (by both sea and inland waterways) can be time consuming and possibly increases overall distance as well. The longer lead time makes the predictability for this modality low though over time, with the improvements to Information Technology, predictability has increased to similar levels to those of road transport. Rail and barge (maritime and river) are lagging behind on this.
- **Emphasis on security** has become more important as a direct consequence of the increased value of transported items (either the raw product/material or the finished article/goods). This trend focuses more on the security aspect and initially will be detrimental to rail and water transport simply because each truckload of goods transported by road has a driver whereas rail and water transport tends to comprise of multiple truckloads with just one driver/controller.
- **Responsiveness**. Rail's ability to react and respond to traffic enquiries and deploy traction, rolling stock, train crews and train paths rapidly is constrained compared to that of the road sector. This will need to be addressed if rail is to secure any competitive share of markets particularly those markets which are not constrained by bulk commodity requirements. Methods of rapidly compiling service responses to shipper's requests will be needed together with systems to identify available empty space on trains.
- **Flexibility.** Rail will need to develop a greater ability to react to changing traffic, commodity and account profiles. The supply side model at present acts as a limit to the level of market penetration that can be achieved by the use of long and heavy trains as the main product and service offer. The retention of vehicles for long periods (30 years) may not be tenable if rail is to be an attractive option. The flexibility aspect is strongly interlinked to responsiveness.
- **Managerial competence.** Rail will need to improve commercial and operational competence particularly in terms of asset management, train planning, very short term planning and a real appreciation of the cost base and levels of productivity which need to be secured to come anywhere close to road based competition.

Price is an important aspect in relation to service and although competition within the internal market sets this there are other influences which impact price, such as:

- **Further Liberalisation of the transport market**. The continuing trend will allow greater choice in price between for example Eastern and Western European freight service providers, especially in the road sector. The developing ICT tools allow the liberalised markets to quickly offer their services and strike deals more efficiently as well. If there ever was a time when liberalisation of markets is likely to have a big effect, it is now.
- **Oil dependency**. This driver of transport will naturally increase prices at least for the medium term up to 2030. The prices for primary energy carriers traded on the global markets have increased in the 2 years leading up to mid-2008 and increased to a level that was considerably above the values used in energy scenarios and projections in the past. High oil prices affect all economic sectors and determine several macroeconomic impacts. Nevertheless, the transport sector's demand for oil is less price sensitive than any other part of the economy. This is in part because demand for transport services is relatively insensitive to price and in part because supply substitutes for oil in road transport are currently far from cost-effective. Transport is the one sector of the economy where substitution with other fuels has been negligible. Rail has the supreme advantage of being able to use electric power directly at the point of use and regeneration where other modes do not have this inherent capability.
- Coupled with the new technologies are**, green products and reverse logistics**. Recycling efforts, creating reverse logistic streams may increase transport demand initially unless existing empty equipment is used. Eventually as more efficient methods are developed for integration of the forward and reverse logistics, this effect will become negligible. Local production using local short haul and medium haul transport together with an increase in demand from wealthier populations will follow the same trend - initial rise of total transport demand, and a later decline due to efficiency.

Aside from the observed trends that create challenges for future policies, there are also a number of imminent technological developments that might shape future solutions. Technological developments

and the on-going search for logistic strategies are the drivers behind this. The following are important here:

1. Much more effective Multimodal networks
2. Intelligent Transport Systems
3. Energy availability & security of supply
4. Network investments
5. Environmental taxes and constraints on the use of liquid hydrocarbon fuels

– **Multimodal networks**

The development of multimodal networks is dependent on securing more efficient use of existing infrastructure assets. The current information flow amongst transport chain partners is often disaggregated. This results in missing and incorrect data and unnecessary delays. This is especially true for transport chains where more than one transport mode is involved. Moreover, the information flow between carriers (shipping companies, rail freight and trucking companies, airlines), transport operators/freight forwarders, providers of transport equipment services, shippers and terminal operators, is not standardised, because each partner has their own methods, protocols and even traditions of information exchange and information processing. The service or cost saving measures from using the infrastructure more effectively is the key driver that makes multimodal networks a potentially more viable option.

Additional drivers for the success of Multimodal networks are **Intelligent Transport Systems** (ITS). Integrated telecommunications, electronics and information technologies (telematics) are applied to transport systems, in order to plan, design, operate, maintain and manage transport systems. Intelligent Transport Systems can be regarded as an important means to increase the efficiency, quality, safety, security, and environmental performance of transport. Thus, the further development, enhancement and application of ITS belongs to the goals of the European Commission in freight transport policy, as stated in its Freight Transport Logistics Action Plan[11] or its Action Plan for the Deployment of Intelligent Transport Systems in Europe[12] ITS systems are predominantly focussed on road transport, however there are similar initiatives for other transport modes. Rail needs to match what the road freight sector has developed and now routinely uses to secure productivity enhancements and cost reductions to ensure competitiveness.

– **Energy availability**

Rising energy consumption and declining long term availability of fossil fuels leads to higher energy prices and considering the transport sector accounts for 67% of the final demand for oil, transport prices are likely to increase. An increased introduction of new (alternative) fuel types and energy sources (e.g. bio fuels and electric batteries for vehicles) is expected in the future if they can produce comparable levels of operational performance produced by existing technologies. Pressure to reduce carbon emissions, waste and resources is growing. The increase in world population is expected to have a serious impact on global resources, putting more pressure on the need for a more sustainable transport system. Rail freight transport is considered and is being promoted as a cleaner alternative to road transport. The study of CE Delft 2011[13] found that given certain circumstances, trucks on road are also becoming more environmental friendly with technology and regulations. Issues of fuel availability, costs, safety and levels of emissions need to be factored into any such comparisons. Motor cars in general have become much more fuel-efficient and the amount of emissions per kilometre driven has dropped significantly over the past decade. Aircraft have also steadily become more fuel-efficient. Developments like hybrid locomotives, more energy efficient electric locomotives with regeneration and last mile options to allow access to terminals without catenary will contribute to these developments. In case of a demand for greener transport, freight transport by rail has an advantage, although also further improvements are needed particularly in relation to asset management and planning.

[11](COM(2007) 607 final)
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0607:FIN:EN:PDF
[12]COM(2008) 886 final)
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0886:FIN:EN:PDF
[13]STREAM International Freight 2011 Comparison of various transport modes on a EU scale with the STREAM database
http://www.ce.nl/publicatie/stream_international_freight_2011/1174

– **Network investments**

Network investments are not directly related in the method, one reason being that they are difficult to predict. It should be mentioned as this is an important issue and not only for congestion. The European Environment agency found the following:[14]

- "While infrastructure length is only a proxy measure for capacity, the steady in-crease in the length of the motorway infrastructure between 1990 and 2008 suggests that road capacity has expanded to the detriment of conventional rail. The data may not show the full extent of the divergence as motorway length may have increased even more than noted since additional lanes are not counted in the statistics. The data shows that the negative effect is bigger for the new Member States (EU-12) than for the EU-15 countries. For example, the length of rail infrastructure fell much more in the EU-12 than in the EU-15 during this time period. However, it should be noted here that there is no clear evidence about the implications of the road network growth on the rail demand.
- Increasing infrastructure capacity is not always necessary. Optimisation of the capacity of the existing infrastructure through interconnectivity, interoperability, intermodal and road pricing still has lots of potential throughout Europe. The application of these principles might be more beneficial to society and definitely to the environment than the construction of new infrastructure when capacity problems arise. "

– In summary during the last decade the total length of Europe's motorway network, High Speed Rail (HSR) network, inland waterways and pipelines has increased leading to greater capacity. The total length of the *conventional* rail network however has decreased. Recent infrastructure trends have focused on local cost cutting measures resulting in the elimination of lines and sidings and with the concentration of function over several decades into fewer and, larger facilities across Europe. Rail networks still have a lot of work to do on this front because current capacity is not that high and increased capacity is expected in the future - for example, to facilitate transport of commodities not traditionally belonging to rail, or for longer-distance haulage etc. Short term cost savings could lead to longer term predicaments as, once removed, infrastructure is difficult to restore and re-activate.

– **Environmental tax**

A major part of the problem in environmental degradation lies in the fact that many of the costs associated with degradation are not charged back to the transport system. This has particularly favoured road transport use. One way to correct this problem is to "internalise" these external costs and there are a number of options: a tax levied on the market for the negative externality, establishing cap and trade systems, or estimating the true external costs (including life-cycle impacts) and charging the full "full" price. Since most transport modalities do not fully cover their external costs, even for public transport, users often pay a lower price for their mobility than the real cost to society and the environment, in many cases keeping demand for transport "artificially" high. Imposing charges on users for infrastructure usage could ensure a more efficient use of transport. This could help address some of the negative consequences whilst raising funds for investment in new or for an optimised infrastructure with alternative transport modes including related information technology.

The idea of establishing a uniform "user-pays" system for all forms of transport is not new, but it has historically failed to materialize due to the obvious complexity of calculating external costs as well as understanding where to stop the calculation (e.g. charging for road accidents or derailments). One other pertinent question would be where to use the resulting revenue. For example should it be used to subsidise a new infrastructure for the taxed transport mode or cross-subsidise cleaner transport alternatives, or just be added to the general budget.

There are at the EU level two main directives on taxing externalities, Directive 2006/38/EC on the charging of heavy freight vehicles for the use of certain infrastructures and Directive 2001/14/EC which includes rules on charging for railways. Should a method be found for realising the tax model, the outcomes are uncertain on where to spend the tax revenue. On one hand the improvements in infrastructure will increase efficiency as the risk of rising fuel costs goes down, but on the other hand demand for transport may decrease as a result of increased taxes.

[14] http://www.eea.europa.eu/data-and-maps/indicators/capacity-of-infrastructure-networks/capacity-of-infrastructure-networks-assessment

Currently the most important drivers are congestion and sustainability which both offer chances for innovative rail concepts. Although the sustainability trend within the EU (as stated in the White Paper) aims to promote a more sustainable rail transport system, the share of freight on rail and inland waterways remains quite low, while road transport of freight is predominant. A similar situation exists with passenger transport, so in order to meet EU goals to increase rail and inland waterway transport it will be important to understand why these modes of transport have conceded market share to road transport.

### 3.2.2. Rail sector developments

The reviews of rail sector developments are conducted along the following major sub-headings:

1. Rail governance and reform measures – impact and prospects
2. EU strategic perspective and aspirations
3. National perspectives
4. Financing and investment
5. Infrastructure investment options – High Speed Rail, freight only options and mixed operations.
6. Passenger developments and their impact on freight activity
7. Freight developments

– **Rail governance and reform measures – impact and prospects**

The main line rail sector in Europe has been the subject of an evolving series of measures and interventions designed to reform and modernise the industry in in an attempt to improve efficiency and effectiveness. Measures were designed to create a degree of transparency in the financial management (including government support and subsidies) of the rail sector. The separation of infrastructure from operations was originally conceived as a financial measure but has invoked wider reforms including measures designed to open access to rail systems to new entrant operators, promote competition within the rail sector at a domestic and international level for both freight and passenger services and operate under a more commercially driven agenda. Rail on rail competition was, and is, seen as a precursor to enhanced competition with road and air transport.

The impact of the reform package has not been consistent or universal in terms of acceptance and implementation. Various models of ownership and operation have evolved ranging from complete separation of functions and the arrival of new market entrants to positions where reform has barely begun or structures have been retained with only a minimal gesture to implementation. The process has also been extended to privatization as a means of minimising state support and subsidies in some national domains.

Other measures have included moves towards inter-operability to allow rolling stock and traction to be operated in domains other than those where the equipment was designed and deployed. This is an evolving process as some railways are strategically different (track gauge, loading gauge and kinematic envelope) and not wholly able to accommodate the stipulations of inter-operability. In addition to this the ERTMS project has been evolving with variable rates of application. The fundamentals remain valid but there are increasing concerns over the cost effectiveness and real impact of this initiative which may constrain the pace of adoption.

– **EU rail strategic perspective**

The White Paper of 2011 set out aspirations for rail to achieve and sustain some ambitious growth targets for both passenger and freight activities. If these are to be achieved then the existing networks and systems will have to be operated in a more intensive and intelligent way. Additional line capacity may well be deployed and there may be some separation of functions with purely passenger operations separated from freight on identified routes. The development of high speed lines may potentially open up capacity on the “classic” lines for passenger and freight activities but even here the implied growth suggests that different models of train technology and operation together with maintenance requirements may be introduced.

The rail sector could see the separation of functions though on mixed traffic lines there may be a commercial and operational need to retain passenger and freight trains in operation on a common network. This could have implications for both market segments. Increased acceleration and deceleration speeds for passenger trains will be required to match the competitive position of cars and short haul flights. For freight this might imply constrained operating “windows” or the ability to move at

similarly fast speeds as the passenger traffic. The move to longer, heavier freight trains may not be a viable option in overall systems benefits if such operations effectively neutralise track capacity because of the speed differentials. Faster and shorter freight trains could provide a wider range of alternative technical, commercial and operational models.

Rail will have to play much more to its environmental and energy strengths. Issues relating to noise generation (braking noise, rail-roar, engine and cooling fans etc) and measures to minimise the impact of emissions if diesel traction is retained will need to be addressed. Compliance with Euro emission limits may favour more electrification and the adoption of in-filling schemes to allow the development of a larger operating network. More electrification from a diverse source of fuels and primary energy inputs (hydro, wind and wave) will effectively insulate the rail sector from impacts of increasing fossil fuel prices and concerns over security of supply. It also gives rail a massive competitive advantage over virtually all other modes of transport because of the ability to use a diverse mixture of energy and fuel inputs and the ability to regenerate.

The use of automotive derived engine technology and technology management may allow the use of diesel traction where electrification is not justified for both passenger and freight services. Traction using this technology set will have to be fully compliant with prevailing and developing Euro emission norms. Other technology options including alternative fuels, regeneration and energy capture may also hold out benefits for specific niche operations. The use of fuel cells and other exotics may prove to be less widespread than imagined given their size, weight and energy density limitations together, in some cases, with the need for a hydrocarbon or hydrogen based fuel. The EU may continue to support new traction technology developments and to encourage the further development of conventional electrification directly or through intervention measures.

Moves to make the energy efficiency of trains through weight reduction, the use of new materials, different driving techniques, regeneration and better management and maintenance of the asset base should make rail, potentially, a more attractive option for both freight and passenger services. The rail sector will have to move significantly away from the sort of supply side positioning and use its inherent advantages in terms of energy efficiency, weight and volume capability to much better commercial as well as technical and operational effect.

– **National rail perspectives**

The railway industry presents a mixed picture across the EU. Some of the railways have adopted reform measures to the fullest extent required by the EC. Others have barely begun to move on this and remain largely un-reformed state entities despite EU strategic perspective and aspirations. A further group has adopted interim or half way house positions but these have attracted the criticism of the EC. This disappointing lack of consistent progress across the EU remains a block to the development of rail on rail competition for both freight and passenger services and, perhaps more importantly, constrains rails effectiveness against other modal competition.

A group of countries (UK, The Netherlands, Sweden, Denmark) have adopted the EC reforms to the fullest extent and also absorbed the privatization of the incumbent, usually state owned[15], rail operation. Some countries now have new privately owned and operated freight services competing with the incumbent with varying degrees of success and competitive impact. Another group has barely moved on any of this and developed shell structures which are, in reality, very little different from the previous composite structure combining infrastructure and operations. Within this latter grouping the larger operators (SNCF & DB) have experienced varying fortunes in terms of market share and competitiveness. Both operators have defended their national stance and response to the need to reform. SNCF has lost significant market share in freight to road and new competition. DB still has a major controlling interest in the German rail freight market but has recognised the arrival of new entrants. The capability and initiative of the respective national regulators appears to have a major bearing on this.

The EC has indicted several Member States for their failure to accommodate reform measures. This is still being played out but significant penalties for non-compliance have been identified.

[15] On the other hand, some private freight operators have entered the market in recent years in several EU countries.

– **Financing issues**

The high cost associated with the rail sector in terms of infrastructure operation, maintenance, train operations and the acquisition of assets makes for some peculiar problems. Unlike the US/Canadian model of vertical integration (infrastructure and operations operating under one ownership) the enforced separation of infrastructure and train operations together with capacity allocation, regulation and safety measures governing new entrants can act as a limitation to market entry for new operators in both freight and passenger service provision, particularly in relation to costs associated with start-up and compliance. New models of ownership (effectively leasing or hire purchase) have been used to mitigate this problem. The adoption of a franchise model with back up funding from the state in the event of deviation from predicted revenue and cost streams when franchises are awarded gives a measure of certainty to the investors/operators bidding for these. In relation to freight this is treated as an open access option with no guaranteed support measures (despite some peripheral subsidies) and can also act as a constraint towards the solicitation of new non-contract business. This particularly applies to freight where train operators may seek high levels of guaranteed traffic to offset the costs of providing new services. The emergence of “consolidators” prepared to purchase train space and services and take the risk of filling the acquired slots/space may have a major bearing on future train composition and weight.

New entrant operators have been able to use existing “banks” of rolling stock and traction to develop their businesses and then acquired more modern assets (through leases). This has led to the emergence of common or standard equipment types that can be widely re-deployed in the event of a business failure but has also constrained the development of new train concepts and technologies that might be better able to exploit the new situation. This also has ramifications in terms of the complexity of design and certification/approvals that may preclude the adoption of new technologies and thereby limit the total market where rail can compete.

– **Infrastructure investment – high speed, freight only and mixed operations options.**

The divergence of freight and passenger interests is demonstrated in the development of high speed lines and networks primarily for HS services. These can be built to accommodate steeper gradients than hitherto but are not really suited to use by conventional freight traffic and technology sets. The HS lines have a lower axle load compared to existing and proposed freight limits. Freight will be largely confined to the existing rail lines with some interaction with conventional passenger services. HS lines have been built as national projects usually supported by government either directly or indirectly with various models of ownership, management, lease and operation involved.

The prospect of more wholly new lines built specifically for freight appears increasingly unlikely given the cost of infrastructure development and implied long development time. The greater likelihood is that pinch points will be eliminated either by enhancing local capacity (signals, track) that may include differing operational methods and traction options particularly focused on maximising the use of electrification as a network concept rather than individual separate lines. Upgrading infrastructure to accommodate faster, heavier and longer trains still represents significant investment that has to be remunerated through access charges levied on operators. The adoption of longer, heavier and faster trains will proportionately inflict more wear and damage on track and infrastructure as well as having infrastructure management and train path/capacity implications. The general trend towards lighter but more volume related traffic may offset some concerns about increasing weight.

– **Passenger developments and their impact on freight activity**

Mention has been made of the HS developments and their implications for residual passenger and freight services. Passenger services are likely to become more frequent in response to increasing ridership as car use incurs increasing costs of ownership and operation. This implies more and faster services and pressure on train paths for freight. For freight to compete and participate implies compliance with the prevailing line speeds and an ability to accelerate/brake at levels equal to that of the passenger services. This really does suggest a different technical, commercial and operational model compared to the long and relatively slow freight formations currently deployed. There are also implications in terms of train sequencing:

- response to disruption and alternative available routes able to accommodate the diverted freight services;
- train priorities and path allocation/train planning;
- compatible traction and rolling stock;
- 24/7 day and night operations;

- accommodation of infrastructure maintenance.

For freight this all suggests a wholly different basis of operation and asset planning and management or it runs the risk of being progressively constrained.

– **Freight Developments**

There have been a series of projects and studies focused on the adoption of longer and heavier freight trains (higher axle loads and greater trailing weights). These precepts are fine for certain well defined traffic and commodity flows (for example, major flows of coal to power plants, ore to/from loading docks) which may be able to take advantage of this new capability. External developments in the energy sector may see a fall-off in coal traffic which provides until now a significant component of total rail freight volumes and revenue. Rail is also locked into the movement of large volumes of low value commodities such as grain, aggregates and minerals but has a far lower presence in the higher value time sensitive sectors which remain dominated by road transport.

The EU has set out general plans (in White Paper 2011) for rail to capture a much higher proportion of medium and longer distance freight without detailed actions as to how this is to be achieved at a strategic or detailed level. So far, existing models of operation and technology have not secured or improved rail's share in the freight market and are unlikely to do so without some profound changes for example, in terms of cost competitiveness, reliability, availability (24/7), responsiveness, attractiveness to shippers and cargo interests, flexibility and a greater level of accessibility to information on services and traffic in transit. Projects such as New Opera have suggested some measures to enhance the competitive performance of rail freight but these have not found widespread application. The Retrack project has demonstrated that conventional wagon load/wagon block freight services can be operated successfully and commercially across multiple international borders.

Inter-modal traffic is likely to take a greater share of total traffic and in some cases can be seen as a replacement for single wagonload activity. The use of block trains is already well developed but rail has to ensure a greater control of its costs and enhance asset utilisation and productivity as well as making services more available and attractive to existing and potential users. This may imply a serious recasting of the entire product and service offer. This could include new train technologies (short, fast bi-directional formations), smarter wagons and modular designs able to accommodate efficiently and effectively a wide array of cargo modules including ISO, ILU and swap body units. The likelihood of twin stack operation without serious infrastructure modifications which must also take into account the use of electric traction is remote. New lines purpose built for freight may be able to accommodate such options.

Axle loads increases are being proposed to levels around 30 tonnes. This gives an indicative benefit compared to prevailing limits but comes at a cost in terms of increased track attrition, greater energy inputs to accelerate and the need for mechanisms to slow the heavier trains. Longer and heavier trains also have an impact on the operation of any mixed traffic system unless these trains can perform at near parity with the other trains on the network and do not sterilise line capacity by virtue of their slower speed performance. Longer trains will also take longer or more resources to load and discharge and this may also have an impact of the commercial aspirations of the train operators.

For D-RAIL the real implications of evolving technologies are the ability to minimise derailment incidents through improved design, materials, engineering, maintenance and operational inputs. Wagons are less likely to be treated as a "dumb" resource and will carry as an integral part of their design remote monitoring sensors for condition monitoring of vital parts (bearing temperature and lubricant levels, weight condition, accurate record of duty cycles undertaken for maintenance planning and utilization together with compliance with any statutory requirements. This will apply especially to bogie, axle and wheel set condition monitoring.

Cargo condition monitoring (temperature, humidity, liquid levels) will also become more commonplace as rail enhances its product and service offers. This also requires rail infrastructure in terms of alignment quality and safety to accept evolving train technologies. The use of line-side equipment to capture train conditions will support the position where the train has "knowledge" about itself in a particular transit particularly in relation to key technical vital signs.

Whilst the EC is proposing that rail will secure a higher market share of freight transport over specified "competitive" thresholds this negates the question as to how all of this will be achieved. Rail will have to evolve not only technical but also operational, commercial and managerial models that will support moves to achieving the targeted aspirations. Rail cannot rely on the discomfiture of its primary competition (road transport) through congestion and increasing concerns over fuel input costs and security of supply. Whilst rail has undoubted environmental benefits in terms of energy efficiency and environmental impact it needs to turn these to commercial and economic advantage. To date it has signally failed to do this. Rail needs to seriously examine the whole model of service and product presentation if it is to succeed. The implications in terms of enhanced safety and minimization of derailment incidents are part of a much wider canvas.

Summary of main issues and trends:

- Rail remains locked into flows of low value time insensitive commodities and has a low share of high value time sensitive logistics traffic which is governed by requirements and precepts the rail sector fails to recognise and respond to.
- Rail retains a model of operation based on large locomotive hauled train formations which limits the attractiveness of such market and service offers to a wider market well served by competing modes.
- Rail is weak in servicing smaller and intermittent volume flows and many railway administrations have seriously reduced SWL traffic activities
- Rail wagons remain as undervalued dumb resources which are not as intensively managed or supervised as the competition leading to lower productivity and higher costs.
- Responsibility for a wagon's status, location, condition and presentation is diffuse.
- Few wagons are equipped with condition monitoring apparatus to underpin their deployment and allocation into traffic and manage their maintenance.
- Wagon leasing by specialist providers (leasing companies/banks) has grown often back to back with contracted freight traffic. General purpose wagon fleets owned and deployed by major incumbents have become a less significant part of the European wagon fleet.
- Specialist wagons have become much more widely used
- Wagon sizes and weight capabilities have increased but are limited by variable axle loads, coupling strength and coupling technology and the retention of obsolescent braking technologies.
- Wagon life is still set at >20 years which is 3-4 equivalent truck generations.
- Rail has few attractive product and service initiatives that are competitive or compatible with shipper's requirements
- Inter-modal traffic has been a significant development but remains constrained by the retention of the large train formats, low levels of IT and e-documentation compatibility and poorer response levels compared to road.
- SWL and wagon load traffic can be made to work successfully in well-defined applications subject to close and routine scrutiny and to appropriate positioning in the market.
- Rail wagons have not adopted advances in materials, design, running gear and braking together with automatic couplers that could significantly enhance productivity, speed and commercial competitiveness.

### 3.2.3. Conclusions of rail sector developments

The EU White Paper 2011 expects that rail freight is becoming a growing force within the European freight market for both national and international traffic. In particular rail freight is taking a growing share of traffic over distances of 300km by 2050 and being the lead player over much longer hauls. This is a very positive and optimistic aspiration but raises several key questions as to how this might be achieved and what the implications for the sort of growth indicated by the D-RAIL project.

The growth forecasts suggest a significant increase in train activity on the existing rail network, most of which is shared with other services, largely passenger trains, with widely varying speed and performance requirements. Existing loco-hauled freight trains are not always allocated the priorities or quality of train paths sought by the operators, largely because of speed differentials and lack of track capacity plus running loops for overtaking. Even though longer and heavier trains may be part of the answer, these will still need to operate at higher speeds in order to be competitive with much higher

levels of track attrition and vehicle wear, increasing the risk of derailments. Consequently, longer, larger and heavier trains could also become a major commercial risk for operators and shippers, in case of disruptive scenarios, and turn rail into a less reliable option.

Intermodal and co-modal services involving rail for a component of a freight transit are likely to figure much more in the overall portfolio of services offered. These will be a mix of container, swap body and trailer carrying trains. The temptation to go for longer and heavier trains by the train service provider for economies of scale may accelerate the levels of track and vehicle wear. The need for increased traction power to allow trains to run faster also introduces additional elements of cost which needs to be recouped and could compromise cost competitiveness against other modes. Taking individual axle loads to much higher levels than those prevailing at present has implications about the ability of heavier vehicles to be deployed only on restricted routes at full load and has direct infrastructure implications for raising the weight standard and on-going maintenance.

Rail has significant generic technical advantages which it could exploit much better to commercial effect. It already has major advantages in terms of energy efficiency, the ability to use electric power generated from a mixture of inputs, speed and weight advantages and operates within a controlled environment. These advantages have not been used to full commercial and competitive effect over recent years and there has been a growing gap between the product, service and quality aspects of rail compared to the primary competing mode.

The list of previously completed projects have individually raised issues about the technical, operational and commercial performance of the rail freight sector and have contributed some value in identifying where the rail product and service offer needs to be enhanced. The main concern is that these projects in aggregate have achieved very little towards the rectification of the modal balance and begun to demonstrate what is needed at a fundamental level to make rail a more attractive option.

Some of the projects listed have identified potential market opportunities and in the case of the RETRACK project, actually demonstrated that rail freight can be operated successfully at a commercial and operational level with the right structures and operational support, which raises the question as to why these key weakness within the rail freight domain are not being addressed as is being done by other modes of transport.

Some of the larger projects have proposed the development of specialist freight only infrastructures. This again suggests the operational model of bigger, longer and heavier trains is what the market wants across the board. If this was the case then rail's market share would not be as constrained as it is. The use of big trains, where appropriate, is entirely adequate but does not cover the full spectrum of traffic options including medium and shorter distance flows. The use of the big train is, arguably, a constraint on rail's ability to enhance its market share.

Many of the other projects have addressed individual issues relating to rail freight but none have taken a global view with sound and current forecasts of traffic volumes and revenue. Modelling ten plus years out has major uncertainties and the impact of the most recent economic downturn has distorted activity patterns which results in even more uncertain long term forecasting. Rail may well see some of its base traffic in commodities such as coal and steel dwindle in response to changes in the energy and manufacturing sectors. These externally imposed changes will need to be offset by the attraction and retention of traffic which is either wholly new to rail or that which is attracted back on merit.

The cost of new freight only routes/infrastructure is a major barrier to this sort of initiative and could also act as a constraint on traffic development if the access charges for such lines was penal. More can, and needs to be secured from the existing infrastructure through the use of different methods of train planning and train control including disruption response. (Big trains in disrupted train sequences become a major operational and commercial issue irrespective of the infrastructure used).

The impact of the rail reform measures has realised major changes within the European rail freight but with patchy and variable implementation. This inconsistency militates against rail's potential competitive competence at both a domestic and international level and could constrain the levels of traffic rail is able to secure on the back of the reform measures being implemented in full. There remain issues about the level of priority accorded to freight as a priority on the mixed traffic railway. If

rail is to secure the market aspiration the EU is targeting then this remains a key issue to be addressed.

In summary the rail freight sector within Europe faces many challenges and difficulties some of which are of its own making. There are technical challenges that need to be addressed to exploit rail's inherent endowments in terms of speed, energy efficiency and weight capability together with wholly new approaches to asset management and productivity. Rail needs to get its productivity up by factor level increases and its cost base down also by factor levels. These are the real touchstones to success. For D-RAIL a more intensively used rail system in Europe implies better use of existing assets together with intelligent design of train planning and management systems. Train and infrastructure assets will need to be worked much harder and this has implications for design, technology and technology transfer. D-RAIL can build on earlier projects which focused on individual aspects and measures but may also have to examine a wider spread of issues and concerns in the development of the project.

# 4. Description of modelling methodology

## 4.1. Introduction to modelling

The aim of this chapter is to introduce the methodology used for modelling rail transport demand in tonne kilometres for 2030 and 2050. For this purpose, a basis year for forecasting was established using 2010 iTREN transport data. The adapted iTREN (or ETISplus) data show the annual growth figures, up to the year 2030. This is “top-down” model data which also provides insight into the years after 2030. Growth rates are corrected using a “bottom-up” approach with historical data, resulting from the investigated trends in section 3 and the scenario definitions. For the D-RAIL reference scenario the growth factors have been defined per year up to 2030 and extrapolated for the future trend towards 2050.

The forecast method is conducted in two consecutive steps. The first step uses the TRANS-TOOLS model, which provides demand projections up to the year 2030. As not all components of TRANS-TOOLS can provide concrete results after 2030, there is need for meta-models in order to calculate the demand projections up to 2050. Here it is important to mention the sensitivity of the results for the time period of 2030 to 2050 due to the high level of uncertainties and assumptions of the system. The meta-models will incorporate to a certain level the degree of uncertainties and use existing expertise in order to assess the outcomes.

The results of the reference scenario will constitute the basis for the White Paper scenario as well. Based on the assumption that there will be an 100% shift from road to rail freight for distances of more than 300 kilometres by 2050, the output from the reference scenario will be re-examined and the new modal split will be recalculated, keeping the same total freight demand (for all modes).

In short, a description of TRANS-TOOLS and other models will be provided, followed by the operationalisation of the scenarios based on the outcomes of Chapter 3. TRANS-TOOLS will be the modelling tool of D-RAIL for the projection of demand up to 2030 though other models will be assessed so that the most appropriate - to DRAIL - parameters will be defined for the time period of 2010 to 2030 and from 2030 to 2050.

## 4.2. TRANS-TOOLS description

TRANS-TOOLS is a model that forecasts transport demand between regions in the EU 27 for different transport modes. It consists of a sequential trade module and traffic module that predicts freight demand and of a module with multiple inputs for passenger transport.
Other main inputs consist of Infrastructure developments and transport policy (mainly in the form of charging costs for transport). As is often with forecast models, there is also the possibility of evaluating external scenarios.
Outputs are given on NUTS II level for freight transport (and NUTS III for passenger) and encompass the following areas:

- Transport data: (this gives ton-km, vehicle-km etc.)
- Modal split (the distribution of transport demand per modality)
- Load on corridors (aggregated results for multiple regions).

Another output is the origin destination (O/D) matrixes. This contains the predicted transport demand from an Origin towards a Destination for a certain NUTS level and for a certain commodity.

The TRANS-TOOLS model can be seen as well-established in terms of its representation in a “four stage transportation model” (trip generation, trip distribution, mode choice and assignment). The model provides a trend extrapolation based on developments such as economy and transport policy.

As the model relies upon trend extrapolation it is less capable to take into account trend-breaks unless these are fully specified in advance. “Normal use” of models such as TRANS-TOOLS implicitly assumes that there are no trend-breaks in the future; otherwise they are brought in exogenously.

## 4.3. Models description up to 2030

### 4.3.1. iTREN scenario for 2030

Based on the transport estimates from the year 2010, forecasts have been made towards 2030 using the Integrated Scenario developed by the EU project iTREN-2030. The basic objective of iTREN is to extend the forecast and measurement capabilities of TRANS-TOOLS. For this reason it is considered a stable source for data up to the year 2030. The iTREN project adds multiple modules to TRANS-TOOLS which provide specific input types. These input types are: transport types, vehicle technology, transport policy, TEN-investments, resource prices, energy technology and energy policy. For these inputs comparable assumptions were selected such that a common base is created. The extension will draw on experiences from other projects such as TRIAS, TREMOVE II, REFIT and WorldNet. The tools and approaches developed for these projects will be connected with TRANS-TOOLS. Therefore iTREN-2030 combines four existing assessment tools to develop its scenarios:

- TRANS-TOOLS – for transport networks; (http://energy.jrc.ec.europa.eu/transtools/TT_model.html)
- TREMOVE – looking at the environmental effects of the transport sector; (http://www.tremove.org/)
- POLES – simulating long-term energy scenarios for different parts of the world; (http://ipts.jrc.ec.europa.eu/activities/energy-and-transport/documents/POLESdescription.pdf)
- ASTRA –forecasting the long-term consequences of EU transport policies. (http://www.astra-model.eu/structure-overview.htm)

The iTREN-2030 project has developed different scenarios, including the Reference Scenario and the Integrated Scenario. The latter is based on a number of key assumptions regarding:

- The development of the world and EU economy.
- Depletion of resources of raw materials, world market prices for resources.
- Demographic, social, technological and cultural developments.
- Economic and transport policy environment in the EU.

The Reference Scenario is the result of the integration and harmonisation of the four iTREN-2030 models that use common or comparable external assumptions (e.g. population growth rates) and consider a common set of policies. In particular, the Reference Scenario is based on the transport demand projections coming from the TRANS-TOOLS model. The TEN-T network will be constructed and road pricing is assumed to be implemented in the reference scenario.

The Integrated Scenario is driven by changing framework conditions, a few breaks-in-trend as well as by energy and transport policies until 2030. This scenario is supplied with very detailed quantified indicators by Member State and EU region for energy, transport, vehicle fleets, environment and economic development until 2030 (see Annex 1).

The iTREN-2030 Integrated Scenario also takes the impacts of the financial and economic crisis of 2008/2009 into account, describing a world shaped by the crisis, but which is also gradually recovering from it. Transport policy is leaving its traditional paths and instead is being driven by newly emerging issues, i.e. climate policy and growing GHG mitigation requirements for the transport sector, demand- and supply-driven fossil fuel scarcity and new propulsion technologies, leading to the application of a diversity of fuels and engine technologies in the transport sector. However, behavioural change in the scenario remains limited to adopting new engine technologies, without changing urban settlement structures, travelling behaviour or mobility concepts.

The results from iTREN were established in 2009 and 2010 and incorporate the effect of the crisis. In fact, the ETISplus project which will produce outputs for the European Commission also acknowledges this scenario and thereby showing that this scenario is still the best scenario, given the continuing economic downturn from 2009 on, to be used for future prediction up to 2030.

Following the adaptations, a calibration was performed to ensure the quality of the data. Data from different countries was used to compare both aggregate and detailed results. Eurostat rail freight transport data was also evaluated. Furthermore, the distance or impedance data plus the resulting ton-km numbers were thoroughly checked at country level (national rail freight transport, import, export and trans-national) and at regional levels (both NUTS 2 and 3). Where needed adaptations were made.

The iTREN output data was considered to be the most relevant to D-RAIL; hence, for the years 2010-2030, the assumptions for the D-RAIL model were based on the iTREN project.

## 4.4. Extrapolation towards 2050-reference scenario

For D-RAIL a reference scenario up to the year 2050 is developed. This scenario should provide information about transport flows in 2050 for different modes. In order to avoid discussions about the transport flows (which in fact could be regarded as being outside the scope of the study), it has been decided to base the D-RAIL scenarios on results from available forecasting studies. Several scenario studies were identified as being potentially relevant, for which results have been compared and discussed. The following scenario studies/projects have been considered:

- European Commission: White paper (2011)
- FREIGHTVISION (2010)
- HOP! (2008)
- TEN-CONNECT (2011)

Each of the above studies has briefly been assessed on their relevance with respect to transport forecasting to D-RAIL. Aspects such as forecasting horizon, geographical scope and methodology are used as indicators. In the concluding section we describe our preferred (and selected) reference scenario for D-RAIL.

### 4.4.1. FREIGHTVISION

"FREIGHTVISION - Freight Transport 2050 Foresight" was a project funded by the European Commission Directorate General Move to design a long term vision for European freight transport in 2050 and to identify actions and research to progress appropriate freight transport measures in Europe (see the Freightvision website). The research was carried out between 2008 and 2010 as a foresight process encompassing four conferences in which the project team identified and developed, with the aid of more than 100 experts, an action plan for securing long term freight transport in Europe. The forecasting horizon is 2050, therefore relevant for D-RAIL and the geographical scope is the EU which is even more relevant for D-RAIL. The objective of the study was to develop a long term vision and action plan for a sustainable European long distance freight transport system in 2050.

The methodology follows a combination of forecasting and modelling. Modelling is used for simulating the trend analyses of the key drivers and for, consequently projecting the output parameters. The following models were considered:

- TRANS-TOOLS for transport modelling
- PRIMES for energy modelling
- SYKE for GHG emission and fossil fuel share

The book (Helmreich & Keller, 2011[16]) and project deliverables (available by this http://www.freightvision.eu/ ) from the FREIGHTVISION project provide information about the scenarios. Future uncertainty is addressed with three different forecasts for the future freight transport demand: a trend forecast (most likely development), a low forecast and a high forecast. The first scenario may be considered as a reference scenario for D-RAIL purposes. FREIGHTVISION produces forecasts for freight transport demand, modal split and average load (See Table 4.1). Freight transport demand in the trend forecast scenario for total land transport in EU27 increases by 58% (2005-2050). It increases from 2315 billion tonne-km to more than 3600 billion tonne-km in 2050. Modal split changes slightly over time in favour of rail and inland waterways. This is based on certain assumptions, for instance on the development of load factors for trucks (in order to determine vehicle km's). These are projected to change from 9.8t in 2005 to 11.0t in 2050.

[16] Helmreich & Keller (2011). FREIGHTVISION - Sustainable European Freight Transport 2050: Forecast, Vision and Policy Recommendation. *Springer Editions*.

On the surface this study seems relevant because of the time horizon, however it does not provide the level of detail that the D-RAIL project requires.

**Table 4.1 Rail freight demand based on TRANS-TOOLS, PRIMES and SYKE**

| FREIGHTVISION Results | Unit | 2005 | 2030 | 2005-2030 (pa growth) |
|---|---|---|---|---|
| Total | btonnekm | 2.158 | 3.238 | 0,016 |
| Regional | btonnekm | 179 | 196 | 0.040 |
| Domestic | btonnekm | 605 | 558 | -0.030 |
| intraZone | btonnekm | 411 | 593 | 0.015 |
| extraZone | btonnekm | 445 | 726 | 0.020 |
| Total intra EU | btonnekm | 1.640 | 2.072 | 0.009 |

*Source: FREIGHTVISION*

### 4.4.2. HOP! (High Oil Price)

The objective of this study was to gain an insight into the effects of High Oil prices on trade and industry. The objective was to determine the impact of a (sudden) high oil price on volume (in tonnes-km) of road, rail and inland waterway transport (Table 4.2). The forecasting horizon is 2050 and the geographical scope the EU - both relevant to D-RAIL. However, the modal split also includes water transport which is not part of the D-RAIL study (as it is assumed that there will not be a modal shift for freight demand to the railway from water transport).

The model comprises a POLES and ASTRA combination and has been applied for different scenarios. The level of detail in results is very aggregate but gives an indication and can be used in D-RAIL. Tables 4.3 – 4.5 projects the Modal splits (tonne-km) for the EU27, EU15 and EU12 groups from 2005 up until 2050. As one can see the growth indexes for rail are increased significantly due to the fact that the oil prices are very high, hence, the demand shifts to more cost-efficient transport modes. However, there is not a very significant change in the modal split. There are additional parameters which should be taken into consideration such as the energy efficiency technologies, effectiveness of logistics etc.

**Table 4.2 Growth indexes for the road, rail and IWW modes (based on tonne-km)**

| Index 2005 = 100 (HOP! Results) | 2005 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| Road | 100 | 122 | 145 | 172 | 202 | 242 |
| Rail | 100 | 130 | 150 | 178 | 209 | 244 |
| IWW | 100 | 129 | 148 | 169 | 188 | 212 |

*Source: HOP! project*

**Table 4.3 Modal split for EU27 (based on tonne-km)**

| Share EU27 (% based on tonne-km) in HOP! | 2005 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| Road | 53.5% | 52.4% | 53.3% | 54.7% |
| Rail | 14.3% | 14.7% | 14.7% | 15.3% |
| Ship | 32.4% | 32.9% | 32.0% | 30.0% |

*Source: HOP! project*

The Hop! results have been used as input to the iTREN 2030 exercise (D5 Integrated scenario). Hence, they could be used as sensitivity indexes for the D-RAIL results. In particular, this study was consulted to provide an indication of the modal split by 2050 and the potential shift to rail from other modes in the event that fuel prices increase radically.

### 4.4.3. TEN-CONNECT study[17]

The TEN-CONNECT study aimed to redefine the TEN-T network. However, due to different circumstances, including the financial crisis, the results were not used for this purpose. A second round of calculations was completed in TEN-CONNECT II in 2011 where a new data collection process was conducted and a new methodology applied. In this project the TRANS-TOOLS model was used to produce forecasts for different scenarios of freight transport up to 2030 (Tetraplan and partners, 2009). The forecasting horizon was 2030 and therefore is of less relevance to D-RAIL though the geographical scope is the EU which is relevant. The objectives of the study were: a calibration of the 2005 freight model; calculation of Baseline Forecast to 2030 and modelling of three infrastructure scenarios.

Methodology and models: A multi-modal modelling framework based on the STEMM concept was developed during the WORLDNET project in 2009. This methodology was used, calibrated and developed for use in the TEN-T Ports study in 2010. Growth assumptions come from the iTren study. The TRANS-TOOLS model was used to forecast the different scenarios.

Table 4.6 below shows the modal split outcomes for the base year, 2005, and 2030 together with the pa Growth for road and rail.

**Table 4.4 TEN-CONNECT II transport growth**

| EU27 in TEN-CONNECT | Unit | 2005 | 2030 Baseline with priority projects | pa Growth |
|---|---|---|---|---|
| Road | bn truckkm | 1775 | 2493 | 1.4% |
| Rail | bn tonnekm | 404 | 690 | 2.2% |

*Source: Tetraplan and partners, 2009*

TEN-CONNECT forecasting horizon is limited to 2030 so demands up to 2050 would need to be extrapolated from the 2030 outcomes if used by D-RAIL.

## *4.5. Factors related to the Reference Scenario*

When reviewing the results, the iTREN 2030 scenario seems most appropriate for D-RAIL project as the most relevant inputs factors are taken into account. These include:

- Multiple input
- Economic downturn
- Policy measures
- Network (infrastructure)
- Detailed output

For the period 2010 to 2030 there are annual growth factors available at commodity level (per region). For the period 2030 to 2050, it was necessary to evaluate and extrapolate growth factors from iTREN data and applied these to the 2005 basis of the Origin Destination matrix for D-RAIL. Two further models, the HOP! Model, which is based on iTREN, and FREIGHTVISION are considered when defining the meta-models from 2030 and on.

[17] Petersen M.S., Bröcker J., Enei R., Gohkale R., Granberg T., Hansen C.O., Hansen H.K., Jovanovic R., Korchenevych A., Larrea E., Leder P., Merten T., Pearman A., Rich J.,
Shires J., Ulied A. (2009): Report on Scenario, Traffic Forecast and Analysis of Traffic on the TEN-T, taking into Consideration the External Dimension of the Union – Final Report, Funded by DG TREN, Copenhagen, Denmark.

## 4.6. Additional factors for the White Paper Scenarios

As previously mentioned the D-RAIL Reference Scenario is created using extracted results from the White Paper Scenario (See Section 2.4) using the assumptions listed in Table 4.7 below.

**Table 4.5 Additional assumptions for the White paper scenario**

| | 2010 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| White Paper relevance to Reference scenario | The same as Reference | The White paper starts to be effective. No change from the Reference | 30% freight shift to rail and waterborne transport from road for distances greater than 300km | 50% freight shift to rail and waterborne transport from road for distances greater than 300km |

As the policy changes (table 4.7) and the socio economic framework are already defined, in order to simulate the shifts from road to rail we need to introduce into the model some further conditions. In reality, the road freight demand is far more extensive and is used in many more regions than rail. For this reason, it was necessary to add two control variables in the freight model clearly depict the effects of the White Paper on the rail sector. The first variable indicates the *existence of rail network* in each region. The second points out the existence *of rail freight demand* in the region.

In this way we (1) ensure that there is an existing network to support the shift of freight transport from the road sector and (2) we highlight the areas of the network which is already used for freight transport by rail. This was an important step in the analysis as it reflected the most accurate use of the network, assuming it would remain the same for the present forecasting.

Based on the White Paper targets and the control variables we built in two more scenarios: the Low White Paper and the High White Paper. The Low White Paper scenario allocates additional road demand to rail only if both conditions are true, i.e. there is an existing rail network which is currently used for freight transport and the High White Paper scenario calculates rail freight demand considering the first condition only - ie that there is an existing rail network.

# 5. **Outcome scenarios up to 2050**

This chapter describes the modelling processes and presents their results for EU27, EU15 and EU12. As mentioned in the previous section, due to the limitations of TRANS-TOOLS, there was a need for meta-models to calculate the projections from 2030 up to 2050.

## *5.1. Freight Demand*

EU27[18] freight demand plays a very important role in determining vehicle fleet. Demand for freight transport is affected by many factors, including population, economic growth, (international) trade, journey costs and journey times. The results from 2010 to 2030 for the reference scenario come directly from the TRANS-TOOLS simulation, using as indicated in the previous chapters, the drivers from the iTREN model (also see Annex 2). From 2030 and on, the projection of rail demand was based on trend extrapolations, similar to iTREN scenarios. As expected, these are differentiated for the two transport modes (road and rail) as well as for the different geographical coverage clusters of EU15 and EU12. In this way, we introduce a type of weight control to more accurately speculate/forecast demand.

Although the White Paper (EC, 2011) estimated a modal shift from road to rail the existing structure of the TRANS-TOOLS model required an alteration to some of the major features in its modules for use in D-RAIL freight forecasting. More specifically, the method of *backcasting* was used to define the meta-model for the White Paper scenario. This method, in terms of modelling, was based on the results of the Reference scenario combined with the EC (2011) speculation on freight demand. The White Paper scenario was based on Table 4.7 assuming a 30% shift from road in 2030 and 50% shift from road in 2050 to rail and waterborne transport for distances more than 300 kilometres (given that the network infrastructure remains the same).

The freight model of TRANS-TOOLS modified the Reference scenario to produce the two White Paper (Low and High) scenarios results. The High scenario differs from the Low Scenario by just considering one of the two control variables i.e. rail freight demand whereas the Low scenario is calculated using both the rail freight demand variable and an infrastructure condition.

This way, rail corridors which are not currently used for goods transport could be incorporated into the freight transport rail network for the future.

Due to the scope of the D-RAIL project, results presented are for EU27[19] road and rail. Interestingly the actual differences between the two scenarios are only visible after 2030, due to the expectation that there will be changes to White Paper after 2020. Hence, it is only possible to see the effects of the changes in 2030 results onwards.

**Results in tonnes**

Table 5.1 depicts the scenario results for the rail demand in 1000 tonnes. Here, it should be stated that in the present calculations, we take into account both domestic and international demand. Hence, as the shifted percentages to rail result from distances greater than 300 kilometres, they do not, in most cases, include domestic demand, which is a crucial part of the road demand. That is why the modal split results (see Table 5.3) are relatively low.

With regard to the Reference scenario, we anticipate, in the period 2010-2050, a moderate growth of 1.5% annually. The average annual growth rate for the total of EU15 countries remains at relatively low levels of around 1%, while for the EU12 this number is more than 2%. This assumes that the EU12 countries will have a higher GDP growth than the others. The bulk of transport for all the EU27 remains on national territory; on average only 34% of the total demand is international. Exceptions to this are countries such as Austria, Belgium and the Netherlands from the EU15 and Slovenia and Slovakia from the EU12, which can all be characterised as “transit” countries.

[18] The present analysis excludes the countries of Malta and Cyprus, as these have no rail transport.
[19] However, in Annex 3, these are presented analytically per country including Switzerland and Norway, as well as the total results for EU15 and EU12 separately. In addition, Annex 4 depicts the main flows in form of maps.

The effect of White Paper targets for the transport system is an average[20] annual growth for rail demand which almost doubles in the High case (from on annual average of, 1.5% to 2.9%). At the same time, shifted demand in the Low scenario is limited due to the strict conditions imposed within the scenario – ie having to meet two control variables. More specifically, 2030 shows a 90 million tonnes shift to rail and a 165 million tonnes shift in 2050, coming mainly from the EU15 (for example Germany and Italy are responsible for 40% of the shifted load).

The White Paper estimates a shift of 30% in 2030 and a 50% in 2050 from road to other types of transport. Based on the overall modelling assumptions, the shift from road is expected to be quite low, with the total rail demand being quite close to the Reference scenario. On the contrary, the High scenario anticipates a shift of more than 600 million tonnes in 2030 and more than 1 billion tonnes in 2050, raising the shifted road percentage up to 5.37%. Again, this is mainly due to the EU15 countries. From the EU12 perspective this main shift to rail occurs in the Czech Republic, Poland and Romania.

**Table 5.1 Freight demand in tonnes (EU27)**

| Rail Demand per scenario (in mtonnes) | 2010 | 2020 | 2030 | 2050 | pa growth |
|---|---|---|---|---|---|
| Reference | 1,040 | 1,260 | 1,590 | 1,902 | 1.52% |
| Low White Paper | 1,040 | 1,260 | 2,915 | 2,067 | 1.73% |
| High White Paper | 1,040 | 1,260 | 2,307 | 3,224 | 2.87% |
| **Rail Demand (% shift from road)** | **2010** | **2020** | **2030** | **2050** | **pa growth** |
| Shift from road to Low Scenario | | | 0.46% | 0.77% | |
| Shift from road to High Scenario | | | 3.22% | 5.37% | |

Figure 5.1 presents rail demand results (for comparison purposes) of the different EU groups for the two White Paper versions. As one can see, the total demand is greater for the High scenario where the total shift is allocated entirely to rail and this is clearly depicted by the sharp increase between scenarios for the period 2020-2030. In the Low scenario, the growth rate from 2030-2050 for EU12 is marginally greater than in the EU15, however EU15 growth is more pronounced in the High scenario. The Low scenario reflects a more realistic result where growth in is higher in the EU12, even if there is a shift from road. On the other hand, in a more extreme High scenario, the road shift mainly occurs in the EU15.

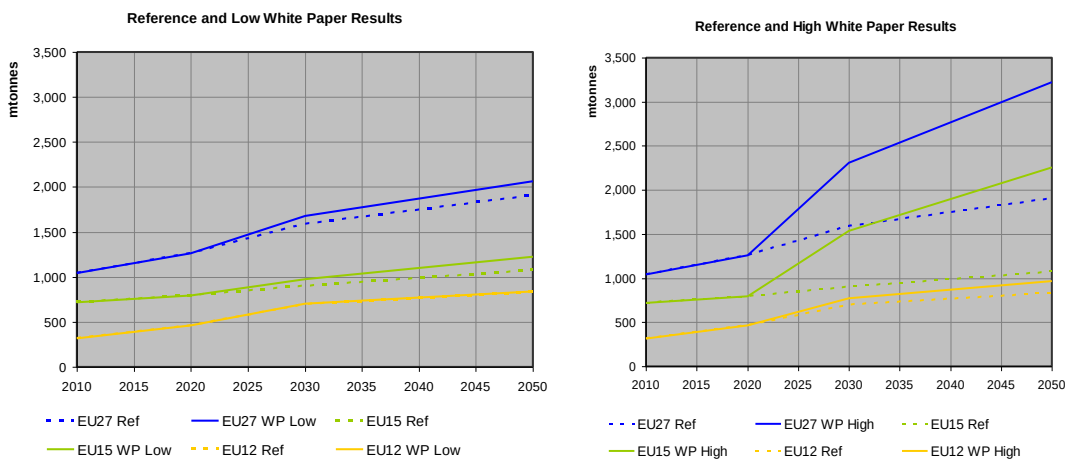


**Figure 5.1 Rail demand for the EU27, EU15 and EU12 in 1000 tonnes**

[20] The average annual growth is calculated for the period 2010-2050.

**Results in tonne-km**[21]

Table 5.2 illustrates projections from the two scenarios in billion tonnes-kilometres (btonne-km). The results in tonne-km are similar to the ones for road, especially relating to the trends of the different regions (EU27, EU15 and EU12). Nonetheless, the results in tonne-km depict the importance of the distance factor in the description of the results. For the Reference and Low scenario, the average growth rates are not significant. However, the growth rate of the High scenario is more than double, compared to the Reference[22]. In short, while only a slightly more than 1% is expected to shift from road to rail in the Low scenario, a move of around 5% and 8% respectively for 2030 and 2050, is anticipated for the High Scenario.

At a national level, compared to the Reference scenario, the countries which depict the highest relative growth belong to the EU15, with Germany and Italy still maintaining the highest positions. For the EU12, the higher flows originate from Poland, Czech Republic and Romania, representing 60% of the total EU12 demand.

**Table 5.2 Results in btonne-km**

| Rail Demand per scenario (in btonne-km) | 2010 | 2020 | 2030 | 2050 | pa growth |
|---|---|---|---|---|---|
| Reference | 316 | 365 | 439 | 521 | 1.26% |
| White Paper Low | 316 | 365 | 488 | 611 | 1.66% |
| White Paper High | 316 | 365 | 699 | 1000 | 2.92% |
| **Shift from road to rail percentage** | **2010** | **2020** | **2030** | **2050** | |
| Shift from road to Low Scenario | | | 1.13% | 1.18% | |
| Shift from road to High Scenario | | | 4.86% | 8.10% | |

The demand in billion tonne-km for the three scenarios depicted in Figure 5.2 illustrates the shift in relation to distance. The growth in 2020-2030 is significantly high for both the EU15 and the EU12[23]. This shows that a possible shift (for distances greater than 300 kilometres) of 30% from the road could result in considerable growth in the rail. From 2020 to 2030, where the highest average growth takes place as a result of the White Paper, the EU27 results from a less than 2% average annual growth to 3% for the Low Scenario and to almost 7% for the High scenario. After 2030, growth rates are more similar to those for 2010 to 2020. EU15 and EU27 growth is very similar. Conversely for EU12, growth rates follow a different pattern. Average grow from 2010 to 2020 is much higher than that of either EU27 or EU15. However, the change is comparably smaller from 2020 and on.

The EU27 growth rates are closer to the EU15 because volume demand stems from the EU15, which strongly influences the overall trend. As Figure 5.2 illustrates, EU12 contributes approximately one third of the total volume in billion tonne-km. This share is lower in the Low and High Scenarios due to country tonne-km definitions, which reflect origin of flow with the point of origin being mainly within the EU15 group.

[21] The results in tonne-km exclude Denmark, Estonia, Ireland, Latvia, Lithuania, Luxembourg and Slovenia.

[22] The growths calculated for tonne-km are smaller than those for tonnes, showing a decrease of the average distance for the cases of the Reference and the Low scenario (which have similar modelling limitations). The High scenario depicts more or less the same growth, showing that the average distance increases compared to the previous scenarios, again because of the modelling assumptions.

[23] The growth is not so obvious for the EU12 in the graph due to the relatively small absolute numbers.

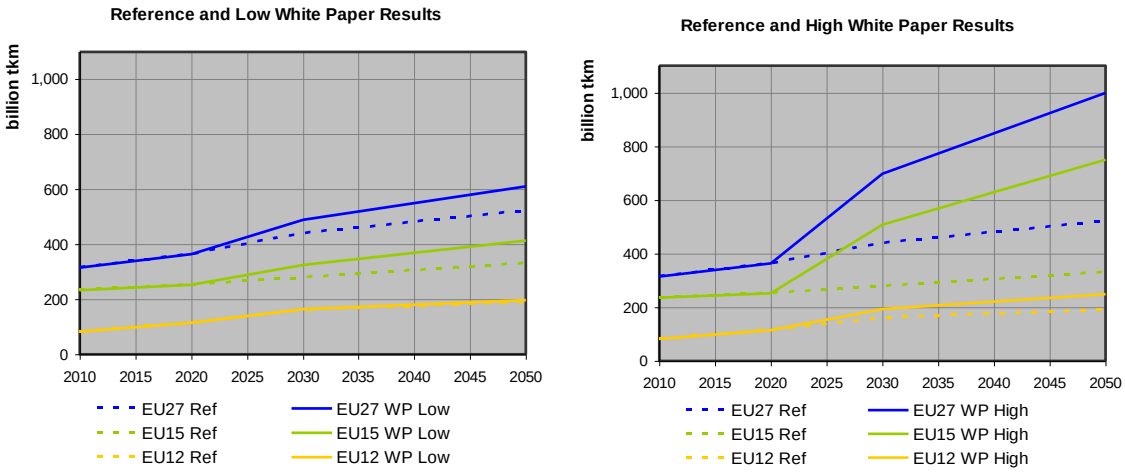


**Figure 5.2 Rail demand for the EU27, EU15 and EU12 in btonne-km**

## *5.2. Freight modal split*

**Modal split based on freight demand in tonnes**

The modal split is described for the White Paper scenario in order to clarify the rationale of the changes in the rail demand. The modal split is defined only between the modes of road and rail. In Table 5.3, the Reference scenario describes a modal split where the road still maintains its leading position in the EU27 freight transport. In the Reference scenario, only 7% of the total demand is attributed to rail (in terms of tonnes) reaching up to almost 9% in 2050. On average, the share of rail for the Reference scenario throughout the years is 8%.

Regarding the White Paper scenarios, this growth in road demand is now partially allocated to rail (based on the distance, the network and its use). This is the main reason that a 5% of the total demand, in tonnes, is shifted to rail by 2050 for the Low scenario and an 8% by 2050 for the High scenario.

Assuming the implementation of the White Paper (EC, 2011) targets, this is the projected split between these two modes. For the split in tonnes, the results show clearly the differences between the two scenarios. While the rail share grows less than 1%, in 2050, in the case of the Low scenario, it increases by 6% for the High scenario.

**Table 5.3 Rail proportion of total rail and road volume in tonnes and tonne-km**

| in tonnes | 2010 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| Reference | | | | |
| **Rail** | 7.4% | 7.7% | 8.2% | 8.8% |
| White Paper Low | | | | |
| **Rail** | 7.4% | 7.7% | 8.6% | 9.6% |
| White Paper High | | | | |
| **Rail** | 7.4% | 7.7% | 11.8% | 15.0% |
| **In tonne-km** | 2010 | 2020 | 2030 | 2050 |
| Reference | | | | |
| **Rail** | 10.1% | 10.1% | 10.1% | 10.8% |
| White Paper Low | | | | |
| **Rail** | 10.1% | 10.1% | 11.2% | 12.7% |
| White Paper High | | | | |
| **Rail** | 10.1% | 10.1% | 16.1% | 20.8% |

## 5.3. Commodity Split

This section presents the aggregated results for each scenario per commodity (for national freight demands, please refer to Annexes 3 and 4) and describes general trends in commodities within the specific scenarios, including distribution for EU15 and EU12. Average Annual growth rates are also presented. NSTR1[24] nomenclature is used for transported good classification and commodity shares are produced based on the freight demand model in TRANS-TOOLS. Information relating to the development of goods is relevant particularly to the scenarios as it will assist in identifying future needs for wagon types.

### 5.3.1. Commodities overview

Changes in commodity distribution for 2030 are shown in Figure 5.3 for the three scenarios. The difference between the Low scenario and the Reference is quite small due to the fact the shift from road is not that extensive in this instance. The main discrepancies in commodity split can be observed between these two scenarios and the High scenario which anticipates the highest shift from road demand.

Figure 5.3 demonstrates these changes.

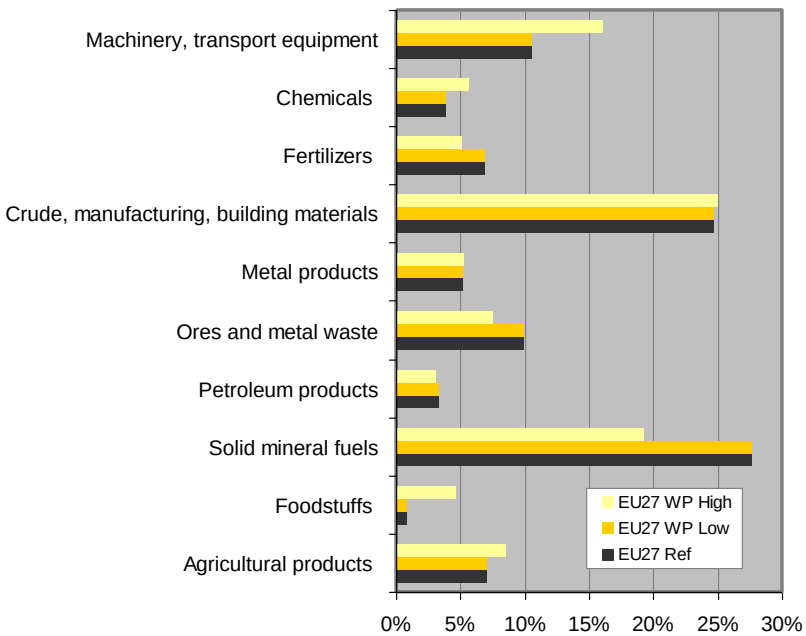


**Figure 5.3 Commodities share for 2030 (volume in tonnes)**

For 2030 (Figure 5.3) and compared to TRANS-TOOL data presented in Annex 3, the demand share for petroleum and solid mineral fuel products transported by rail decreases significantly when the projection incorporates a shift from road for the distances above 300 km (per White Paper targets). More specifically, decreases of 9% and 7% respectively occur between the Reference and the White paper scenarios. In addition the metal products share is decreased by 4%. At the same time, a strong increase is anticipated for the construction material, transport equipment and, in further, food products by 9, 6 and 4%. Metal waste products, fertilisers and chemicals remain the same. This shows that these types of goods already belong to the rail sector.

[24] Clarification note on the commodities, NSTR1 nomenclature is used, which stands for Standard Goods Classification for Transport Statistics / Revised from 1967. It consists of 10 groups: 0 := agricultural products and live animals, 1:= foodstuffs and animal fodder, 2:= solid mineral fuels, 3:= petroleum products, 4 := ores and metal waste, 5 := metal products, 6 := crude and manufactures minerals, building materials, 7 := fertilizers, 8 := chemicals, 9 := machinery, transport equipment, manufactures and miscellaneous articles

The transport equipment as well as the building materials together represent, for 2030 in the White Paper scenarios more than 40% of the total demand. Adding to this the food products, the share rises up to 60%.

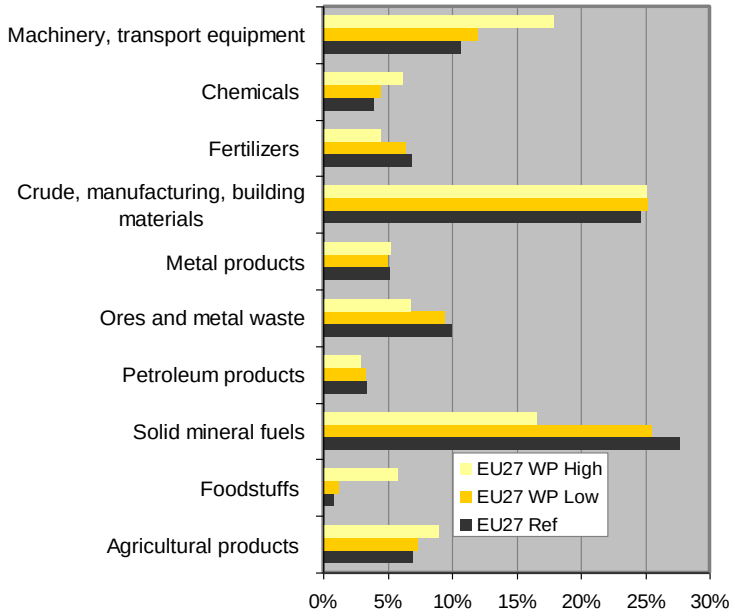


**FIGURE 5.4 Commodities share for 2050 (tonnes)**

For 2050, the situation is quite similar to 2030. The share of commodities as well as the differences between the scenarios is maintained. This is expected as the demand figures for the year 2050 are extrapolated from 2030 for both rail and road.

### 5.3.2. Reference Scenario

**Results in Tonnes**

Figure 5.5 shows percentage distribution of commodities between EU15 and EU12 in the Reference Scenario. EU15 accounts for almost 70% of the total freight transport and this percentage decreases to 56% by 2050, indicating a shift in freight transport to within the EU12.

Petroleum products, coming from second generation biofuels, followed by machinery and transport equipment, building materials and solid mineral fuels represents the greatest volume of freight distribution, hence the tendency of freight transport to focus on energy and construction materials rather than transport equipment. In general, the main volumes come from Germany, followed by Poland. However, each commodity depicts different trends in terms of origin country. For example, for the year 2050, the main origin for foodstuffs is France, for coal it is Poland and so on. With regard to building materials, the main origins are EU12 countries such as Poland and Romania. In fact, this commodity is the only type where the flows for EU12 and EU15 are almost equal.

The outcomes for all commodities slightly differ for EU15 and EU12 in the year 2050, as shown in the figure below, mainly concerning the actual percentages of share than the commodities themselves. This means that both construction material and coal are the most important commodities, however, their share differ for the EU12 and the EU15. In the EU12, these two commodities account for 66% (mainly coming from Czech Republic, Romania and Poland) of the total, while for EU15 this accounts for 42% (Germany, France, Netherlands, UK etc). On the other hand, commodities such as transport equipment, metal products and waste obtain a higher share for the EU15.

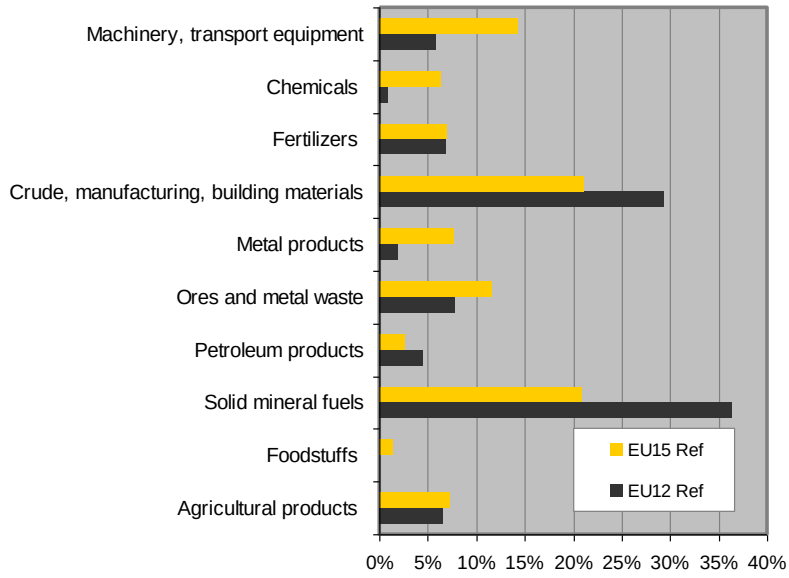


**Figure 5.5 Tonnes in Reference Scenario in 2050**

Table 5.4 depicts the average percentage annual growth rates and the total volumes in billion tonnes. The Solid Mineral Fuel and Petroleum product – ie energy, industries shows the highest annual growth rates, followed by building materials. Again, here we should note the importance of the EU12 results to the total. Overall, the growth rates are moderate for the Reference scenario.

**Table 5.4 Average EU27 Commodity growth in the Reference Scenario for the time period 2010 – 2050 (tonnes)**

| Average growths pa | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores, metal waste |
|---|---|---|---|---|---|
| EU27 (2050) in btonnes | 133 | 15 | 526 | 64 | 190 |
| EU27 pa growth | 1.49% | 1.04% | 1.71% | 1.71% | 1.40% |
| **Average growths pa** | **Metal products** | **Building materials** | **Fertilisers** | **Chemicals** | **Machinery, transport equipment** |
| EU27 (2050) in btonnes | 98 | 469 | 131 | 75 | 202 |
| EU27 pa growth | 1.17% | 1.64% | 1.52% | 1.10% | 1.27% |

*Source: NEA (TRANS-TOOLS) Reference Scenario in tonnes*

### Results in Tonne-km

The results in tonne-km (Table 5.5) differ considerably from the tonnes results (Table 5.4) as they incorporate the distance (in kilometre) factor. The actual NSTR Commodity group distribution results differ in tonnes although tonnes and tonne-km demonstrate similar general trends in most cases. The commodities with the greatest demand remain the same. Germany, representing almost one fifth of the total demand, has a strong impact on the share distribution particularly in manufacturing and construction products.

In 2010, the EU15 accounted for 74% share of total demand in tonne-km. By 2050 this percentage is expected to decrease to 64%. This is likely to be due to increased flow stemming from Poland, Czech Republic, Hungary and Romania. In total, outflow from the EU12 countries are expected to grow faster than those of the EU15 as they anticipate higher rates of economic growth.

In the EU12, the main flow of commodities is solid mineral fuels and building materials (Figure 5.6). In fact, these are the only commodities with a greater than 10% share. The solid mineral fuel share of more than 35% includes Poland and Czech Republic who account for 60% of the total EU27 demand. Interestingly, building materials for the two clusters are almost equal. In addition, the transport equipment, chemical and metal product commodity group share is higher in the EU15 cluster. This is due to large transport demand from Germany and France (metal products) and Germany and Spain (for transport equipment). The chemicals transport originates mainly from Germany (40% of the total EU27).

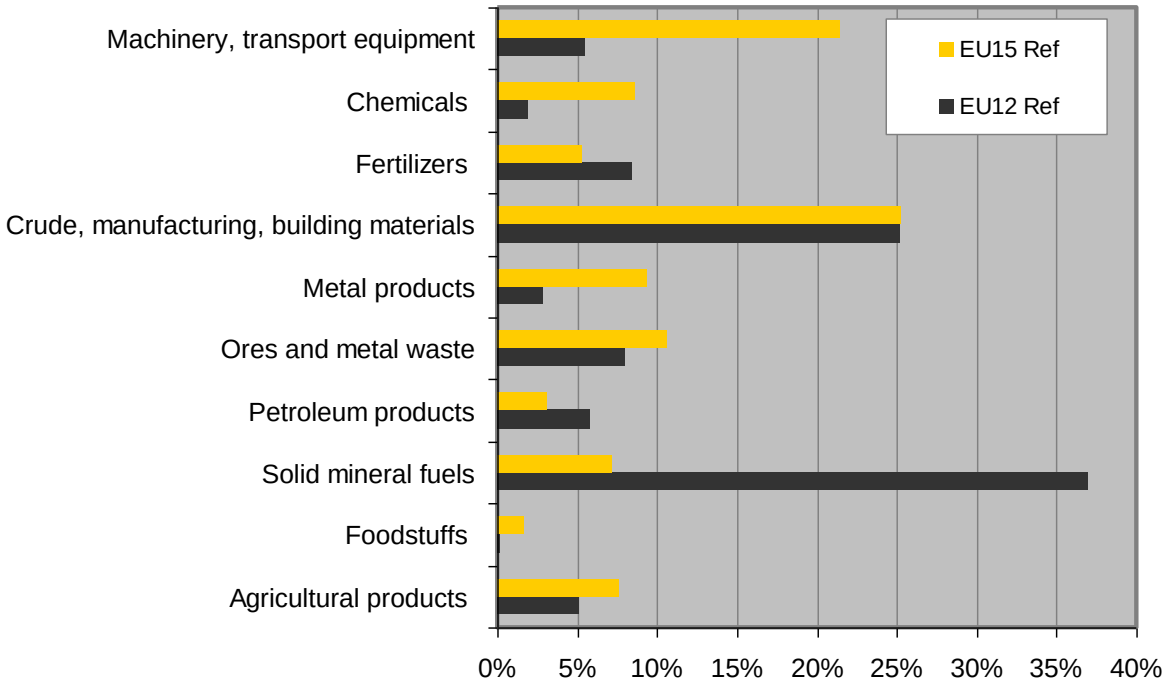


**Figure 5.6 Reference Scenario commodities distribution for 2050 in tonne-km**

The average annual growth for tonne-km (Table 5.5) are similar to those for tonnes (Table 5.4), however they are slightly lower and linked to original assumptions in relation to the external variables (see Table 3.1).

**Table 5.5 Average EU27 Commodity growth in the Reference Scenario for the time period 2010 – 2050 (tonne-km)**

| | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores, metal waste |
|---|---|---|---|---|---|
| EU27 (2050) in btkm | 34.8 | 5.9 | 93.9 | 21.0 | 50.3 |
| EU27 pa growth | 1.16% | 0.92% | 1.76% | 1.44% | 1.19% |
| | **Metal products** | **Building materials** | **Fertilisers** | **Chemicals** | **Machinery, transport equipment** |
| EU27 (2050) in btkm | 36.4 | 131.3 | 33.8 | 32.1 | 81.3 |
| EU27 pa growth | 1.02% | 1.26% | 1.39% | 0.98% | 0.87% |

*Source: NEA (TRANS-TOOLS) Reference Scenario in tonne-km*

### 5.3.3. Low White Paper scenario

This section presents the commodity trends (aggregated figures) for the White paper scenarios in tonnes and tonne-km. The results are presented only for 2050.The national results for all years can be found in Annex 3 and the main flows in Annex 4.

**Results in Tonnes**

Figure 5.7 presents the distribution of goods for the year 2050 separately for the EU15 and the EU12 for both the Reference and Low Scenarios. Results are similar in each cluster, as the anticipated changes do not radically alter total demand or the commodities distribution.

At EU27 level, there is a decrease of coal, metal waste and fertilisers of less than 10%. At the same time, chemicals and transport equipment shares grow by 12%. The highest growth though, is observed for the food industry. However, this percentage has a small share, only 1.2% of the total demand. These changes are outcomes of the EU15 results in the Low Scenario. In fact, the EU12 commodities shares do not anticipate any significant changes.

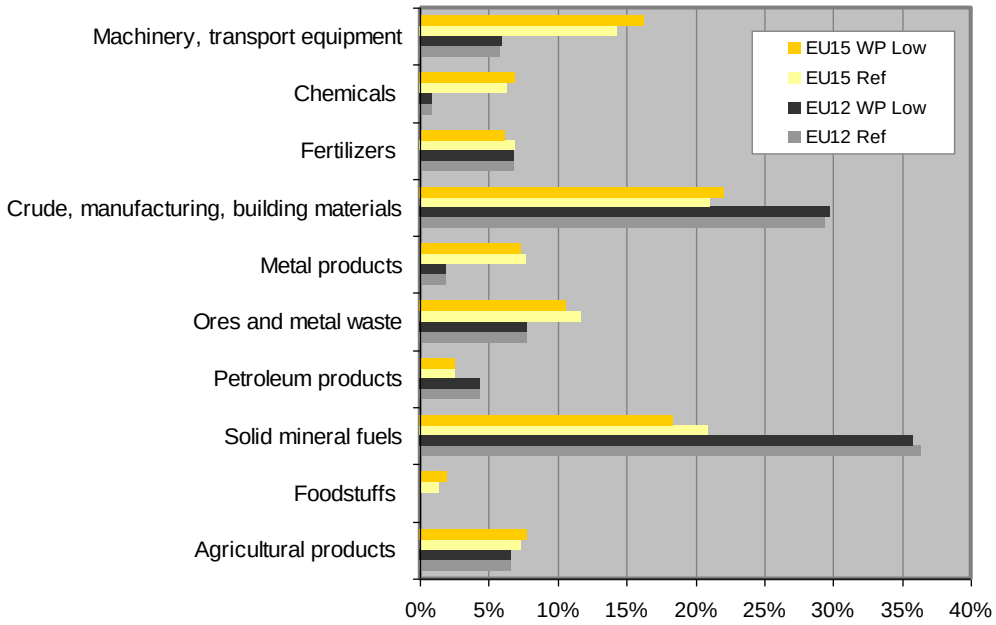


**Figure 5.7 Low White paper commodities distribution for 2050 (tonnes)**

Table 5.6 shows the annual percentage change in commodity distribution (in terms of growth). The average growth rates are, in general, slightly increased compared to the Reference ones, with the exception of fertilisers (see Table 5.4 and 5.6). The highest increase is depicted for the foodstuffs[25].

The growth rates for all commodities in the EU12 are greater than EU15 and in all commodity groups the growth is more than 2.4% pa. Additionally countries who maintain the greatest share of volume remain the same. Germany maintains a significant volume for all commodities, and especially for petroleum, metal, chemical and transport products. Poland also plays an important role with a commodity contribution to coal and manufacturing products.

[25] Even though, compared to the total these numbers are insignificant, nevertheless, it is worth mentioning that rail transport almost doubles for foodstuffs, in relation with the Reference scenario.

**Table 5.6 Average Low Scenarios Commodity growth for the time period 2010 – 2050 (tonnes)**

| | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores, metal waste |
|---|---|---|---|---|---|
| EU27 in pa | 1.81% | 2.19% | 1.72% | 1.86% | 1.48% |
| EU15 in pa | 1.49% | 2.16% | 1.01% | 1.31% | 1.10% |
| EU12 in pa | 2.46% | 3.05% | 2.43% | 2.44% | 2.47% |
| | **Metal products** | **Building materials** | **Fertilisers** | **Chemicals** | **Machinery, transport equipment** |
| EU27 in pa | 1.36% | 1.91% | 1.54% | 1.65% | 1.81% |
| EU15 in pa | 1.20% | 1.46% | 1.03% | 1.58% | 1.65% |
| EU12 in pa | 2.50% | 2.50% | 2.43% | 2.57% | 2.51% |

*Source: NEA (TRANS-TOOLS) White Paper Low in tonnes*

### Results in Tonne-km

Results between tonnes (Table 5.6) and tonne-km (Table 5.7) remain almost the same in terms of commodity distribution. In comparing the EU27 annual percentage growth, the differences for all commodities between the Low and Reference scenarios (Table 5.5 and 5.7) are fairly significant.

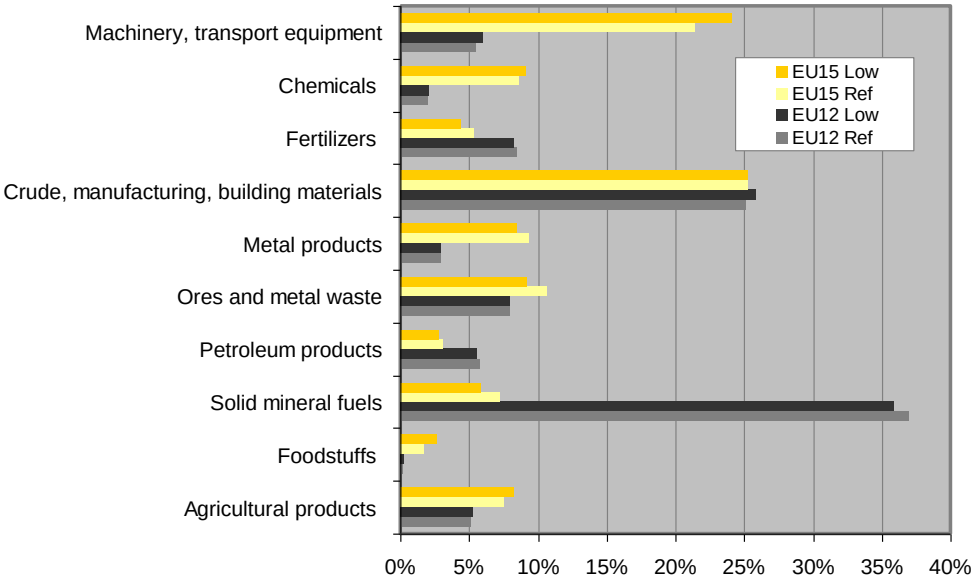


**Figure 5.8 Low White paper commodities distribution for 2050 in tonne-km**

The main load of goods stem from the EU12 countries. The growth rates for all commodities in the EU12 are greater than EU15 and for all commodity groups the growth is more than 2.4% pa. Table 5.7 shows the average Low Scenario percentage growth for the time period 2010 – 2050 for all commodities (tonne-km). Besides the slightly elevated growth rates for all commodities, the main addition coming from the road segment is in the sector of foodstuffs, depicting besides the modal shift a small commodity shift as well. In cases such as Austria, Czech Republic, United Kingdom and Spain the demand is more than double. However, these countries share a small portion of the total foodstuffs demand. In the cases of Germany and France, who own a larger part of the foodstuffs demand, the results are still significant. Countries such as Portugal, Luxembourg and Slovenia, do not have significant rail freight transport; hence, only a part of international transport is accounted for the road shift. This is why these countries demonstrate so small changes. For detailed results, the reader can advise Annexes 3 and 4.

**Table 5.7 Average Low Scenario growth for the time period 2010 – 2050 for all commodities (tonne-km)**

| | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores, metal waste |
|---|---|---|---|---|---|
| EU27 in pa | 1.78% | 2.59% | 1.78% | 1.64% | 1.35% |
| EU15 in pa | 1.65% | 2.58% | 0.92% | 1.23% | 1.05% |
| EU12 in pa | 2.29% | 2.76% | 2.16% | 2.18% | 2.24% |
| | **Metal products** | **Building materials** | **Fertilisers** | **Chemicals** | **Machinery, transport equipment** |
| EU27 in pa | 1.31% | 1.69% | 1.44% | 1.64% | 1.80% |
| EU15 in pa | 1.18% | 1.43% | 0.94% | 1.58% | 1.73% |
| EU12 in pa | 2.31% | 2.31% | 2.17% | 2.34% | 2.48% |

*Source: NEA (TRANS-TOOLS) White Paper Low in tonne-km*

### 5.3.4. High White Paper scenario

The results for the High scenario represent an extreme case of the White paper implementation (50% shift from road to the other modes by 2050). This section describes how the shift from road (even in cases where the rail network is not currently used for freight transport[26]) effects on the commodities split. The results are presented for 2050 in both tonnes and tonnes-km.

**Results in tonnes**

Contrarily to the Low scenario, the High scenario depicts more observable changes by 2050 with regard to the Reference scenario. The main flows are for manufacturing materials, transport equipment and coal. Compared to the Reference data, the commodities whose share is shrunk are: coal by 8.3% and metal waste by 3.6%. The actual demand for these commodities has either remained the same or was slightly increased. This indicates that the shifted road demand does not entail these commodities. The main increase is observed for transport equipment and foodstuffs, followed by chemicals and agricultural products. Hence, these commodities represent to a certain extent the demand transferred from road to rail.

Another observed change is the share between the EU15 and EU12. For both the Reference and the Low scenario, the split between the two clusters was 60% to 40%. The High scenario results to a split of 70% (for the EU15) to 30% (for the EU12). Therefore, the countries which mainly contribute to the road reallocated demand are within the EU15. In fact, the countries whose demand increases more than 100% are Denmark, Spain, France, Greece, Ireland, Italy, Netherlands and Portugal. The rest of the EU15 countries also experience an increase of more than 50%, besides the United Kingdom. On the other hand, the EU12 countries do not increase their traffic more than 24%, with the exception of Slovenia[27] (45%) which is strongly characterised by transit demand.

[26] As mentioned in the scenario definition (section 4.6), the High scenario assumes that the whole railway network is used for freight transport.

[27] Here, we should note again that the results are based on the scenario assumptions, especially for the High scenario. In addition, the total shift depends, besides the existence of railway network of the NUTS3 region, on the road demand of the specific region. Therefore, even in cases that the rail network exists, there is the possibility that the road freight demand for the specific region is small. In general, no conclusions can be obtained whether there is a relationship between the length of the railway network (also in respect to the total surface) and the shifted demand.

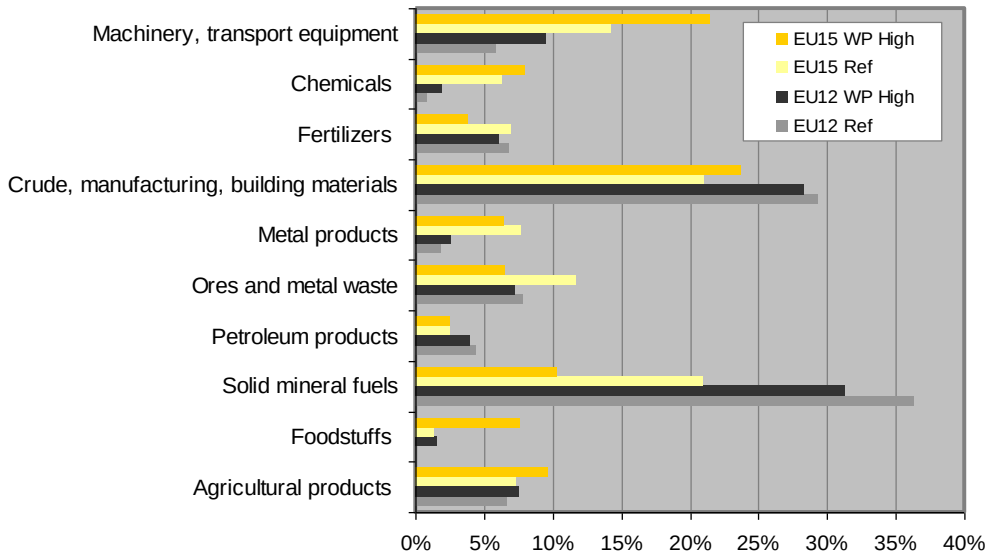


**Figure 5.9 High White paper commodities distribution for 2050 (tonnes)**

The shifted demand can be better demonstrated through the commodities split. Countries with strong demand, for example, in foodstuffs, expect a higher average growth rate. This is partly because commodity products e.g. coal, are transferred almost exclusively by rail. The table below demonstrates which commodities experience the highest growth. Besides foodstuff, other shifted demand comes from chemicals, transport equipment and to a less extent from metal and agricultural products. Commodities such as energy products do not change radically. This is why, for example, Poland whose main commodity transported is coal, experiences a small increase in demand.

**Table 5.8 Average growths for the time period 2010 – 2050 for all commodities**

| | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores, metal waste |
|---|---|---|---|---|---|
| EU27 in pa | 3.48% | 7.55% | 1.75% | 2.73% | 1.75% |
| EU15 in pa | 3.59% | 7.39% | 1.07% | 2.87% | 1.43% |
| EU12 in pa | 3.16% | 10.79% | 2.44% | 2.54% | 2.63% |
| | **Metal products** | **Building materials** | **Fertilisers** | **Chemicals** | **Machinery, transport equipment** |
| EU27 in pa | 2.58% | 3.03% | 1.78% | 3.61% | 3.97% |
| EU15 in pa | 2.43% | 3.20% | 1.37% | 3.51% | 3.94% |
| EU12 in pa | 3.73% | 2.73% | 2.51% | 4.86% | 4.09% |

*Source: NEA (TRANS-TOOLS) White Paper High in tonnes*

**Results in Tonne-km**

Tonne-km results are presented in figure 5.10 below

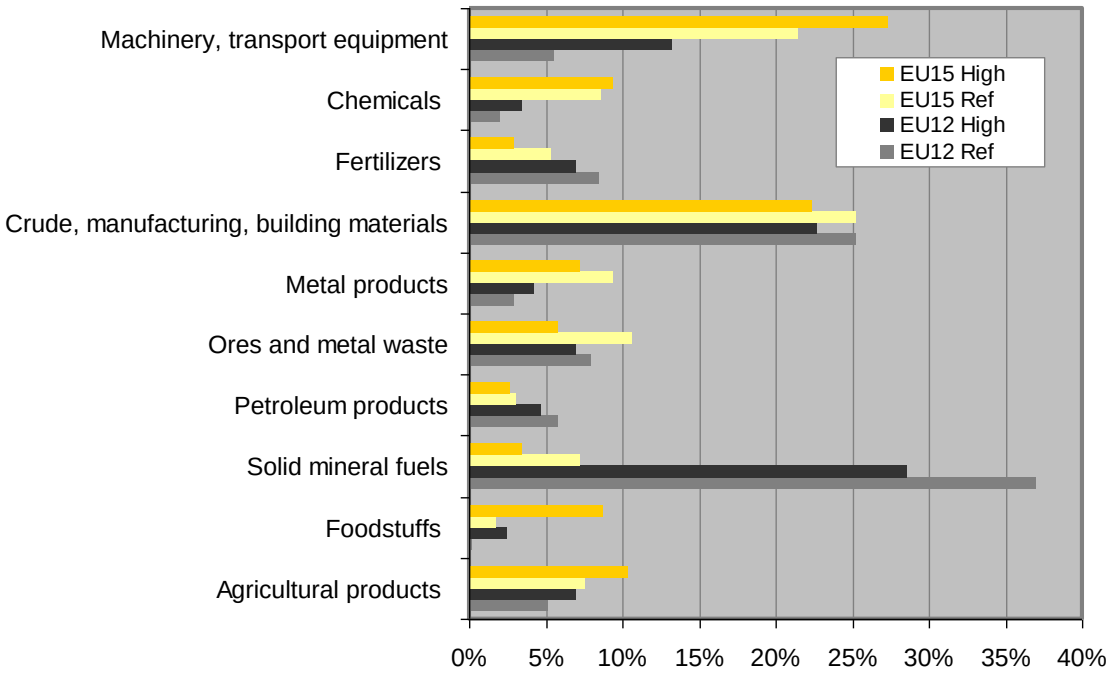


**Figure 5.10 High White paper commodities distribution for 2050 in tonne-km**

Based on the figures below, the shift from road has significantly influenced the average tonne-km growth rate, suggesting that, besides the total demand, the average distance has increased. Here, the differences with the Reference scenario are clearer. There is a strong increase in demand for foodstuffs and secondary for agricultural products and fertilisers. In addition, strong sectors such as building materials and transport products increase significantly their demand mainly in the EU15 (the total demand is 127% higher than the Reference; for the EU12 this value is 31%). Countries with strong activity in these commodities, for example Belgium, Germany, Netherlands but also Portugal achieves increases of more than 100% in their rail freight demand.

**Table 5.9 Average growths for the time period 2010 – 2050 for all commodities in tonne-km**

| | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores, metal waste |
|---|---|---|---|---|---|
| EU27 in pa | 3.74% | 7.43% | 1.84% | 2.46% | 1.66% |
| EU15 in pa | 3.77% | 7.29% | 1.08% | 2.55% | 1.39% |
| EU12 in pa | 3.61% | 9.73% | 2.19% | 2.32% | 2.48% |
| | **Metal products** | **Building materials** | **Fertilisers** | **Chemicals** | **Machinery, transport equipment** |
| EU27 in pa | 2.63% | 1.74% | 3.27% | 3.74% | 2.92% |
| EU15 in pa | 2.64% | 1.36% | 3.17% | 3.57% | 2.95% |
| EU12 in pa | 2.58% | 2.32% | 4.30% | 5.13% | 2.85% |

*Source: NEA (TRANS-TOOLS) White Paper High in tonnes-km*

### 5.3.5. Overview of commodities (tonnes basis)

In terms of tonnes, the whole situation is summarized in figures 5.11-13. This figure shows the development of the commodity distribution over time for the different scenarios for the EU27.

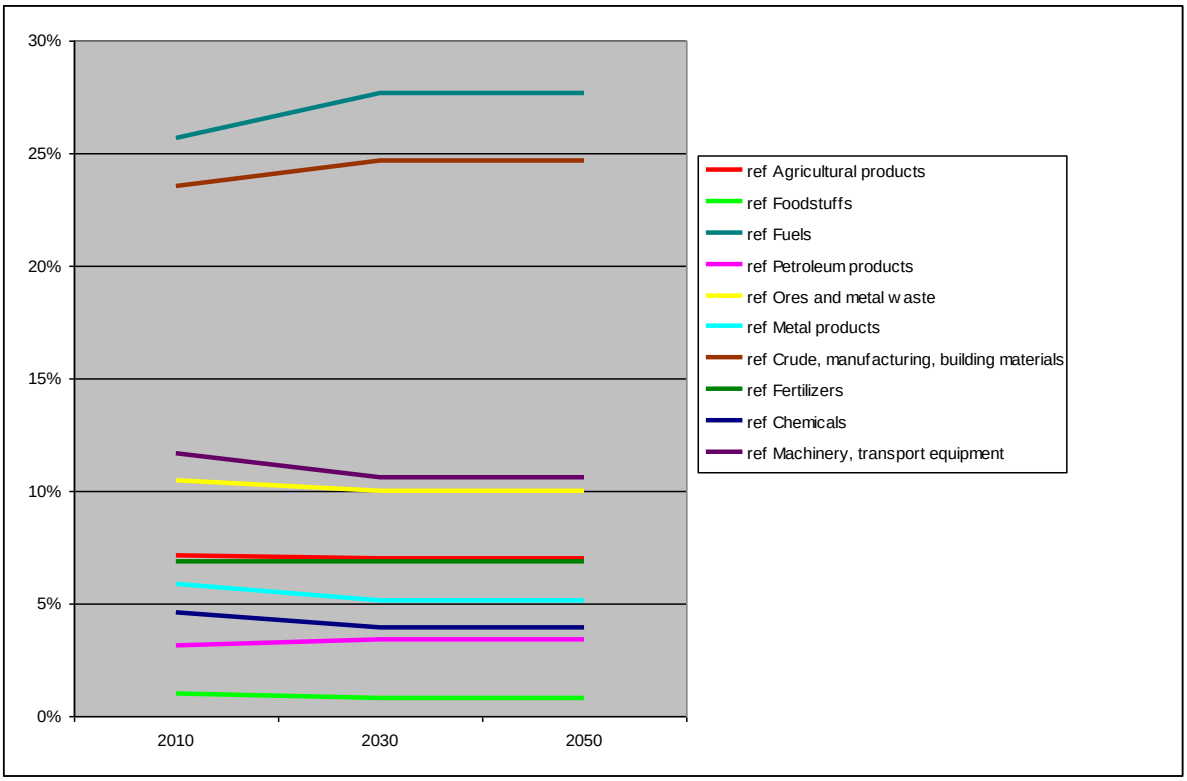


**Figure 5.11 Overview of commodity distribution in percentages Reference Scenario for EU27.**

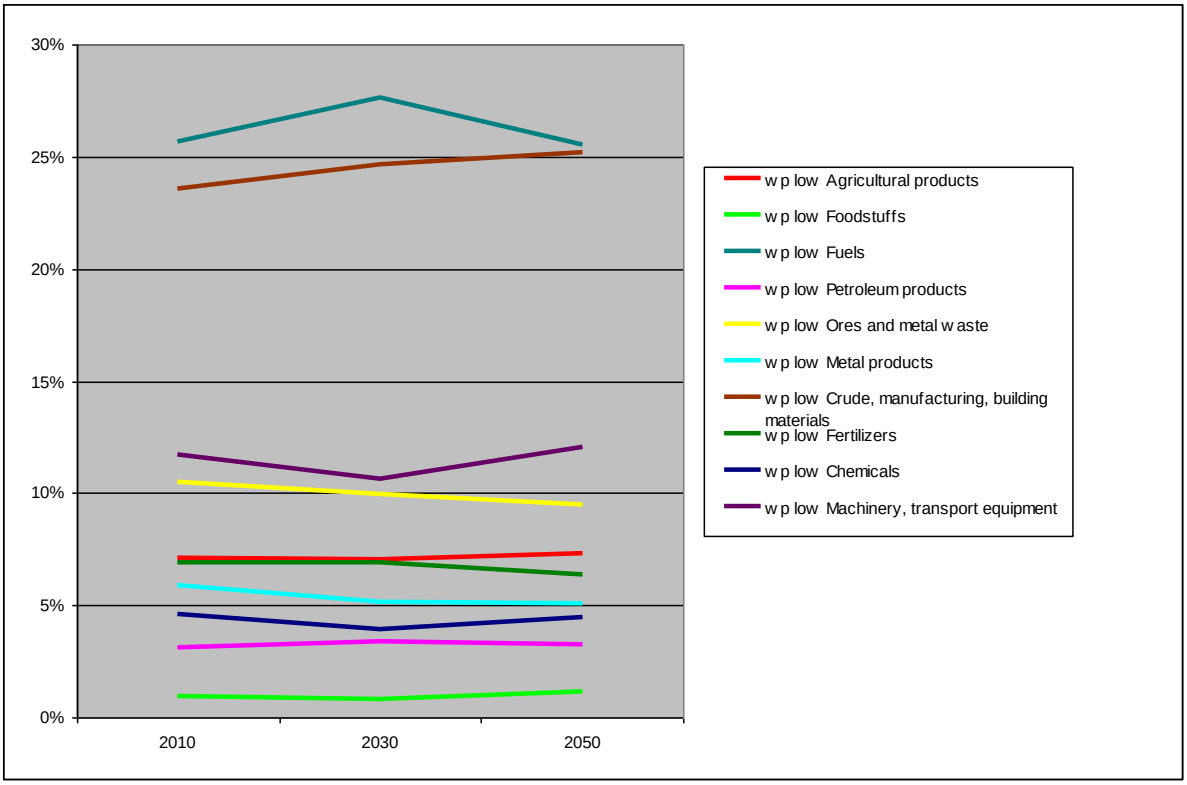


**Figure 5.12 Overview of commodity distribution in percentages White Paper Low scenario for EU27.**

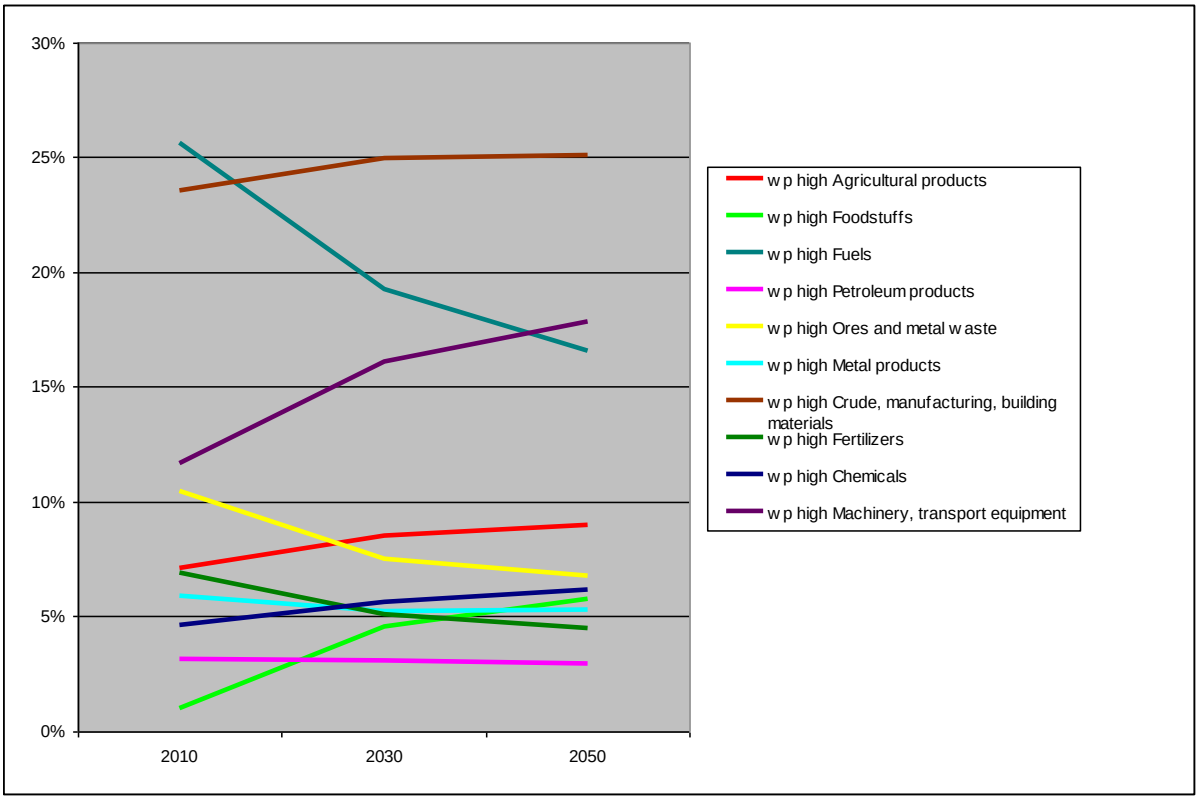


**Figure 5.13 Overview of commodity distribution in percentages White Paper High scenario for EU27.**

As before products with the greatest distribution percentage are fuels, crude, manufacturing and building materials. The fertilizers and agricultural products are grouped close together and are expected to stay that way. The shift from road anticipated in the White paper scenarios will decrease the distribution percentage in fuels, ores and metal waste (the extent depends on the success of the White Paper implementation: Low or High scenario). The prospective demand for foodstuffs and container goods (Machinery, transport equipment) is uncertain, as this shows little change in the Reference and Low scenarios (Figures 5.11 and 5.12), yet a major increase in the High scenario (Figure 5.13). Based on the model outcomes, the extent of the road shift is in general uncertain, especially considering the discrepancy between the Low and High Scenarios.

Nonetheless, in order to deal with prospective changes in demand/ commodities, flexibility is required of rail transporters. In all scenarios, for the period 2030 – 2050 percentage distribution appears to level out, with a few exceptions. Fuels, Machinery and Transport Equipment commodity groups in the High Scenario show the greatest changes in percentage distribution after 2030 whilst Ores and Metal waste show greater change (decline) in the period leading up to 2030 but levels out between 2030 and 2050 (Figure 5.13). The only other major shift in percentage distribution is in the Low Scenario where Fuels show a sharp decline between 2030 and 2050 (Figure 5.12). This suggests a degree of flexibility will be required in rail transport to accommodate such changes and exceptions. As the White Paper provides a policy objective from which the model predictions in this report are derived, it would be appropriate to assume that a few years of uncertainty, in terms of growth or decline, which may result in efficiency loss could be expected.

### 5.3.6. Overview of commodities (btkm basis)

Table 5.10 summarises the results for all commodities as a growth factor from the base year (2010). The differences between the scenarios can be observed between the years 2030 and 2050 of the scenarios. The first row of the table shows in absolute values the demand per commodity in billion tonne-km. The rest of the rows demonstrate the differences between the 2010 values and the other years and scenarios[28].

For example, in order to calculate the volume of Foodstuffs in the year 2050 using the High Scenario we use the formula:

Demand in volume$_{_Comm_Scenario_Year}$ = 2010 Base$_{_Comm_Ref_2010}$*(1+ scenario factor$_{_comm_scenario_year}$)

Hence, the demand is 72.16 btkm:

Demand in Volume = (4.1)*(1+16.6) = 72.16 (btkm)

**Table 5.10 Values of commodity factor from above equation for all three scenarios**

| Scenario | Year | Agric. products | Food-stuffs | Solid mineral fuels | Petroleum products | Ores | Metal products | Crude, manuf., building materials | Fertilizers | Chemicals | Machinery, transport equipment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| REF | **2010** | **21.9** | **4.1** | **46.8** | **11.8** | **31.4** | **24.2** | **79.6** | **19.4** | **21.7** | **54.7** |
| | 2020 | 0.1 | 0.1 | 0.3 | 0.2 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 |
| | 2030 | 0.3 | 0.2 | 0.7 | 0.5 | 0.4 | 0.3 | 0.4 | 0.5 | 0.2 | 0.3 |
| | 2050 | 0.6 | 0.4 | 1.0 | 0.8 | 0.6 | 0.5 | 0.6 | 0.7 | 0.5 | 0.5 |
| LOW | 2030 | 0.6 | 0.9 | 0.7 | 0.6 | 0.4 | 0.4 | 0.6 | 0.5 | 0.5 | 0.6 |
| | 2050 | 1.0 | 1.8 | 1.0 | 0.9 | 0.7 | 0.7 | 1.0 | 0.8 | 0.9 | 1.0 |
| HIGH | 2030 | 1.8 | 9.0 | 0.7 | 1.0 | 0.5 | 0.9 | 1.0 | 0.6 | 1.4 | 1.8 |
| | 2050 | 3.3 | 16.6 | 1.1 | 1.6 | 0.9 | 1.7 | 1.8 | 1.0 | 2.6 | 3.3 |

[28] For the detailed values for all commodities the reader is referred to Annex 3.

# 6. **Conclusions**

The focus of this report was to investigate the potential EU27 rail freight demand trajectories to 2050 using a range of projected scenarios based on specific socio-economic trends extracted from an extensive literary review. Three options were developed: the reference option, where no major policy change occurs in the future and two White Paper options, which adopt the assumption that there will be a significant shift in freight demand from road to rail in the period to 2050.

In terms of tonnes, total freight demand is expected to grow on average by 1.53% annually according to the Reference scenario. This average growth rate increases significantly in the High White Paper scenario strongly affecting the modal split and doubling rail demand. In the Low scenario, total demand is increased by almost 20% over the present position (Reference Scenario in 2050) while in the High scenario, the total demand is expected to almost double favouring long-distance transport. The implications for the rail freight sector in terms of wagon fleet capacity and capability are therefore significant as is availability of infrastructure (e.g. line capacity and train paths) to accommodate the much higher demands expected.

The Reference scenario indicates a commodity split that will change in terms of tonnes; there will be an increase in volume (tonnes) in all commodity groups except machinery, transport equipment goods, metal products and chemicals transport which will lag behind the rest. Fuels and building materials will (currently the top groups in terms of tonnes) further increase their share towards 2030 and consolidate by 2050. The shares of commodities change dependently on the Scenarios with the most observable increase in food products, chemicals and total products (machinery and transport equipment).

Flexibility in the transport of a variety of commodities will be necessary if and when the White Paper Low and High scenarios become a reality. The predicted changes in product and commodity demand, development and service etc will influence customer service expectation and directly impact flexibility of rail operations and their inevitable integration of transport modes to meet demand and expectation. This will influence the rail and transport infrastructure at a national and European level and it will be important for industry and governments to maintain a policy of investment and development for this to succeed.

# Annexes

## Annex 1 Literature review

| Project acronym | | FP/ other | Main work package | Subject and scope | Summary of project results | Assumptions of the forecasting (e.g., GDP growth, policies, etc.) | Project outcomes relevant to D-RAIL |
|---|---|---|---|---|---|---|---|
| **Completed projects** | | | | | | | |
| **BESTUFS** | | **5** | Ensuring sustainable (sub)urban transport (incl.modal shift, suburban and regional rail, light rail and metro, and sustainable urban mobility) | Urban Freight Best practise | | Not detailed | Stats data/use of rail/night delivery/PPP & ITS in urban freight/Urban freight platforms/consol centres. Primarily city logistics |
| **Co-Act** | | **5** | Encouraging modal shift and decongesting transport corridors | Rail Air Interaction | validation of air/rail freight transport concepts at European level & the development of integrated and inter-modal systems including airfreight by rail to improve sustainability | | Technical/economic/materials. No follow up. |
| **F-Man** | | **5** | Encouraging modal shift and decongesting transport corridors | Rail Car Asset Management of International Freight Wagons | main goal of F-Man was to investigate the feasibility and benefits related to the development of new tools towards the international management of international wagon fleets | Not accessed | Fleet management and issues of international wagon fleet monitoring and control. Possibly relevant for de-rail. No forecasts identified |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **LIBERTIN** | | **5** | Ensuring sustainable (sub)urban transport (incl.modal shift, suburban and regional rail, light rail and metro, and sustainable urban mobility) | Light Rail Thematic Network: standards and testing | Concensus building between manufacturers in relation to LRT future design, manufacture and implementation | | Not relevant |
| **RAILSERV** | | **5** | Encouraging modal shift and decongesting transport corridors | Enhancing competivenes s of Rail Freight | Focus on re-vitalization of rail freight in relation to the EU unification process. Research into completed and ongoing tasks from user perspective. 2nd phase is market oriented for reality check on proposals. | | Market focused approach to rail freight identifying key issues constraining operational and commercial performance. No relevant forecasts |
| **SAIL** | | **5** | Encouraging modal shift and decongesting transport corridors | Improvement of the intermodal transport of semi trailers in Europe (increasing the percentage of semi trailers transported by rail) | Project aimed to research the potential for semi-trailers to be moved by rail on international and long haul transits using innovative intregrated systems | | Not known |
| **BESTUFS II** | | **6** | Ensuring sustainable (sub)urban transport (incl.modal shift, suburban and regional rail, light rail and metro, and sustainable urban mobility) | Urban Freight Best practise | Further development of BESTUFs 1with similar focus | | Marginal relevance to De-Rail given the focus on city logistics |
| **ISTU** | | **6** | Encouraging modal shift and decongesting transport corridors | Self Guided freight container transportation systems on rail | New vehicle technology for the movement of containers within ports and between ports and DCs | Not identified | prototype development and demonstration |

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|---|---|---|---|---|---|---|---|
| **NEWOPERA** | | **6** | Encouraging modal shift and decongesting transport corridors | Development of Rail Freight Networks | Europe wide investigation of optimised rail freight networks and new capacity | Need for detailed analysis of growth forecasts underlying demands for new capacity and infrastructure | relevant in terms of identifying issues constraining rail freight performance and options for development at a trechnical, operational and policy level. |
| **REORIENT** | | **6** | Encouraging modal shift and decongesting transport corridors | Seamless international rail freight transportation, focusing on up to 10 trans-European corridors | Focused on business concepts for trans-European rail freight to enhance competitiveness and to review EC interoperability legislation | Forecasts for growth included within the study | relevant for Derail as a pan-European exercise |
| **TREND** | | **6** | Encouraging modal shift and decongesting transport corridors | New concepts for trans-European rail freight services | The TREND Co-ordination Action sees its responsibilities in providing two major results: first, to gather all necessary information to assess the general progress in the establishment of a European Railway Area and second, to recommend a coherent conception of individual actions as a "break down" of the White Paper's general framework. If the actions suggested by TREND are implemented it is expected to achieve a quantum leap for Trans-European rail services in quality, efficiency, and in volume, in particular | GDP, Volume of cargo | TREND is not directly Derailment related. But it is rail freight service related, its main works are: Agreement upon geographical extent and routing of the corridors; Analysis of the corridors, especially as concerns current freight volume (incl. modal split), analysis of the rail infrastructure capacity and border crossing procedures; Diagnosis of impediments and problems that are jeopardising the development of rail freight services on the corridors; Analysis of alleviation projects already under way ; and Deduction of action plans, sub-divided into priorities |
| **CREAM** | **Customer-driven Rail-freight services on a European mega-corridor based on Advanced business and operating Models** | **6** | new business models for rail freight | Innovative supply chains using rail, inter-modal and IT | Project focus on rail based supply chains using rail and multi-modal. Focus on quality and cross border issues plus interoperability. Telematics and remote sensors plus semi-trailer systems | Forecasts used for business cases to be reviewed. | relevant to de-Rail |

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|---|---|---|---|---|---|---|---|
| **FREIGHTVISION** | Freight Transport FORESIGHT 2050 | **7** | Transport and energy project for policy development long term | Sustainable freight | Built around scenarios on GHG reduction, fossil fuel dependency reduction, accident reduction and congestion reduction. Rail freight demand is expected to go up 160% by 2050, as well as a large increase in person rail transport. This of course makes the rail network a limiting factor and this could limit the actual transport growth. The restriction of the railway capacity is not taken into account in the model. A 10% decrease of average rail transport costs is expected. This is due to increased planning efficiency and improved interoperability. | Transportation network developments are estimated conservatively as only the current network expansions are taken into account, no future network expansion.<br>The global map of Europe is considered as a closed system in the model. This is not the case of course, still external flows are assumed not to exist since they cannot be divided per region. Financial crises are not (100%) taken into account. GDP is the most important driver of the TRANS-TOOLS model. Demographic changes are assumed to reflect in the GDP. The changes are however used to model the interaction between person and freight transport. | Relevant to de-Rail demand forecasting. The 2050 estimate based upon extrapolation seems high. Especially the newer EU27 membership states have shown a considerable rise in GDP, this trend is modelled to continue up to 2050 |
| **TIGER** | | **7** | Encouraging modal shift and decongesting transport corridors | European Intermodal Rail solution to EU ports and road congestion. | Development of concepts on longer, faster and heavier trains between ports and major terminals. Ship to train concept demonstrated in TIGER demo | ned for project review to identify underpinning rationale for new long train concepts | Relevant to De-rail |
| **USTIR** | User driven stimulation of radical new technological steps in surface transport | **7** | | | ITS sustainable surface transport. Marginal relevance | not identified or relevant to de-rail | |

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|---|---|---|---|---|---|---|---|
| **Transvisions** | | | Encouraging modal shift for a more sustainable network | to assist the DG TREN in carrying out mid- and long-term analysis of different policy means to provide data for the debate on transport policies. | The study ends up with recommendations concerning transport policy issues to address in the coming years in order to meet aims concerning economic, environmental and social sustainability. When faced with multiple policy measures, bundle these into a limited number of scenarios for manageability. Also these scenarios (or policy packages) can be used such that the individual measures complement each other, or such that the negative element is offset by the positive element. It is clear that transport is an extremely complex phenomenon, as shown by the many strands of results and analysis presented in the TRANSvisions study. Given this complexity it inevitably follows that any policy thinking concerning the long term future (over the next 40 years) must be doubly complex", given the uncertainties concerning the future. This leads to more qualitative arguments. Policy measures can be combined with social consensus (some travel is unwanted / undesirable from the point of view of the people making the journey) such that these seem less as a "restriction to freedom". Furthermore policy making needs to be considered carefully as it can be costly and EU has a limited role in urban policy-making. For this reason there also is a "hope" expressed for technological | TRANS-TOOLS forecasts up to 2030. One consideration mentioned is that, since a forecasting model relies upon trend extrapolation it cannot, by its nature, take account of trend-breaks unless these are fully specified in advance. "Normal use" of models such as TRANS-TOOLS implicitly assumes that there are no trend-breaks in the future. Meta models forecast up to 2050. Since TRANS-TOOLS isn't capable to accurately do this. One of the reasons being that, the effect of policy makers on the outcomes is impossible to predict. Different from conventional transport forecast models, Meta-models do not include complex equilibrium algorithms, and sophisticated statistical calibrations. | Relevant to de-Rail demand forecasting. The TRANS-TOOLS forecast for 2030 rail freight is certainly relevant. Given that the assumptions are acceptable and feasible. The Meta models forecast can be reasonable. The backcasting technique, a large section of the Meta models, is also required for D-RAIL and therefore interesting. |

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|---|---|---|---|---|---|---|---|
| **TEN-CONNECT** | | | Encouraging modal shift and decongesting transport corridors | Forecasting traffic flows, identifying corridors, researching policies for lifting bottlenecks in corridors. Plus the interaction between European and Asian trade. | The study has developed a concept for identifying Trans European Networks for the main transport modes. The study has also applied the suite of transportation models, economic models and environmental models developed in a series of research projects for analyzing Commission policies within the large field of infrastructure.<br>Considered important is that the study has detailed and improved the Commission's TRANS-TOOLS model. The study has carried out an analysis of transport networks in EU, including an inventory of main roads in the Eastern part of EU as well. Finally, the project has delivered a specific analysis of the characteristics of the competing transport routes between major Asian trading partners.<br>The Baseline scenario for 2030 indicates an increase in the number of passenger trips in Europe (the complete coverage area of the TRANS-TOOLS model) of about 29 % and in lifted tonnes of about 24 %. Tonnes km in Inland freight in EU increases with 49 %, the highest growth being envisaged for rail transport with 78 %. This would mean that rail freight transport would account for 33 % of all inland freight in EU in 2030 compared to only 26 % in 2005. The major rail freight flows in 2030 are linked to the development in Russia and the outlet to the Baltic countries and via Poland to Germany. | TRANS-TOOLS is a sequential state-of-practice transport model, hence, it has all the "usual" limitations of transport modeling. Uncertainty increases as future scenarios significantly change compared to base year (for this reasons the updating from 2000 to 2005 was significant). It cannot model major shifts in travel behavior and trade relations because the model is estimated on basis of actual travel behavior and trade in the base year.<br>Defining scenarios require input concerning demographic and economic development, input related to transport costs for the different transport modes and input related to networks and their development. The drivers that are included in the model are considered important. This is because they have proven to be important. This practice does not guarantee that all necessary drivers are considered and included in the model for which there is no data but (in reality) are important | Relevant to de-Rail demand forecasting. The TRANS-TOOLS forecast for 2030 rail freight are certainly relevant, especially since the baseline of 2000 has been updated. Given that the assumptions are acceptable and feasible. For 2050 there are no results. |

| **Ongoing projects** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **MARATHON** | | **7** | Follow on from NO/Tiger with big train technologies using line capacity more fully | Technical, commercial, IT and operational specifications being | major focus on new models of operation and technology. No explicit market forecasts yet identified | Not yet identified in detail. Focus on longer faster and heavier trains with new technologies. May not align with market requirements. | Longer and faster and heavier trains may impose additional infrastructure burdens (axle weights/rail wear and also imply greater risk of failure under heavier load conditions |
| **RETRACK** | Reorganisation of Transport Networks by Advanced Rail Freight | **7** | New privately operated rail freight operation | train service research and implementation | Service developed and operated. Initial commodity and traffic forecasts overtaken by revision of product and service profile | initial market projections available but not relevant to actual services operated | relevant to De-Rail in view of operational experience gained and impact of service disruption from derailment incidents |
| **SPECTRUM** | | **7** | New train technologies and asset management systems | technical, commercial and operational research to develop new | Project started | No indications on market studies/market application | relevant to de-rail as this involves new technology and possible methods and systems to mitigate derailment risk |
| **SUSTRAIL** | | **7** | encouraging modal shift to rail for medium and longer distance traffic | Vehicle dynamics/traction & braking/new vehicle designs/predic | Project started | No indications on market studies/market application identified | relevant to de-rail in terms of infrastructure and vehicle interactions at higher weights/speeds. Suggests market information will become available |

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|---|---|---|---|---|---|---|---|
| **INDICSER** | Indicators for evaluating international performance in service sectors | **7** | WP1 provides the key data framework that the other work packages will build upon. | The objective of the INDICSER project is to develop indicators which provide information on the performance of service sectors in the EU. | At the heart of the project are concerns that such indicators should be valid in terms of concepts, measurement methods and feasibility but should also have value in terms of their usefulness for policy. Therefore the approach adopted is to include both an EU-wide application of existing concepts and develop and experiment with new concepts. This will be carried out within an overall coherent structural framework designed to address the key issues of productivity and value for money. | Not relevant, although the WP1 does mention transport as one of the service area but the research outputs are not directly relevant to (rail freight) derailments. | The Table 4: Conditions for which mortality data are available from NCHOD of the INDICSER Review Paper 8 titled 'Review of indicators of outcomes and effectiveness of treatment for some specific diseases' mentions Land Transport Accidents. |

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|---|---|---|---|---|---|---|---|
| **PASHMINA** | Paradigm Shift Modelling and Innovative Approaches | **7** | The PASHMINA project has developed four major explorative scenarios (Page 135-36): Growth without limits, Growth within limits, Stagnation, Beyond growth. The scenarios have a strong energy and fuel input but these may also reflect the input of the participants (eg additional nuclear in the Stagnation option appears to be categorised as regressive). There is mention of rail and inter-city connectivity by rail. This may have implications for rail freight but perhaps beyond the orthodoxies.<br><br>The move to more local production of food, goods and services is also highlighted. This could constrain the use of rail freight unless technologies and systems are available that can allow rail participation in shorter section movements.<br><br>The scenarios are overarching but provide an established framework to develop within. We may wish to adopt some of the inputs but qualify the impact of others. | The project is far ranging but does have some significance for De-Rail in so far as the four scenarios could usefully be used as the basis for the projections governing the future likely levels of rail freight activity | PASHMINA Metamodel is composed by a main module inherited from TRANSvisions metamodel which projects present socioeconomic data up to 2050, departing from a limited set of basic indicators. D1.2 has harmonised and integrated available long-term forecasts. The results of prospective studies made by international institutions (e.g. UN, WB, OCDE, EIA), the European Commission (e.g. on the different DG's., the EEA, ESPON etc.), sectorial institutions and associations (e.g. EUROCONTROL, UIC, ERF…) have been scrutinised and harmonised as much as feasible with the main goal of building a baseline for the PASHMINA scenarios. Different models providing alternative long-term forecast use different data, different modelling paradigms, consider different scenarios and have different concerns. Results provided by them are not directly comparable, but each one provides a particular view on the future. | PASHMINA used a set of 50 variables including GDP, population. external trde, container volume, tkm, transport price etc. All variables have 2010 data and forecasts up to 2050. D1.2 of PASHMINA (Page 236) suggets that 'Freight rail transport can grow as much as 200%, its modal share remaining unvaried, but still road freight traffic will grow more than 350%, gaining an extra 10% modal share.' Based on the long-term database, in order to develop long-term forecast models, key relations have been identified with a multidisciplinary approach. Whenever trends/policies/scenarios consider explicitly shifts, they have been analysed in depth. Megatrends (permanent overtime, for all sectors and the World and basic regions including the EU) Seeds (emerging trends, potentially important in the future) Limiting factors (carrying capacity, at human, social, territorial and environmental) Wildcars (unexpected events, so important to break previous trends). | PASHMINA may not be directly related derailment but it is relevant to D-RAIL freight forecast. For D2.1 we have to exmaine the D1.1 and D1.2 further during modelling. |

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|---|---|---|---|---|---|---|---|
| **GHG-TRANSPORD** | Reducing greenhouse-gas emissions of transport beyond 2020: linking R&D, transport policies and reduction targets | **7** | The project aims at developing an integrated European strategy that links R&D efforts with other policies and measures to achieve substantial GHG emission reductions in transport that are in line with the overall targets of the EU | The project will propose GHG reduction targets for transport as a whole as well as for each transport mode for 2020 and 2050 | The project will backcast from existing GHG emission reduction targets set at the level of the overall economy to the contribution required from the transport sector. It will analyse the GHG emission mitigation potentials offered by a broad portfolio of transport technologies and measures. The desk research will be complemented by a model-based comparison of ambitious technology pathways with present policies and measures. This will also reveal areas with a largely under-exploited mitigation potential. GHG-TransPoRD will then further assess the R&D and other measures that can mobilise additional reduction potentials so as to achieve GHG emission reductions in line with the overall EU commitments until 2050. | it discusses GDP, volume of freight in general. As it is not directly rail freight service related project, it does not discuss freight forecast or rail freight forcase. | The outcome of this project is not direclty related to D-RAIL project freight forcaste. Its deliverables are: D1.1: Transport R&D capacities in the EU - an analysis of present research efforts and the European innovation system transport. D2.1: Ranking of measures to reduce GHG emissions of transport: reduction potentials and feasibility qualification. D3.1: Bottom-up quantifications of selected measures to reduce GHG emissions of transport for the time horizons 2020 and 2050. D4.1: Results of the techno-economic analysis of the R&D and transport policy packages for the time horizons 2020 and 2050. D5.2: Bridging the high level policy context - conclusions and recommendations. D7.1: Final Report: Aligned R&D and transport policy to meet EU GHG reduction targets. |
| **ENCI-LowCarb** | European Network engaging CIvil Society in Low Carbon Scenarios | **7** | | The objective of the project is to create a European Network on Low Carbon Scenarios composed by CSOs (Civil Society Organizations) and researchers. | Final report not yet available, regional report is available. For example the report 7 discusses 'How to deal with special emission sources in local CO2-balances?'. Also it discusses modal shift to rail for exampl in report 'ENERGY SCENARIOS IN GERMANY AND FRANCE – COMPARING APPLES TO ORANGES' to achieve lower carbon emisson (page 9 tables 10-11) | not directly relevant | Transport in general and rail in particular is noted as the source of carbon and thus is important in developing a LowCarbon society. The output/deliverabel is not direclty related to rail freight forecast |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PACT | Pathways for Carbon Transition | 7 | D6:3 scenarios to assess post | sustainable post-carbon society | The project aimed at shaping a sustainable post-carbon society that would look like and how we could reach it within the next 50 years. It discusses transport in general as a source of carbon and how it will change due to many changes such as technology. | GDP/per capita, transport speed, | The project is not directly related to D-RAIL project objective. It is unlikely to contribute to the derailment issues. However the D6 can be used as a reference during scenarios of D-RAIL D2.1 |
| MONITOR | Monitoring system on the development of global air transport | 7 | | Collection, analysis, updating and effective dissemination of relevant information - to generate a valid, harmonised one-stop solution of data needs for long term air transport development related activities, especially for strategic decision making, modelling activities and quantification exercises such as ACARE Vision 2020 +, EUROCONTROL Long Term Forecast, the JTI Clean Sky | The expected results of the monitoring system installed will be in first place both a one-stop solution for a set of reliable data, meta-data and key features on air transport development. This constitutes the base for decision making in aviation and regular qualitative and - as far as possible and needed - quantified information on new developments of key factors in air transport. The proposed strategy will allow for a periodic updating and possibly modification of aviation scenarios which has been required by stakeholders of the aviation community as an indispensable prerequisite for an effective use of the scenario technique for short-, medium-, and long-term planning. The set of data - collected, analysed and effectively disseminated by the Monitoring System - will include both internal information on air transport and information on factors and features of those key external fields frame-setting for aviation. | nil | deliverables are not yet available. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| OPEN:EU | OPEN: EU : One planet economy network: Europe. | 7 | OPEN:EU Scenario Quantification Report: Scenarios for a One Planet Economy | Methodology and results of scenario quantification undertaken in parallel to the development of One Planet Economy Network scenario narratives (the OPEN:EU scenarios). The OPEN: EU scenarios were developed to demonstrate how we might move towards a One Planet Economy over the next four decades. The ultimate aim of the scenarios is to provide better policy support and to stimulate | Four scenarios created were developed: Scenario 1 - Clever and caring - a future with a quality driven mindset towards development with dynamic technological innovation; Scenario 2 - Fast forward - a future with a quantity driven mindset towards development with dynamic technological innovation; Scenario 3 - Breaking point - a future with a quantity driven mindset towards development with technological stagnation; Scenario 4 - Slow motion - a future with a quality driven mindset towards development with technological stagnation. | GDP, Volume of trade, taxation policy, | the project is not directly related to D-RAIL project objective. It is unlikely to contribute to the derailment issues. However the deliverable can be used as a reference during consideration of scenarios for D-RAIL D2.1 |

# Annex 2 iTren 2030 scenario input

Key indicators of the iTren 2030 scenario

| Indicator | Absolute values | | Aver.% change per year |
|---|---|---|---|
| | 2005 | 2030 | |
| Population total (1,000 persons) | 488,594 | 494,331 | 0.0 |
| GDP (billion euros 2005) | 10,573 | 15,772 | 1.6 |
| Oil price (euro 2005 per bbl) | 44 | 90 | 2.9 |
| Freight transport activity (billion tkms) | 6,875 | 10,193 | 1.6 |
| *Road* | *2,073* | *3,056* | *1.6* |
| *Rail* | *447* | *798* | *2.3* |
| *Inland navigation* | *192* | *335* | *2.2* |
| *Maritime* | *4,162* | *6,004* | *1.5* |
| Passenger transport activity (billion pkms) | 6,457 | 7,873 | 0.8 |
| *Car* | *4,665* | *5,633* | *0.8* |
| *Bus* | *615* | *585* | *-0.2* |
| *Rail* | *477* | *695* | *1.5* |
| *Air* | *442* | *628* | *1.4* |
| *Slow* | *259* | *333* | *1.0* |
| Gross Inland Energy Consumption (ktoe per year) | 1,821,472 | 2,149,186 | 0.7 |
| *Oil* | *669,119* | *646,031* | *-0.1* |
| *Gas* | *442,979* | *551031* | *0.9* |
| *Coal, Nuclear* | *582,937* | *641,535* | *0.4* |
| *Renewables* | *126, 437* | *310,589* | *3.7* |
| Share of renewables in final energy demand | 8.3% | 16.1% | 2.7 |
| Share of bio-fuels in transport demand | 1.0% | 9.9% | 9.6 |
| Car fleet size (1,000 vehicles) | 211,062 | 294,212 | 1.3 |
| *Gasoline* | *149,304* | *148,788* | *0.0* |
| *Diesel* | *57,588* | *135,371* | *3.5* |
| *LPG/CNG* | *3,229* | *2,016* | *-1.9* |
| *Innovative* | *941* | *8,037* | *9.0* |
| CO2 Transport emissions (million tonnes) | 1,268 | 1,485 | 0.6 |

*Source: iTREN-2030*

Overview of transport and energy policies in the iTren integrated scenario

| Measure | Type | Start year | Description |
|---|---|---|---|
| Road user charge trucks | P | 2020 | Implementation of Greening Transport Package using the cost values identified by the IMPACT Handbook on external cost of transport (about 7 to 10 €ct/vhc-km) |
| Road user charge cars | P | 2025 | Implementation of Greening Transport Package transferring the cost values identified by the IMPACT Handbook to car transport (about 2.5 €ct/vhc-km) |
| City tolls | P | 2025 | Implementation for metropolitan areas in EU27 only at the level of about 35.7 €ct/vhc-km during peak-period |
| Fuel tax harmonisation | P | 2020 | Following EC directive 2003/96/EC tax levels of 35.9 €ct/l gasoline and 41 €ct/l diesel introduced |
| Air transport into EU-ETS | P | 2012 | Inclusion of all air transport within or leaving the EU27 into EU-ETS with reduction targets of -3% in 2012 and -5% after 2012 compared to average of 2004 to 2006 |
| Road transport into EU-ETS (upstream) | P | 2020 | Inclusion of road transport into EU-ETS by upstream approach ($CO_2$ price in 2020 about 28 $€_{2005}$ per tonne $CO_2$) |
| Railway liberalisation | P | 2010 | Implementation of 3rd railway package reducing passenger rail cost by -2% |
| CO2 limits cars | P | 2015, 2020 | Regulation setting $CO_2$ limits for average new car fleet with a limit value of 130 g $CO_2$/km in 2015, 105 g $CO_2$/km in 2020 |
| CO2 limits LDVs | P | 2015, 2020 | Regulation setting CO2 limits for average new LDV fleet with a limit value of 175 g CO2/km in 2016 and 135 g CO2/km in 2020 |
| Binding use of low resistance tyres HDV | P | 2012 | The binding use of low resistance tyres for trucks will reduce energy consumption by -3.5% |
| Battery electric cars | TA | 2012 | Breakthrough of battery technology and market diffusion of electric city cars after 2012 |
| Battery electric LDVs | TA | 2015 | Breakthrough of battery technology and market diffusion of electric LDVs for urban deliveries after 2015 |
| Hydrogen fuel cell cars | TA | 2025 | R&D support and support for market introduction will lead to market diffusion after 2025 |
| Car efficiency labelling | P | 2009 | Effective labelling of cars according to their energy/CO2 efficiency affecting choices of car buyers to reduce CO2 emissions by -3.5% |
| Driver education for drivers of HDV | TA | 2010 | Driver education can reduce energy demand by -20%. It is assumed that due to changing framework conditions -10% is achieved by ambitious education programmes of companies |
| Increased implementation of CNG fuelling stations | TA | 2010 | The requirements of climate policy and price differentials increase attractiveness of CNG generating incentives to implement more CNG fuelling stations |
| GHG reduction target for the EU for 2020 | P | 2012 | Agreement of binding reduction target of GHG emissions of EU27 of -20% until 2020 against 1990. Extension of EU-ETS with certificate price of 28 $€_{2005}$ per tonne of CO2 in 2020 |
| Renewable energy target | O | 2008 | Harmonized renewable energy support premiums across the EU to reach 20% renewable energy by 2020 |
| Energy efficiency action plan | P | 2008 | Increase of energy efficiency by 1% annually |
| Support for CCS | P | 2010 | Support of R&D and demonstration sites for CCS such that around 2030 first large-scale plants can be built |

*Source: iTREN-2030. P = policy, O = objective without specifying implementation, TA = trend adaptation*

# Annex 3 TRANS-TOOLS output, results per country

– **Tonnes per country for the reference scenario (NSTR) Year 2010**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 15339.44 | 11.26 | 73.62 | 1295.91 | 4263.94 | 2391.56 | 9008.96 | 938.61 | 1102.55 | 10569.47 | 44995.32 |
| 102 | BE | 731.30 | 1592.36 | 3837.72 | 2508.44 | 2088.91 | 5518.85 | 5651.02 | 129.71 | 4576.88 | 15383.10 | 42018.29 |
| 103 | BU | 62.64 | .06 | 2.05 | 92.09 | 136.83 | 2704.73 | 7463.95 | 13.58 | 37.45 | 699.63 | 11213.01 |
| 104 | CH | 1503.11 | 113.24 | 120.23 | 110.53 | 926.89 | 996.36 | 9626.33 | 263.14 | 1352.72 | 480.09 | 15492.63 |
| 106 | CZ | 502.73 | .79 | 41769.72 | 974.72 | 867.14 | 976.69 | 1851.69 | 2293.36 | 574.96 | 1313.87 | 51125.67 |
| 107 | DE | 8204.19 | 1261.13 | 59541.39 | 8816.19 | 15073.56 | 20434.43 | 53699.14 | 43417.14 | 21394.61 | 29350.39 | 261192.16 |
| 108 | DK | 87.11 | 89.15 | 229.45 | 19.19 | 65.19 | 265.07 | 3045.89 | 62.46 | 209.14 | 2379.52 | 6452.17 |
| 109 | EE | 12677.56 | 42.48 | 4649.81 | 1560.39 | 41.67 | 31.66 | 22.15 | 1154.97 | 81.78 | 7.20 | 20269.67 |
| 110 | ES | 993.26 | 167.13 | 4618.66 | 12.79 | 8221.51 | 33.08 | 2633.23 | 118.53 | 1144.50 | 2661.28 | 20603.97 |
| 111 | FI | 7830.03 | 48.16 | 2075.20 | 300.20 | 1732.16 | 555.93 | 148.84 | 743.32 | 2045.75 | 2990.09 | 18469.68 |
| 112 | FR | 14734.87 | 2803.41 | 2975.50 | 281.76 | 21633.16 | 16109.23 | 22649.60 | 3636.60 | 4421.94 | 3972.15 | 93218.22 |
| 113 | GR | 12.06 | 50.32 | .54 | 3.88 | 229.00 | 4.97 | 318.87 | .79 | 33.44 | 466.91 | 1120.78 |
| 115 | CR | 2395.60 | 21.28 | 557.16 | 2190.95 | 1045.28 | 591.43 | 1973.28 | 439.71 | 591.40 | 14189.82 | 23995.92 |
| 116 | IE | 24.76 | 321.60 | 5.09 | 19.43 | 663.30 | 10.54 | 6.47 | .01 | 61.91 | 1158.62 | 2271.74 |
| 118 | IT | 415.08 | 441.35 | 269.75 | 1179.89 | 1832.21 | 2215.69 | 23969.17 | 148.39 | 474.16 | 9106.62 | 40052.31 |
| 120 | LI | 1301.39 | 23.05 | 419.28 | 4410.69 | 719.00 | 6.75 | 1006.35 | 4955.82 | 3.74 | 11.15 | 12857.22 |
| 121 | LU | 40.64 | 15.56 | 70.12 | 7.43 | 232.70 | 1409.64 | 122.58 | 22.02 | 80.68 | 89.19 | 2090.56 |
| 122 | LV | 550.97 | 5.66 | 2176.26 | 369.91 | 508.00 | 72.92 | 600.44 | 359.57 | 28.96 | 21.51 | 4694.18 |
| 124 | NL | 203.46 | 473.00 | 6141.67 | 550.16 | 7312.58 | 1669.98 | 12175.01 | 229.30 | 1901.77 | 1210.26 | 31867.18 |
| 125 | NO | 289.84 | 76.19 | 1512.21 | 38.64 | 3404.60 | 39.09 | 1879.47 | 169.10 | 280.44 | 2112.35 | 9801.94 |
| 126 | PL | 162.53 | 2.45 | 57684.93 | 229.37 | 9134.98 | 197.98 | 36194.26 | 7014.29 | 612.18 | 452.90 | 111685.88 |
| 127 | PT | 634.41 | 2321.00 | 2451.34 | 129.51 | 1118.22 | 38.07 | 112.36 | 2.43 | 207.53 | 523.80 | 7538.67 |
| 128 | RO | 2826.47 | 150.87 | 5316.32 | 2330.24 | 1905.09 | 457.75 | 40223.80 | 2690.46 | 461.92 | 481.82 | 56844.75 |
| 129 | SE | 3505.66 | 184.67 | 1092.43 | 519.79 | 9466.17 | 3188.88 | 806.03 | 332.10 | 2771.84 | 6645.21 | 28512.79 |
| 130 | SI | 41.58 | 4.98 | 780.50 | 381.63 | 3646.04 | 113.62 | 2521.08 | 150.82 | 243.21 | 294.51 | 8177.97 |
| 131 | SK | 545.89 | .30 | 2375.29 | 1534.33 | 6755.65 | 706.70 | 1564.21 | 2744.14 | 158.15 | 1113.02 | 17497.70 |
| 133 | UK | 51.24 | 112.52 | 67649.94 | 2771.84 | 10231.95 | 1555.17 | 17073.05 | 14.26 | 4921.68 | 16529.48 | 120911.13 |
| | EU27 | 73,875 | 10,145 | 266,764 | 32,491 | 108,924 | 61,261 | 244,841 | 71,612 | 48,142 | 121,622 | 1,039,677 |
| | EU15 | 52,808 | 9,893 | 151,032 | 18,416 | 84,165 | 55,401 | 151,420 | 49,796 | 45,348 | 103,036 | 721,315 |
| | EU12 | 21,067 | 252 | 115,731 | 14,074 | 24,760 | 5,860 | 93,421 | 21,817 | 2,794 | 18,585 | 318,362 |
| | EU27+CH+NO | 75,668 | 10,334 | 268,396 | 32,640 | 113,256 | 62,297 | 256,347 | 72,045 | 49,775 | 124,214 | 1,064,971 |

– **Tonnes per country for the reference scenario (NSTR) Year 2020**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 16940.93 | 12.44 | 81.30 | 1431.21 | 4709.11 | 2641.25 | 9949.53 | 1036.61 | 1217.66 | 11672.96 | 49692.99 |
| 102 | BE | 807.65 | 1758.61 | 4238.39 | 2770.33 | 2307.00 | 6095.03 | 6241.01 | 143.26 | 5054.72 | 16989.15 | 46405.14 |
| 103 | BU | 91.01 | .08 | 2.98 | 133.81 | 198.81 | 3929.98 | 10845.14 | 19.73 | 54.42 | 1016.56 | 16292.53 |
| 104 | CH | 1660.04 | 125.06 | 132.78 | 122.07 | 1023.66 | 1100.38 | 10631.35 | 290.61 | 1493.95 | 530.21 | 17110.11 |
| 106 | CZ | 730.47 | 1.15 | 60691.52 | 1416.28 | 1259.95 | 1419.13 | 2690.51 | 3332.26 | 835.42 | 1909.05 | 74285.73 |
| 107 | DE | 9060.73 | 1392.80 | 65757.71 | 9736.63 | 16647.29 | 22567.85 | 59305.51 | 47950.03 | 23628.28 | 32414.67 | 288461.51 |
| 108 | DK | 96.21 | 98.46 | 253.41 | 21.20 | 72.00 | 292.75 | 3363.89 | 68.98 | 230.97 | 2627.95 | 7125.80 |
| 109 | EE | 18420.52 | 61.73 | 6756.18 | 2267.25 | 60.55 | 46.00 | 32.19 | 1678.18 | 118.83 | 10.47 | 29451.88 |
| 110 | ES | 1096.96 | 184.58 | 5100.87 | 14.13 | 9079.86 | 36.54 | 2908.14 | 130.90 | 1263.99 | 2939.13 | 22755.10 |
| 111 | FI | 8647.51 | 53.19 | 2291.86 | 331.54 | 1913.00 | 613.97 | 164.38 | 820.93 | 2259.34 | 3302.27 | 20397.98 |
| 112 | FR | 16273.25 | 3096.09 | 3286.15 | 311.18 | 23891.74 | 17791.09 | 25014.30 | 4016.27 | 4883.60 | 4386.85 | 102950.52 |
| 113 | GR | 13.32 | 55.57 | .60 | 4.28 | 252.91 | 5.49 | 352.16 | .87 | 36.93 | 515.66 | 1237.79 |
| 115 | CR | 3480.81 | 30.92 | 809.56 | 3183.45 | 1518.80 | 859.35 | 2867.18 | 638.90 | 859.31 | 20617.84 | 34866.13 |
| 116 | IE | 27.34 | 355.18 | 5.62 | 21.46 | 732.55 | 11.64 | 7.15 | .01 | 68.37 | 1279.59 | 2508.91 |
| 118 | IT | 458.42 | 487.43 | 297.92 | 1303.07 | 2023.49 | 2447.02 | 26471.63 | 163.88 | 523.66 | 10057.38 | 44233.91 |
| 120 | LI | 1890.93 | 33.49 | 609.21 | 6408.75 | 1044.71 | 9.81 | 1462.23 | 7200.81 | 5.43 | 16.20 | 18681.57 |
| 121 | LU | 44.89 | 17.18 | 77.45 | 8.21 | 256.99 | 1556.81 | 135.38 | 24.32 | 89.10 | 98.50 | 2308.82 |
| 122 | LV | 800.56 | 8.22 | 3162.11 | 537.48 | 738.12 | 105.95 | 872.44 | 522.46 | 42.08 | 31.25 | 6820.66 |
| 124 | NL | 224.70 | 522.38 | 6782.88 | 607.60 | 8076.04 | 1844.33 | 13446.12 | 253.24 | 2100.32 | 1336.62 | 35194.23 |
| 125 | NO | 320.10 | 84.15 | 1670.10 | 42.67 | 3760.05 | 43.17 | 2075.69 | 186.76 | 309.72 | 2332.89 | 10825.29 |
| 126 | PL | 236.16 | 3.55 | 83816.36 | 333.28 | 13273.15 | 287.66 | 52590.36 | 10191.79 | 889.51 | 658.06 | 162279.87 |
| 127 | PT | 700.64 | 2563.32 | 2707.27 | 143.03 | 1234.97 | 42.04 | 124.09 | 2.69 | 229.20 | 578.48 | 8325.73 |
| 128 | RO | 4106.87 | 219.22 | 7724.63 | 3385.85 | 2768.10 | 665.12 | 58445.29 | 3909.24 | 671.18 | 700.09 | 82595.57 |
| 129 | SE | 3871.67 | 203.95 | 1206.48 | 574.06 | 10454.47 | 3521.81 | 890.18 | 366.78 | 3061.23 | 7338.99 | 31489.62 |
| 130 | SI | 60.42 | 7.24 | 1134.07 | 554.52 | 5297.70 | 165.09 | 3663.14 | 219.14 | 353.38 | 427.92 | 11882.62 |
| 131 | SK | 793.18 | .44 | 3451.31 | 2229.39 | 9815.98 | 1026.84 | 2272.80 | 3987.24 | 229.80 | 1617.22 | 25424.20 |
| 133 | UK | 56.59 | 124.27 | 74712.82 | 3061.23 | 11300.20 | 1717.54 | 18855.53 | 15.75 | 5435.52 | 18255.22 | 133534.66 |
| | EU27 | 88,932 | 11,291 | 334,959 | 40,789 | 128,927 | 69,700 | 302,970 | 86,694 | 54,142 | 140,798 | 1,259,203 |
| | EU15 | 58,321 | 10,925 | 166,801 | 20,339 | 92,952 | 61,185 | 167,229 | 54,994 | 50,083 | 113,793 | 796,623 |
| | EU12 | 30,611 | 366 | 168,158 | 20,450 | 35,976 | 8,515 | 135,741 | 31,700 | 4,059 | 27,005 | 462,581 |
| | EU27+CH+NO | 90,912 | 11,501 | 336,762 | 40,954 | 133,711 | 70,844 | 315,677 | 87,172 | 55,946 | 143,661 | 1,287,139 |

– **Tonnes per country for the reference scenario (NSTR) Year 2030**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 19064.75 | 13.99 | 91.50 | 1610.63 | 5299.48 | 2972.37 | 11196.86 | 1166.56 | 1370.31 | 13136.35 | 55922.82 |
| 102 | BE | 908.90 | 1979.08 | 4769.74 | 3117.64 | 2596.22 | 6859.15 | 7023.42 | 161.21 | 5688.41 | 19119.02 | 52222.79 |
| 103 | BU | 136.43 | .12 | 4.47 | 200.58 | 298.03 | 5891.17 | 16257.22 | 29.58 | 81.57 | 1523.86 | 24423.03 |
| 104 | CH | 1868.15 | 140.74 | 149.43 | 137.37 | 1151.99 | 1238.33 | 11964.17 | 327.04 | 1681.24 | 596.68 | 19255.14 |
| 106 | CZ | 1095.00 | 1.72 | 90978.53 | 2123.04 | 1888.71 | 2127.32 | 4033.16 | 4995.16 | 1252.32 | 2861.73 | 111356.70 |
| 107 | DE | 10196.65 | 1567.41 | 74001.52 | 10957.27 | 18734.30 | 25397.11 | 66740.43 | 53961.36 | 26590.48 | 36478.38 | 324624.90 |
| 108 | DK | 108.27 | 110.80 | 285.17 | 23.85 | 81.02 | 329.45 | 3785.61 | 77.63 | 259.93 | 2957.41 | 8019.13 |
| 109 | EE | 27612.96 | 92.53 | 10127.73 | 3398.67 | 90.76 | 68.95 | 48.25 | 2515.64 | 178.13 | 15.69 | 44149.32 |
| 110 | ES | 1234.48 | 207.72 | 5740.34 | 15.90 | 10218.17 | 41.12 | 3272.73 | 147.31 | 1422.45 | 3307.59 | 25607.82 |
| 111 | FI | 9731.62 | 59.86 | 2579.18 | 373.11 | 2152.82 | 690.94 | 184.98 | 923.84 | 2542.58 | 3716.26 | 22955.20 |
| 112 | FR | 18313.36 | 3484.24 | 3698.13 | 350.19 | 26886.96 | 20021.50 | 28150.25 | 4519.77 | 5495.84 | 4936.82 | 115857.06 |
| 113 | GR | 14.99 | 62.54 | .67 | 4.82 | 284.62 | 6.17 | 396.31 | .98 | 41.56 | 580.30 | 1392.97 |
| 115 | CR | 5217.84 | 46.36 | 1213.56 | 4772.10 | 2276.73 | 1288.20 | 4298.00 | 957.74 | 1288.13 | 30906.81 | 52265.45 |
| 116 | IE | 30.77 | 399.71 | 6.33 | 24.15 | 824.39 | 13.10 | 8.04 | .01 | 76.94 | 1440.01 | 2823.45 |
| 118 | IT | 515.89 | 548.54 | 335.26 | 1466.43 | 2277.17 | 2753.79 | 29790.29 | 184.43 | 589.31 | 11318.24 | 49779.35 |
| 120 | LI | 2834.56 | 50.20 | 913.23 | 9606.92 | 1566.05 | 14.70 | 2191.93 | 10794.25 | 8.14 | 24.29 | 28004.27 |
| 121 | LU | 50.51 | 19.33 | 87.16 | 9.23 | 289.21 | 1751.98 | 152.35 | 27.36 | 100.28 | 110.85 | 2598.27 |
| 122 | LV | 1200.06 | 12.32 | 4740.10 | 805.70 | 1106.47 | 158.82 | 1307.81 | 783.18 | 63.08 | 46.85 | 10224.39 |
| 124 | NL | 252.87 | 587.87 | 7633.23 | 683.77 | 9088.50 | 2075.55 | 15131.81 | 284.99 | 2363.63 | 1504.18 | 39606.40 |
| 125 | NO | 360.23 | 94.69 | 1879.47 | 48.02 | 4231.44 | 48.58 | 2335.92 | 210.17 | 348.55 | 2625.35 | 12182.42 |
| 126 | PL | 354.01 | 5.33 | 125643.41 | 499.60 | 19896.88 | 431.22 | 78834.64 | 15277.81 | 1333.40 | 986.46 | 243262.74 |
| 127 | PT | 788.48 | 2884.68 | 3046.67 | 160.96 | 1389.79 | 47.31 | 139.65 | 3.03 | 257.93 | 651.00 | 9369.50 |
| 128 | RO | 6156.32 | 328.62 | 11579.47 | 5075.50 | 4149.47 | 997.03 | 87611.36 | 5860.08 | 1006.11 | 1049.45 | 123813.41 |
| 129 | SE | 4357.04 | 229.52 | 1357.74 | 646.03 | 11765.10 | 3963.33 | 1001.78 | 412.76 | 3445.01 | 8259.05 | 35437.36 |
| 130 | SI | 90.57 | 10.85 | 1700.01 | 831.24 | 7941.43 | 247.47 | 5491.17 | 328.49 | 529.73 | 641.46 | 17812.42 |
| 131 | SK | 1189.00 | .66 | 5173.62 | 3341.93 | 14714.47 | 1539.27 | 3407.00 | 5977.01 | 344.47 | 2424.27 | 38111.69 |
| 133 | UK | 63.68 | 139.85 | 84079.30 | 3445.00 | 12716.86 | 1932.86 | 21219.38 | 17.72 | 6116.96 | 20543.81 | 150275.42 |
| | EU27 | 111,519 | 12,844 | 439,786 | 53,544 | 158,534 | 81,620 | 391,674 | 109,408 | 62,447 | 168,540 | 1,589,916 |
| | EU15 | 65,632 | 12,295 | 187,712 | 22,889 | 104,605 | 68,856 | 188,194 | 61,889 | 56,362 | 128,059 | 896,492 |
| | EU12 | 45,887 | 549 | 252,074 | 30,655 | 53,929 | 12,764 | 203,481 | 47,519 | 6,085 | 40,481 | 693,423 |
| | EU27+CH+NO | 113,747 | 13,079 | 441,815 | 53,730 | 163,917 | 82,907 | 405,975 | 109,945 | 64,476 | 171,762 | 1,621,353 |

– **Tonnes per country for the reference scenario (NSTR) Year 2050**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 22802.18 | 16.74 | 109.43 | 1926.38 | 6338.38 | 3555.07 | 13391.88 | 1395.25 | 1638.95 | 15711.59 | 66885.86 |
| 102 | BE | 1087.08 | 2367.06 | 5704.79 | 3728.82 | 3105.18 | 8203.80 | 8400.28 | 192.82 | 6803.56 | 22867.09 | 62460.48 |
| 103 | BU | 163.20 | .14 | 5.35 | 239.94 | 356.52 | 7047.32 | 19447.71 | 35.39 | 97.58 | 1822.91 | 29216.07 |
| 104 | CH | 2234.38 | 168.33 | 178.72 | 164.30 | 1377.82 | 1481.09 | 14309.61 | 391.16 | 2010.83 | 713.65 | 23029.90 |
| 106 | CZ | 1309.89 | 2.06 | 108833.17 | 2539.69 | 2259.37 | 2544.81 | 4824.67 | 5975.47 | 1498.09 | 3423.35 | 133210.58 |
| 107 | DE | 12195.58 | 1874.68 | 88508.69 | 13105.32 | 22406.95 | 30375.92 | 79824.14 | 64539.87 | 31803.24 | 43629.56 | 388263.96 |
| 108 | DK | 129.49 | 132.52 | 341.08 | 28.53 | 96.91 | 394.03 | 4527.74 | 92.84 | 310.88 | 3537.18 | 9591.19 |
| 109 | EE | 33032.03 | 110.69 | 12115.31 | 4065.67 | 108.58 | 82.48 | 57.72 | 3009.34 | 213.09 | 18.77 | 52813.67 |
| 110 | ES | 1476.49 | 248.45 | 6865.67 | 19.02 | 12221.33 | 49.18 | 3914.31 | 176.19 | 1701.30 | 3956.01 | 30627.95 |
| 111 | FI | 11639.40 | 71.59 | 3084.80 | 446.25 | 2574.86 | 826.39 | 221.25 | 1104.95 | 3041.03 | 4444.79 | 27455.31 |
| 112 | FR | 21903.49 | 4167.28 | 4423.10 | 418.84 | 32157.85 | 23946.48 | 33668.79 | 5405.82 | 6573.24 | 5904.63 | 138569.54 |
| 113 | GR | 17.92 | 74.80 | .80 | 5.76 | 340.41 | 7.38 | 474.00 | 1.17 | 49.71 | 694.06 | 1666.04 |
| 115 | CR | 6241.85 | 55.45 | 1451.72 | 5708.62 | 2723.54 | 1541.01 | 5141.49 | 1145.69 | 1540.92 | 36972.31 | 62522.60 |
| 116 | IE | 36.80 | 478.06 | 7.57 | 28.89 | 986.00 | 15.66 | 9.62 | .01 | 92.02 | 1722.30 | 3376.95 |
| 118 | IT | 617.02 | 656.07 | 400.99 | 1753.91 | 2723.59 | 3293.64 | 35630.34 | 220.58 | 704.84 | 13537.05 | 59538.04 |
| 120 | LI | 3390.84 | 60.06 | 1092.45 | 11492.29 | 1873.39 | 17.59 | 2622.09 | 12912.63 | 9.74 | 29.05 | 33500.14 |
| 121 | LU | 60.41 | 23.13 | 104.24 | 11.04 | 345.91 | 2095.44 | 182.22 | 32.73 | 119.93 | 132.58 | 3107.63 |
| 122 | LV | 1435.57 | 14.73 | 5670.35 | 963.82 | 1323.61 | 189.99 | 1564.47 | 936.88 | 75.46 | 56.04 | 12230.94 |
| 124 | NL | 302.44 | 703.11 | 9129.64 | 817.82 | 10870.20 | 2482.44 | 18098.23 | 340.86 | 2826.99 | 1799.06 | 47370.79 |
| 125 | NO | 430.85 | 113.26 | 2247.92 | 57.43 | 5060.97 | 58.10 | 2793.85 | 251.38 | 416.87 | 3140.02 | 14570.65 |
| 126 | PL | 423.48 | 6.37 | 150301.07 | 597.64 | 23801.66 | 515.84 | 94306.02 | 18276.10 | 1595.08 | 1180.05 | 291003.32 |
| 127 | PT | 943.05 | 3450.18 | 3643.94 | 192.52 | 1662.24 | 56.59 | 167.02 | 3.62 | 308.50 | 778.63 | 11206.28 |
| 128 | RO | 7364.51 | 393.11 | 13851.95 | 6071.57 | 4963.81 | 1192.70 | 104805.19 | 7010.13 | 1203.56 | 1255.41 | 148111.94 |
| 129 | SE | 5211.19 | 274.52 | 1623.91 | 772.67 | 14071.52 | 4740.30 | 1198.17 | 493.68 | 4120.36 | 9878.14 | 42384.46 |
| 130 | SI | 108.34 | 12.98 | 2033.64 | 994.37 | 9499.94 | 296.04 | 6568.81 | 392.96 | 633.69 | 767.35 | 21308.13 |
| 131 | SK | 1422.34 | .79 | 6188.95 | 3997.79 | 17602.20 | 1841.35 | 4075.63 | 7150.00 | 412.08 | 2900.03 | 45591.16 |
| 133 | UK | 76.16 | 167.27 | 100562.10 | 4120.35 | 15209.86 | 2311.78 | 25379.20 | 21.20 | 7316.12 | 24571.19 | 179735.23 |
| | EU27 | 133,391 | 15,362 | 526,055 | 64,048 | 189,624 | 97,623 | 468,501 | 130,866 | 74,690 | 201,589 | 1,901,748 |
| | EU15 | 78,499 | 14,705 | 224,511 | 27,376 | 125,111 | 82,354 | 225,087 | 74,022 | 67,411 | 153,164 | 1,072,240 |
| | EU12 | 54,892 | 656 | 301,544 | 36,671 | 64,513 | 15,269 | 243,414 | 56,845 | 7,279 | 48,425 | 829,509 |
| | EU27+CH+NO | 136,056 | 15,643 | 528,481 | 64,269 | 196,063 | 99,162 | 485,604 | 131,509 | 77,118 | 205,443 | 1,939,349 |

– **Tonnes per country for the White Paper Low scenario (NSTR) Year 2030**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 22802.18 | 16.74 | 109.43 | 1926.38 | 6338.38 | 3555.07 | 13391.88 | 1395.25 | 1638.95 | 15711.59 | 66885.86 |
| 102 | BE | 1087.08 | 2367.06 | 5704.79 | 3728.82 | 3105.18 | 8203.80 | 8400.28 | 192.82 | 6803.56 | 22867.09 | 62460.48 |
| 103 | BU | 163.20 | .14 | 5.35 | 239.94 | 356.52 | 7047.32 | 19447.71 | 35.39 | 97.58 | 1822.91 | 29216.07 |
| 104 | CH | 2234.38 | 168.33 | 178.72 | 164.30 | 1377.82 | 1481.09 | 14309.61 | 391.16 | 2010.83 | 713.65 | 23029.90 |
| 106 | CZ | 1309.89 | 2.06 | 108833.17 | 2539.69 | 2259.37 | 2544.81 | 4824.67 | 5975.47 | 1498.09 | 3423.35 | 133210.58 |
| 107 | DE | 12195.58 | 1874.68 | 88508.69 | 13105.32 | 22406.95 | 30375.92 | 79824.14 | 64539.87 | 31803.24 | 43629.56 | 388263.96 |
| 108 | DK | 129.49 | 132.52 | 341.08 | 28.53 | 96.91 | 394.03 | 4527.74 | 92.84 | 310.88 | 3537.18 | 9591.19 |
| 109 | EE | 33032.03 | 110.69 | 12115.31 | 4065.67 | 108.58 | 82.48 | 57.72 | 3009.34 | 213.09 | 18.77 | 52813.67 |
| 110 | ES | 1476.49 | 248.45 | 6865.67 | 19.02 | 12221.33 | 49.18 | 3914.31 | 176.19 | 1701.30 | 3956.01 | 30627.95 |
| 111 | FI | 11639.40 | 71.59 | 3084.80 | 446.25 | 2574.86 | 826.39 | 221.25 | 1104.95 | 3041.03 | 4444.79 | 27455.31 |
| 112 | FR | 21903.49 | 4167.28 | 4423.10 | 418.84 | 32157.85 | 23946.48 | 33668.79 | 5405.82 | 6573.24 | 5904.63 | 138569.54 |
| 113 | GR | 17.92 | 74.80 | .80 | 5.76 | 340.41 | 7.38 | 474.00 | 1.17 | 49.71 | 694.06 | 1666.04 |
| 115 | CR | 6241.85 | 55.45 | 1451.72 | 5708.62 | 2723.54 | 1541.01 | 5141.49 | 1145.69 | 1540.92 | 36972.31 | 62522.60 |
| 116 | IE | 36.80 | 478.06 | 7.57 | 28.89 | 986.00 | 15.66 | 9.62 | .01 | 92.02 | 1722.30 | 3376.95 |
| 118 | IT | 617.02 | 656.07 | 400.99 | 1753.91 | 2723.59 | 3293.64 | 35630.34 | 220.58 | 704.84 | 13537.05 | 59538.04 |
| 120 | LI | 3390.84 | 60.06 | 1092.45 | 11492.29 | 1873.39 | 17.59 | 2622.09 | 12912.63 | 9.74 | 29.05 | 33500.14 |
| 121 | LU | 60.41 | 23.13 | 104.24 | 11.04 | 345.91 | 2095.44 | 182.22 | 32.73 | 119.93 | 132.58 | 3107.63 |
| 122 | LV | 1435.57 | 14.73 | 5670.35 | 963.82 | 1323.61 | 189.99 | 1564.47 | 936.88 | 75.46 | 56.04 | 12230.94 |
| 124 | NL | 302.44 | 703.11 | 9129.64 | 817.82 | 10870.20 | 2482.44 | 18098.23 | 340.86 | 2826.99 | 1799.06 | 47370.79 |
| 125 | NO | 430.85 | 113.26 | 2247.92 | 57.43 | 5060.97 | 58.10 | 2793.85 | 251.38 | 416.87 | 3140.02 | 14570.65 |
| 126 | PL | 423.48 | 6.37 | 150301.07 | 597.64 | 23801.66 | 515.84 | 94306.02 | 18276.10 | 1595.08 | 1180.05 | 291003.32 |
| 127 | PT | 943.05 | 3450.18 | 3643.94 | 192.52 | 1662.24 | 56.59 | 167.02 | 3.62 | 308.50 | 778.63 | 11206.28 |
| 128 | RO | 7364.51 | 393.11 | 13851.95 | 6071.57 | 4963.81 | 1192.70 | 104805.19 | 7010.13 | 1203.56 | 1255.41 | 148111.94 |
| 129 | SE | 5211.19 | 274.52 | 1623.91 | 772.67 | 14071.52 | 4740.30 | 1198.17 | 493.68 | 4120.36 | 9878.14 | 42384.46 |
| 130 | SI | 108.34 | 12.98 | 2033.64 | 994.37 | 9499.94 | 296.04 | 6568.81 | 392.96 | 633.69 | 767.35 | 21308.13 |
| 131 | SK | 1422.34 | .79 | 6188.95 | 3997.79 | 17602.20 | 1841.35 | 4075.63 | 7150.00 | 412.08 | 2900.03 | 45591.16 |
| 133 | UK | 76.16 | 167.27 | 100562.10 | 4120.35 | 15209.86 | 2311.78 | 25379.20 | 21.20 | 7316.12 | 24571.19 | 179735.23 |
| | EU27 | 133,391 | 15,362 | 526,055 | 64,048 | 189,624 | 97,623 | 468,501 | 130,866 | 74,690 | 201,589 | 1,901,748 |
| | EU15 | 78,499 | 14,705 | 224,511 | 27,376 | 125,111 | 82,354 | 225,087 | 74,022 | 67,411 | 153,164 | 1,072,240 |
| | EU12 | 54,892 | 656 | 301,544 | 36,671 | 64,513 | 15,269 | 243,414 | 56,845 | 7,279 | 48,425 | 829,509 |
| | EU27+CH+NO | 136,056 | 15,643 | 528,481 | 64,269 | 196,063 | 99,162 | 485,604 | 131,509 | 77,118 | 205,443 | 1,939,349 |

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– **Tonnes per country for the White Paper Low scenario (NSTR) Year 2050**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 23371.20 | 149.05 | 110.20 | 1967.35 | 6423.39 | 3827.54 | 14149.45 | 1401.06 | 1928.92 | 17411.66 | 70739.81 |
| 102 | BE | 1387.44 | 2778.45 | 5820.84 | 3897.61 | 3215.13 | 8542.63 | 12341.37 | 252.37 | 8077.01 | 25146.27 | 71459.12 |
| 103 | BU | 181.48 | .35 | 5.35 | 283.76 | 519.67 | 7047.99 | 19474.80 | 35.39 | 98.24 | 1856.10 | 29503.12 |
| 104 | CH | 2442.86 | 227.16 | 178.76 | 322.31 | 1409.83 | 1670.03 | 14423.51 | 392.50 | 2123.89 | 1392.86 | 24583.71 |
| 106 | CZ | 1486.24 | 11.48 | 108911.50 | 2542.30 | 2319.12 | 2680.26 | 5317.89 | 5983.83 | 1554.27 | 3767.09 | 134573.99 |
| 107 | DE | 15719.72 | 3667.76 | 88508.94 | 13402.17 | 24116.81 | 32473.27 | 93171.80 | 65053.91 | 37213.63 | 60861.97 | 434189.97 |
| 108 | DK | 233.63 | 171.13 | 341.79 | 33.79 | 121.43 | 469.38 | 5784.11 | 95.86 | 378.18 | 4184.21 | 11813.50 |
| 109 | EE | 33094.14 | 128.04 | 12116.94 | 4090.42 | 112.58 | 95.26 | 88.48 | 3010.12 | 232.19 | 35.39 | 53003.56 |
| 110 | ES | 2624.81 | 1125.39 | 7305.86 | 315.14 | 13523.14 | 67.76 | 7723.80 | 253.95 | 3603.86 | 5143.98 | 41687.69 |
| 111 | FI | 12301.47 | 86.93 | 3085.12 | 462.06 | 2577.98 | 987.19 | 353.44 | 1111.75 | 3280.93 | 5112.81 | 29359.68 |
| 112 | FR | 27207.21 | 6396.00 | 4638.83 | 919.88 | 33386.72 | 24992.99 | 42838.10 | 5610.38 | 8690.76 | 10355.81 | 165036.67 |
| 113 | GR | 17.96 | 190.85 | .80 | 5.76 | 340.34 | 7.57 | 475.36 | 1.16 | 50.92 | 720.18 | 1810.91 |
| 115 | CR | 6270.81 | 59.65 | 1455.17 | 5761.48 | 2745.26 | 1556.77 | 5160.99 | 1150.16 | 1598.29 | 37523.04 | 63281.62 |
| 116 | IE | 190.11 | 686.52 | 378.04 | 28.88 | 990.94 | 55.53 | 184.08 | 1.98 | 142.12 | 1995.23 | 4653.43 |
| 118 | IT | 1040.14 | 814.51 | 408.71 | 1839.69 | 3008.34 | 4168.18 | 42721.41 | 233.03 | 1032.86 | 18249.42 | 73516.29 |
| 120 | LI | 3443.46 | 75.78 | 1186.21 | 11538.37 | 1904.20 | 18.64 | 2895.81 | 12943.15 | 9.87 | 54.90 | 34070.40 |
| 121 | LU | 75.21 | 24.83 | 104.18 | 10.98 | 363.20 | 2347.77 | 232.99 | 33.19 | 154.98 | 190.97 | 3538.30 |
| 122 | LV | 1633.59 | 19.73 | 5730.52 | 967.47 | 1387.67 | 200.27 | 1689.30 | 939.60 | 80.20 | 133.62 | 12781.99 |
| 124 | NL | 916.84 | 2090.26 | 9156.99 | 897.88 | 11170.74 | 2871.16 | 20535.86 | 364.26 | 4175.09 | 3148.27 | 55327.35 |
| 125 | NO | 444.80 | 144.13 | 2270.33 | 60.40 | 5070.01 | 59.53 | 2851.81 | 268.58 | 463.21 | 3287.24 | 14920.04 |
| 126 | PL | 466.74 | 23.46 | 150479.28 | 638.88 | 24097.20 | 660.96 | 98598.65 | 18391.26 | 1793.93 | 1501.80 | 296652.16 |
| 127 | PT | 1293.13 | 3578.11 | 3651.68 | 192.79 | 1717.69 | 56.59 | 583.74 | 3.62 | 309.40 | 842.85 | 12229.60 |
| 128 | RO | 7591.33 | 505.21 | 13851.98 | 6071.43 | 5002.85 | 1243.28 | 105284.38 | 7018.42 | 1270.45 | 1314.04 | 149153.36 |
| 129 | SE | 8835.99 | 397.46 | 1625.16 | 1242.04 | 14176.55 | 4986.85 | 1996.25 | 499.50 | 5479.83 | 13333.38 | 52573.02 |
| 130 | SI | 109.04 | 13.64 | 2060.70 | 997.70 | 10022.97 | 321.82 | 7861.35 | 393.73 | 643.30 | 845.19 | 23269.44 |
| 131 | SK | 1518.49 | 1.06 | 6188.84 | 3999.33 | 17634.07 | 1903.02 | 4122.03 | 7152.93 | 435.50 | 3091.31 | 46046.58 |
| 133 | UK | 228.24 | 1117.25 | 100611.41 | 5724.64 | 15334.79 | 3526.10 | 27652.42 | 23.51 | 10330.75 | 31948.36 | 196497.47 |
| | EU27 | 151,238 | 24,113 | 527,735 | 67,832 | 196,213 | 105,109 | 521,238 | 131,958 | 92,565 | 248,768 | 2,066,769 |
| | EU15 | 95,443 | 23,275 | 225,749 | 30,941 | 130,467 | 89,381 | 270,744 | 74,940 | 84,849 | 198,645 | 1,224,433 |
| | EU12 | 55,795 | 838 | 301,986 | 36,891 | 65,746 | 15,728 | 250,494 | 57,019 | 7,716 | 50,122 | 842,336 |
| | EU27+CH+NO | 154,126 | 24,484 | 530,184 | 68,215 | 202,693 | 106,838 | 538,513 | 132,619 | 95,153 | 253,448 | 2,106,273 |

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– **Tonnes per country for the White Paper High scenario (NSTR) Year 2030**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 21721.80 | 2048.96 | 139.51 | 1914.71 | 5527.40 | 4407.43 | 13405.13 | 1293.16 | 3324.59 | 19394.20 | 73176.88 |
| 102 | BE | 3197.67 | 5194.75 | 4976.49 | 3671.77 | 2822.12 | 8322.48 | 14158.08 | 648.08 | 9878.33 | 26333.79 | 79203.57 |
| 103 | BU | 573.02 | 163.08 | 89.25 | 253.84 | 561.67 | 6064.30 | 16456.47 | 43.80 | 259.41 | 1932.50 | 26397.33 |
| 104 | CH | 2462.69 | 585.97 | 152.87 | 382.53 | 1204.11 | 1573.31 | 12260.32 | 339.40 | 2194.60 | 2461.79 | 23617.60 |
| 106 | CZ | 3109.62 | 1150.68 | 91123.92 | 2236.33 | 2390.55 | 3202.78 | 6780.13 | 5070.48 | 2594.77 | 7347.14 | 125006.40 |
| 107 | DE | 26199.23 | 25113.39 | 74547.17 | 12687.24 | 21985.06 | 32662.84 | 125432.35 | 55410.20 | 46406.84 | 91570.99 | 512015.30 |
| 108 | DK | 999.96 | 2222.20 | 357.17 | 87.05 | 358.14 | 615.86 | 5928.95 | 129.14 | 906.66 | 5817.16 | 17422.27 |
| 109 | EE | 27734.78 | 179.49 | 10139.48 | 3429.38 | 98.30 | 99.71 | 160.00 | 2547.85 | 213.99 | 221.89 | 44824.85 |
| 110 | ES | 13358.28 | 10531.52 | 6802.27 | 3222.33 | 13845.29 | 6109.58 | 27779.63 | 1630.83 | 8316.48 | 22045.66 | 113641.87 |
| 111 | FI | 12538.76 | 478.84 | 2637.73 | 423.07 | 2197.10 | 923.87 | 2170.63 | 982.52 | 2905.36 | 4651.21 | 29909.08 |
| 112 | FR | 32858.35 | 16193.45 | 4075.40 | 3131.75 | 29184.04 | 22984.95 | 51963.08 | 5745.06 | 13435.77 | 31001.33 | 210573.18 |
| 113 | GR | 402.41 | 496.20 | 48.83 | 41.02 | 354.04 | 123.67 | 576.47 | 15.54 | 187.30 | 934.95 | 3180.43 |
| 115 | CR | 6282.42 | 825.45 | 1230.11 | 4867.43 | 2444.94 | 1618.05 | 5051.03 | 1030.89 | 1987.86 | 33252.28 | 58590.47 |
| 116 | IE | 255.28 | 662.61 | 412.95 | 86.59 | 867.81 | 50.51 | 533.50 | 34.17 | 142.64 | 1809.87 | 4855.91 |
| 118 | IT | 8810.38 | 12335.62 | 864.95 | 5167.39 | 3656.95 | 11672.28 | 62646.28 | 708.83 | 8560.61 | 40966.52 | 155389.80 |
| 120 | LI | 3353.95 | 456.37 | 1110.16 | 9808.10 | 1745.80 | 78.22 | 2621.29 | 10999.35 | 100.99 | 714.75 | 30988.97 |
| 121 | LU | 187.75 | 238.20 | 87.37 | 14.19 | 324.34 | 2098.91 | 490.74 | 39.68 | 207.12 | 883.45 | 4571.76 |
| 122 | LV | 1762.18 | 305.26 | 4834.81 | 832.71 | 1208.29 | 208.96 | 1494.06 | 805.12 | 87.36 | 578.06 | 12116.81 |
| 124 | NL | 5734.11 | 8170.31 | 7756.52 | 1230.85 | 9495.18 | 3588.52 | 18790.76 | 730.82 | 6166.73 | 11939.61 | 73603.42 |
| 125 | NO | 943.91 | 870.53 | 2018.03 | 552.48 | 4258.47 | 315.81 | 3258.28 | 294.02 | 854.95 | 4019.50 | 17385.98 |
| 126 | PL | 3295.39 | 3316.72 | 125968.48 | 703.63 | 20565.37 | 1785.40 | 87292.19 | 15604.66 | 3487.96 | 9307.23 | 271327.03 |
| 127 | PT | 2484.65 | 5450.17 | 3081.25 | 366.11 | 1529.30 | 717.30 | 2905.66 | 179.87 | 1094.58 | 3842.25 | 21651.13 |
| 128 | RO | 6902.53 | 1407.40 | 11712.96 | 5174.67 | 4465.35 | 2013.04 | 89059.54 | 6130.44 | 1947.92 | 4690.13 | 133503.97 |
| 129 | SE | 9267.69 | 1248.82 | 1387.10 | 1319.70 | 11916.25 | 4384.11 | 3399.10 | 453.44 | 5280.78 | 12468.45 | 51125.45 |
| 130 | SI | 423.56 | 251.71 | 1786.27 | 864.14 | 8593.95 | 806.52 | 7435.22 | 386.85 | 788.86 | 1689.20 | 23026.26 |
| 131 | SK | 2361.30 | 375.48 | 5185.29 | 3428.53 | 14813.18 | 2373.07 | 4124.55 | 6000.20 | 767.35 | 4671.10 | 44100.03 |
| 133 | UK | 2582.50 | 6705.00 | 84250.44 | 5624.99 | 13082.88 | 3854.65 | 25976.07 | 299.79 | 10613.08 | 33639.03 | 186628.43 |
| | EU27 | 196,398 | 105,522 | 444,606 | 70,588 | 174,033 | 120,767 | 576,631 | 116,921 | 129,663 | 371,703 | 2,306,831 |
| | EU15 | 140,599 | 97,090 | 191,425 | 38,989 | 117,146 | 102,517 | 356,156 | 68,301 | 117,427 | 307,298 | 1,536,948 |
| | EU12 | 55,799 | 8,432 | 253,181 | 31,599 | 56,887 | 18,250 | 220,474 | 48,620 | 12,236 | 64,404 | 769,882 |
| | EU27+CH+NO | 199,804 | 106,978 | 446,777 | 71,523 | 179,496 | 122,656 | 592,149 | 117,554 | 132,713 | 378,184 | 2,347,834 |

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– **Tonnes per country for the White Paper High scenario (NSTR) Year 2050**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 27702.12 | 3768.72 | 198.08 | 2487.53 | 6761.00 | 6204.78 | 17464.85 | 1629.74 | 5243.20 | 27249.61 | 98709.61 |
| 102 | BE | 5307.09 | 8295.98 | 6086.91 | 4754.22 | 3522.79 | 10905.03 | 21554.78 | 1090.92 | 14529.62 | 36169.53 | 112216.87 |
| 103 | BU | 968.17 | 300.59 | 161.66 | 338.14 | 842.63 | 7366.64 | 19815.15 | 61.60 | 425.50 | 2576.37 | 32856.45 |
| 104 | CH | 3331.46 | 989.44 | 185.07 | 617.53 | 1476.53 | 2100.30 | 14857.06 | 413.95 | 2959.17 | 4152.54 | 31083.05 |
| 106 | CZ | 5024.41 | 2120.46 | 109102.82 | 2749.08 | 3185.48 | 4527.82 | 9889.62 | 6116.75 | 3973.37 | 11693.33 | 158383.14 |
| 107 | DE | 41723.99 | 45290.58 | 89525.17 | 16312.50 | 28439.12 | 43829.37 | 188049.93 | 67273.25 | 68378.76 | 145218.33 | 734040.99 |
| 108 | DK | 1773.62 | 4025.41 | 473.87 | 145.09 | 607.87 | 922.86 | 8479.80 | 187.85 | 1503.58 | 8809.94 | 26929.89 |
| 109 | EE | 33256.71 | 271.01 | 12137.00 | 4122.30 | 122.47 | 139.20 | 263.75 | 3068.72 | 279.22 | 398.99 | 54059.37 |
| 110 | ES | 23829.71 | 19282.89 | 8823.73 | 5930.88 | 18909.29 | 11237.91 | 49098.93 | 2911.53 | 14412.41 | 38504.36 | 192941.65 |
| 111 | FI | 16815.54 | 844.12 | 3192.77 | 539.04 | 2656.58 | 1256.06 | 3882.57 | 1213.30 | 3710.22 | 6168.68 | 40278.89 |
| 112 | FR | 48722.09 | 27601.23 | 5119.93 | 5550.26 | 36396.57 | 29422.36 | 77575.05 | 7665.74 | 21218.26 | 53962.48 | 313233.97 |
| 113 | GR | 732.32 | 874.39 | 89.59 | 72.50 | 468.46 | 224.03 | 806.30 | 28.03 | 318.45 | 1347.96 | 4962.04 |
| 115 | CR | 8205.22 | 1491.93 | 1482.52 | 5885.77 | 3034.23 | 2150.32 | 6529.95 | 1280.98 | 2831.72 | 41296.95 | 74189.57 |
| 116 | IE | 450.75 | 962.80 | 757.27 | 144.00 | 1066.05 | 84.64 | 978.43 | 62.99 | 213.15 | 2404.23 | 7124.31 |
| 118 | IT | 15910.05 | 22388.48 | 1377.79 | 8577.96 | 5267.80 | 19738.39 | 96210.12 | 1187.61 | 15402.62 | 68201.25 | 254262.07 |
| 120 | LI | 4348.49 | 808.91 | 1456.12 | 11863.23 | 2204.85 | 134.73 | 3413.76 | 13290.96 | 180.97 | 1302.10 | 39004.12 |
| 121 | LU | 313.49 | 426.67 | 104.68 | 20.21 | 410.86 | 2735.19 | 806.14 | 55.48 | 317.00 | 1557.07 | 6746.79 |
| 122 | LV | 2472.08 | 554.87 | 5845.04 | 1013.63 | 1511.37 | 282.43 | 1907.95 | 977.34 | 120.25 | 1035.47 | 15720.44 |
| 124 | NL | 10408.51 | 14683.27 | 9359.29 | 1828.59 | 11623.34 | 5275.30 | 24844.54 | 1163.03 | 9839.76 | 21039.47 | 110065.10 |
| 125 | NO | 1507.03 | 1543.72 | 2503.39 | 987.53 | 5110.81 | 550.84 | 4494.46 | 405.97 | 1350.58 | 5710.54 | 24164.88 |
| 126 | PL | 5846.92 | 6111.77 | 150917.30 | 974.43 | 25045.37 | 3013.87 | 109903.93 | 18887.78 | 5568.40 | 16521.50 | 342791.26 |
| 127 | PT | 4070.36 | 8180.31 | 3707.69 | 570.76 | 1919.48 | 1291.87 | 5266.84 | 329.68 | 1851.05 | 6662.49 | 33850.52 |
| 128 | RO | 8740.42 | 2382.20 | 14098.09 | 6255.75 | 5546.59 | 3066.27 | 107475.69 | 7509.01 | 2940.33 | 7967.93 | 165982.27 |
| 129 | SE | 14265.18 | 2153.84 | 1678.04 | 2014.76 | 14350.19 | 5516.11 | 5618.22 | 568.69 | 7505.05 | 17639.20 | 71309.29 |
| 130 | SI | 722.29 | 457.07 | 2192.70 | 1055.11 | 10704.21 | 1326.83 | 10153.47 | 500.55 | 1111.49 | 2699.16 | 30922.88 |
| 131 | SK | 3583.79 | 691.85 | 6210.51 | 4158.66 | 17784.63 | 3378.85 | 5398.67 | 7195.55 | 1191.94 | 7042.63 | 56637.07 |
| 133 | UK | 4720.31 | 12271.86 | 100878.66 | 8140.76 | 15885.54 | 5856.04 | 34150.23 | 541.32 | 15606.24 | 48718.50 | 246769.46 |
| Total | | 294752.14 | 188774.38 | 537665.66 | 97110.23 | 224854.12 | 172538.02 | 828890.17 | 145618.32 | 202982.31 | 586050.61 | 3279235.96 |
| | EU27 | 289,914 | 186,241 | 534,977 | 95,505 | 218,267 | 169,887 | 809,539 | 144,798 | 198,673 | 576,188 | 3,223,988 |
| | EU15 | 216,745 | 171,051 | 231,373 | 57,089 | 148,285 | 144,500 | 534,787 | 85,909 | 180,049 | 483,653 | 2,253,441 |
| | EU12 | 73,169 | 15,191 | 303,604 | 38,416 | 69,982 | 25,387 | 274,752 | 58,889 | 18,623 | 92,534 | 970,547 |
| | EU27+CH+NO | 294,752 | 188,774 | 537,666 | 97,110 | 224,854 | 172,538 | 828,890 | 145,618 | 202,982 | 586,051 | 3,279,236 |

– **Billion Tonnes-km per country for the Reference scenario (NSTR) Year 2010**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 2.78 | 0.01 | 0.02 | 0.64 | 1.58 | 1.51 | 1.92 | 0.40 | 0.77 | 2.67 | 12.29 |
| 102 | BE | 0.34 | 0.28 | 0.73 | 0.75 | 0.56 | 2.49 | 2.23 | 0.08 | 2.35 | 2.42 | 12.22 |
| 103 | BU | 0.02 | 0.00 | 0.00 | 0.03 | 0.03 | 0.40 | 1.44 | 0.01 | 0.06 | 0.31 | 2.31 |
| 104 | CH | 0.38 | 0.06 | 0.08 | 0.05 | 0.25 | 0.23 | 1.40 | 0.07 | 0.49 | 0.28 | 3.28 |
| 106 | CZ | 0.23 | 0.00 | 8.61 | 0.60 | 0.40 | 0.65 | 0.91 | 1.30 | 0.37 | 0.44 | 13.52 |
| 107 | DE | 3.94 | 0.49 | 4.81 | 4.01 | 5.97 | 7.17 | 16.44 | 9.64 | 8.12 | 10.95 | 71.54 |
| 108 | DK | 0.10 | 0.03 | 0.22 | 0.01 | 0.06 | 0.18 | 1.54 | 0.04 | 0.06 | 0.40 | 2.65 |
| 109 | EE | 1.47 | 0.01 | 0.75 | 0.41 | 0.03 | 0.01 | 0.01 | 0.20 | 0.04 | 0.01 | 2.92 |
| 110 | ES | 0.75 | 0.79 | 0.73 | 0.01 | 1.72 | 0.04 | 10.22 | 0.08 | 2.07 | 18.47 | 34.88 |
| 111 | FI | 1.53 | 0.04 | 0.46 | 0.13 | 0.42 | 0.45 | 0.08 | 0.18 | 0.84 | 1.57 | 5.70 |
| 112 | FR | 5.37 | 0.92 | 0.88 | 0.14 | 5.99 | 4.94 | 7.40 | 1.80 | 2.13 | 1.34 | 30.90 |
| 113 | GR | 0.02 | 0.12 | 0.00 | 0.00 | 0.17 | 0.01 | 0.39 | 0.00 | 0.06 | 0.36 | 1.13 |
| 115 | CR | 1.29 | 0.01 | 0.10 | 1.07 | 0.42 | 0.20 | 0.34 | 0.16 | 0.23 | 2.45 | 6.28 |
| 116 | IE | 0.00 | 0.05 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.01 | 0.15 | 0.33 |
| 118 | IT | 0.19 | 0.32 | 0.09 | 0.61 | 0.73 | 1.27 | 10.20 | 0.02 | 0.39 | 2.73 | 16.55 |
| 120 | LI | 0.15 | 0.01 | 0.52 | 0.93 | 0.14 | 0.01 | 0.18 | 1.10 | 0.00 | 0.01 | 3.04 |
| 121 | LU | 0.02 | 0.00 | 0.01 | 0.00 | 0.05 | 0.63 | 0.03 | 0.01 | 0.03 | 0.03 | 0.81 |
| 122 | LV | 0.20 | 0.01 | 1.59 | 0.11 | 0.48 | 0.08 | 0.43 | 0.09 | 0.02 | 0.02 | 3.03 |
| 124 | NL | 0.14 | 0.42 | 1.59 | 0.30 | 2.94 | 1.10 | 4.07 | 0.16 | 1.10 | 0.36 | 12.17 |
| 125 | NO | 0.14 | 0.07 | 1.22 | 0.02 | 0.96 | 0.03 | 0.86 | 0.09 | 0.18 | 0.39 | 3.96 |
| 126 | PL | 0.11 | 0.00 | 17.11 | 0.12 | 2.03 | 0.19 | 9.23 | 2.18 | 0.39 | 0.23 | 31.58 |
| 127 | PT | 0.15 | 0.29 | 0.35 | 0.01 | 0.16 | 0.00 | 0.02 | 0.00 | 0.02 | 0.06 | 1.06 |
| 128 | RO | 0.53 | 0.11 | 0.78 | 0.75 | 0.39 | 0.31 | 7.24 | 0.85 | 0.27 | 0.54 | 11.75 |
| 129 | SE | 2.42 | 0.17 | 0.21 | 0.25 | 3.12 | 1.90 | 0.65 | 0.11 | 1.51 | 4.10 | 14.44 |
| 130 | SI | 0.01 | 0.00 | 0.07 | 0.11 | 0.92 | 0.07 | 0.32 | 0.01 | 0.13 | 0.18 | 1.83 |
| 131 | SK | 0.17 | 0.00 | 0.47 | 0.53 | 1.63 | 0.41 | 0.34 | 0.96 | 0.09 | 0.27 | 4.88 |
| 133 | UK | 0.01 | 0.01 | 6.71 | 0.35 | 1.35 | 0.22 | 3.97 | 0.00 | 0.67 | 4.58 | 17.88 |
| | EU27 | 21.94 | 4.08 | 46.82 | 11.85 | 31.38 | 24.24 | 79.59 | 19.40 | 21.71 | 54.66 | 315.66 |
| | EU15 | 17.76 | 3.93 | 16.82 | 7.21 | 24.92 | 21.90 | 59.16 | 12.54 | 20.11 | 50.19 | 234.53 |
| | EU12 | 4.18 | 0.15 | 30.00 | 4.64 | 6.46 | 2.33 | 20.43 | 6.86 | 1.59 | 4.47 | 81.13 |
| | EU27+CH+NO | 22.46 | 4.21 | 48.11 | 11.93 | 32.59 | 24.49 | 81.86 | 19.56 | 22.37 | 55.33 | 322.90 |

– **Billion Tonnes-km per country for the Reference scenario (NSTR) Year 2020**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 2.98 | 0.01 | 0.02 | 0.68 | 1.69 | 1.62 | 2.05 | 0.43 | 0.83 | 2.87 | 13.18 |
| 102 | BE | 0.36 | 0.30 | 0.78 | 0.81 | 0.60 | 2.67 | 2.39 | 0.09 | 2.52 | 2.59 | 13.10 |
| 103 | BU | 0.03 | 0.00 | 0.00 | 0.04 | 0.04 | 0.56 | 2.01 | 0.02 | 0.08 | 0.44 | 3.22 |
| 104 | CH | 0.40 | 0.06 | 0.08 | 0.06 | 0.26 | 0.24 | 1.50 | 0.08 | 0.52 | 0.30 | 3.51 |
| 106 | CZ | 0.33 | 0.00 | 12.04 | 0.84 | 0.55 | 0.91 | 1.27 | 1.82 | 0.52 | 0.62 | 18.90 |
| 107 | DE | 4.22 | 0.53 | 5.15 | 4.30 | 6.40 | 7.68 | 17.63 | 10.34 | 8.70 | 11.75 | 76.70 |
| 108 | DK | 0.11 | 0.03 | 0.24 | 0.01 | 0.07 | 0.19 | 1.65 | 0.04 | 0.07 | 0.43 | 2.84 |
| 109 | EE | 2.05 | 0.02 | 1.05 | 0.57 | 0.04 | 0.02 | 0.01 | 0.27 | 0.05 | 0.01 | 4.08 |
| 110 | ES | 0.81 | 0.84 | 0.78 | 0.01 | 1.85 | 0.04 | 10.96 | 0.09 | 2.22 | 19.81 | 37.40 |
| 111 | FI | 1.64 | 0.05 | 0.49 | 0.14 | 0.45 | 0.48 | 0.08 | 0.19 | 0.90 | 1.68 | 6.11 |
| 112 | FR | 5.76 | 0.98 | 0.94 | 0.15 | 6.42 | 5.29 | 7.94 | 1.93 | 2.28 | 1.44 | 33.13 |
| 113 | GR | 0.02 | 0.13 | 0.00 | 0.00 | 0.18 | 0.01 | 0.41 | 0.00 | 0.06 | 0.38 | 1.21 |
| 115 | CR | 1.81 | 0.01 | 0.14 | 1.49 | 0.59 | 0.29 | 0.47 | 0.23 | 0.32 | 3.43 | 8.78 |
| 116 | IE | 0.00 | 0.06 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.00 | 0.01 | 0.16 | 0.35 |
| 118 | IT | 0.21 | 0.34 | 0.10 | 0.65 | 0.78 | 1.36 | 10.94 | 0.02 | 0.42 | 2.93 | 17.75 |
| 120 | LI | 0.21 | 0.01 | 0.73 | 1.29 | 0.20 | 0.01 | 0.25 | 1.54 | 0.01 | 0.02 | 4.25 |
| 121 | LU | 0.02 | 0.00 | 0.01 | 0.00 | 0.06 | 0.67 | 0.04 | 0.01 | 0.03 | 0.03 | 0.87 |
| 122 | LV | 0.29 | 0.01 | 2.23 | 0.15 | 0.68 | 0.11 | 0.61 | 0.13 | 0.02 | 0.03 | 4.24 |
| 124 | NL | 0.15 | 0.45 | 1.71 | 0.32 | 3.15 | 1.18 | 4.36 | 0.17 | 1.17 | 0.38 | 13.05 |
| 125 | NO | 0.15 | 0.08 | 1.30 | 0.03 | 1.03 | 0.03 | 0.92 | 0.09 | 0.19 | 0.42 | 4.25 |
| 126 | PL | 0.15 | 0.00 | 23.92 | 0.17 | 2.84 | 0.26 | 12.91 | 3.04 | 0.55 | 0.32 | 44.15 |
| 127 | PT | 0.16 | 0.31 | 0.38 | 0.01 | 0.17 | 0.00 | 0.02 | 0.00 | 0.02 | 0.06 | 1.14 |
| 128 | RO | 0.73 | 0.15 | 1.09 | 1.04 | 0.55 | 0.43 | 10.12 | 1.19 | 0.38 | 0.75 | 16.43 |
| 129 | SE | 2.59 | 0.18 | 0.22 | 0.26 | 3.35 | 2.04 | 0.70 | 0.12 | 1.62 | 4.40 | 15.48 |
| 130 | SI | 0.01 | 0.00 | 0.10 | 0.15 | 1.28 | 0.10 | 0.45 | 0.02 | 0.18 | 0.26 | 2.55 |
| 131 | SK | 0.24 | 0.00 | 0.65 | 0.74 | 2.28 | 0.57 | 0.48 | 1.34 | 0.13 | 0.38 | 6.83 |
| 133 | UK | 0.01 | 0.01 | 7.20 | 0.38 | 1.44 | 0.24 | 4.26 | 0.01 | 0.72 | 4.91 | 19.17 |
| | EU27 | 24.89 | 4.42 | 59.98 | 14.22 | 35.75 | 26.75 | 92.00 | 23.04 | 23.79 | 60.07 | 364.92 |
| | EU15 | 19.04 | 4.21 | 18.03 | 7.73 | 26.72 | 23.48 | 63.43 | 13.45 | 21.56 | 53.82 | 251.47 |
| | EU12 | 5.85 | 0.21 | 41.95 | 6.49 | 9.04 | 3.26 | 28.57 | 9.60 | 2.23 | 6.25 | 113.44 |
| | EU27+CH+NO | 25.44 | 4.56 | 61.37 | 14.30 | 37.05 | 27.02 | 94.43 | 23.22 | 24.51 | 60.79 | 372.68 |

– **Billion Tonnes-km per country for the Reference scenario (NSTR) Year 2030**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 3.30 | 0.01 | 0.02 | 0.76 | 1.88 | 1.80 | 2.28 | 0.48 | 0.92 | 3.18 | 14.61 |
| 102 | BE | 0.40 | 0.33 | 0.86 | 0.89 | 0.66 | 2.96 | 2.65 | 0.10 | 2.79 | 2.87 | 14.52 |
| 103 | BU | 0.04 | 0.00 | 0.00 | 0.06 | 0.06 | 0.80 | 2.84 | 0.03 | 0.11 | 0.62 | 4.56 |
| 104 | CH | 0.45 | 0.07 | 0.09 | 0.06 | 0.29 | 0.27 | 1.67 | 0.09 | 0.58 | 0.33 | 3.90 |
| 106 | CZ | 0.46 | 0.00 | 17.02 | 1.19 | 0.78 | 1.29 | 1.79 | 2.57 | 0.73 | 0.88 | 26.72 |
| 107 | DE | 4.68 | 0.58 | 5.71 | 4.77 | 7.09 | 8.52 | 19.54 | 11.46 | 9.65 | 13.02 | 85.03 |
| 108 | DK | 0.12 | 0.03 | 0.27 | 0.01 | 0.07 | 0.21 | 1.83 | 0.05 | 0.08 | 0.48 | 3.15 |
| 109 | EE | 2.90 | 0.02 | 1.48 | 0.80 | 0.05 | 0.02 | 0.01 | 0.39 | 0.07 | 0.01 | 5.76 |
| 110 | ES | 0.89 | 0.93 | 0.87 | 0.01 | 2.05 | 0.04 | 12.15 | 0.10 | 2.46 | 21.96 | 41.46 |
| 111 | FI | 1.82 | 0.05 | 0.54 | 0.15 | 0.50 | 0.54 | 0.09 | 0.22 | 1.00 | 1.86 | 6.77 |
| 112 | FR | 6.39 | 1.09 | 1.05 | 0.17 | 7.12 | 5.87 | 8.80 | 2.14 | 2.53 | 1.59 | 36.73 |
| 113 | GR | 0.02 | 0.15 | 0.00 | 0.00 | 0.20 | 0.01 | 0.46 | 0.00 | 0.07 | 0.42 | 1.34 |
| 115 | CR | 2.56 | 0.02 | 0.20 | 2.11 | 0.83 | 0.40 | 0.67 | 0.33 | 0.45 | 4.84 | 12.41 |
| 116 | IE | 0.00 | 0.06 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.01 | 0.17 | 0.39 |
| 118 | IT | 0.23 | 0.38 | 0.11 | 0.72 | 0.87 | 1.51 | 12.12 | 0.02 | 0.46 | 3.25 | 19.67 |
| 120 | LI | 0.29 | 0.02 | 1.03 | 1.83 | 0.28 | 0.01 | 0.35 | 2.17 | 0.01 | 0.02 | 6.01 |
| 121 | LU | 0.02 | 0.01 | 0.01 | 0.00 | 0.06 | 0.74 | 0.04 | 0.01 | 0.03 | 0.03 | 0.96 |
| 122 | LV | 0.40 | 0.01 | 3.15 | 0.21 | 0.96 | 0.15 | 0.86 | 0.18 | 0.03 | 0.04 | 5.99 |
| 124 | NL | 0.16 | 0.50 | 1.89 | 0.35 | 3.49 | 1.31 | 4.84 | 0.19 | 1.30 | 0.42 | 14.46 |
| 125 | NO | 0.17 | 0.09 | 1.45 | 0.03 | 1.15 | 0.03 | 1.02 | 0.10 | 0.21 | 0.46 | 4.71 |
| 126 | PL | 0.21 | 0.00 | 33.82 | 0.24 | 4.01 | 0.37 | 18.25 | 4.30 | 0.77 | 0.46 | 62.42 |
| 127 | PT | 0.18 | 0.34 | 0.42 | 0.02 | 0.18 | 0.01 | 0.02 | 0.00 | 0.02 | 0.07 | 1.26 |
| 128 | RO | 1.04 | 0.21 | 1.53 | 1.48 | 0.77 | 0.61 | 14.31 | 1.68 | 0.54 | 1.06 | 23.23 |
| 129 | SE | 2.87 | 0.20 | 0.25 | 0.29 | 3.71 | 2.26 | 0.78 | 0.14 | 1.79 | 4.87 | 17.16 |
| 130 | SI | 0.01 | 0.00 | 0.14 | 0.21 | 1.81 | 0.14 | 0.64 | 0.02 | 0.26 | 0.37 | 3.61 |
| 131 | SK | 0.34 | 0.00 | 0.92 | 1.05 | 3.23 | 0.81 | 0.68 | 1.90 | 0.18 | 0.54 | 9.66 |
| 133 | UK | 0.01 | 0.01 | 7.98 | 0.42 | 1.60 | 0.26 | 4.72 | 0.01 | 0.80 | 5.44 | 21.25 |
| | EU27 | 29.38 | 4.96 | 79.29 | 17.74 | 42.39 | 30.65 | 110.71 | 28.47 | 27.06 | 68.49 | 439.14 |
| | EU15 | 21.11 | 4.67 | 19.99 | 8.57 | 29.61 | 26.03 | 70.32 | 14.91 | 23.90 | 59.66 | 278.76 |
| | EU12 | 8.27 | 0.29 | 59.30 | 9.18 | 12.78 | 4.61 | 40.39 | 13.57 | 3.15 | 8.84 | 160.38 |
| | EU27+CH+NO | 29.99 | 5.12 | 80.83 | 17.83 | 43.83 | 30.95 | 113.40 | 28.66 | 27.85 | 69.29 | 447.75 |

– **Billion Tonnes-km per country for the Reference scenario (NSTR) Year 2050**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 3.92 | 0.01 | 0.03 | 0.90 | 2.23 | 2.13 | 2.70 | 0.57 | 1.09 | 3.77 | 17.35 |
| 102 | BE | 0.48 | 0.39 | 1.02 | 1.06 | 0.79 | 3.51 | 3.15 | 0.12 | 3.31 | 3.41 | 17.24 |
| 103 | BU | 0.05 | 0.00 | 0.00 | 0.07 | 0.07 | 0.94 | 3.36 | 0.03 | 0.13 | 0.74 | 5.39 |
| 104 | CH | 0.53 | 0.08 | 0.11 | 0.08 | 0.35 | 0.32 | 1.98 | 0.10 | 0.69 | 0.40 | 4.63 |
| 106 | CZ | 0.55 | 0.00 | 20.14 | 1.41 | 0.93 | 1.53 | 2.12 | 3.04 | 0.87 | 1.04 | 31.62 |
| 107 | DE | 5.56 | 0.69 | 6.78 | 5.66 | 8.42 | 10.11 | 23.20 | 13.61 | 11.46 | 15.46 | 100.96 |
| 108 | DK | 0.14 | 0.04 | 0.32 | 0.02 | 0.09 | 0.25 | 2.17 | 0.06 | 0.09 | 0.57 | 3.74 |
| 109 | EE | 3.43 | 0.03 | 1.75 | 0.95 | 0.06 | 0.03 | 0.02 | 0.46 | 0.08 | 0.01 | 6.82 |
| 110 | ES | 1.06 | 1.11 | 1.03 | 0.01 | 2.43 | 0.05 | 14.43 | 0.12 | 2.92 | 26.07 | 49.22 |
| 111 | FI | 2.16 | 0.06 | 0.64 | 0.18 | 0.59 | 0.64 | 0.11 | 0.26 | 1.19 | 2.21 | 8.04 |
| 112 | FR | 7.58 | 1.29 | 1.24 | 0.20 | 8.45 | 6.97 | 10.45 | 2.54 | 3.00 | 1.89 | 43.61 |
| 113 | GR | 0.03 | 0.17 | 0.00 | 0.00 | 0.24 | 0.01 | 0.54 | 0.00 | 0.08 | 0.50 | 1.59 |
| 115 | CR | 3.03 | 0.02 | 0.23 | 2.50 | 0.98 | 0.48 | 0.79 | 0.38 | 0.53 | 5.73 | 14.69 |
| 116 | IE | 0.01 | 0.08 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.01 | 0.21 | 0.46 |
| 118 | IT | 0.27 | 0.45 | 0.13 | 0.86 | 1.03 | 1.80 | 14.39 | 0.02 | 0.55 | 3.86 | 23.36 |
| 120 | LI | 0.35 | 0.02 | 1.22 | 2.16 | 0.33 | 0.02 | 0.41 | 2.57 | 0.01 | 0.03 | 7.12 |
| 121 | LU | 0.03 | 0.01 | 0.02 | 0.00 | 0.07 | 0.88 | 0.05 | 0.01 | 0.04 | 0.04 | 1.14 |
| 122 | LV | 0.48 | 0.01 | 3.72 | 0.25 | 1.13 | 0.18 | 1.01 | 0.21 | 0.04 | 0.04 | 7.09 |
| 124 | NL | 0.19 | 0.59 | 2.25 | 0.42 | 4.15 | 1.55 | 5.75 | 0.23 | 1.55 | 0.50 | 17.17 |
| 125 | NO | 0.20 | 0.10 | 1.72 | 0.03 | 1.36 | 0.04 | 1.22 | 0.12 | 0.25 | 0.55 | 5.60 |
| 126 | PL | 0.25 | 0.00 | 40.02 | 0.28 | 4.75 | 0.43 | 21.59 | 5.09 | 0.91 | 0.54 | 73.86 |
| 127 | PT | 0.22 | 0.40 | 0.50 | 0.02 | 0.22 | 0.01 | 0.02 | 0.00 | 0.03 | 0.09 | 1.50 |
| 128 | RO | 1.23 | 0.25 | 1.82 | 1.75 | 0.91 | 0.72 | 16.93 | 1.99 | 0.63 | 1.26 | 27.48 |
| 129 | SE | 3.41 | 0.24 | 0.30 | 0.35 | 4.40 | 2.68 | 0.92 | 0.16 | 2.13 | 5.79 | 20.38 |
| 130 | SI | 0.01 | 0.00 | 0.17 | 0.25 | 2.14 | 0.16 | 0.75 | 0.03 | 0.31 | 0.43 | 4.27 |
| 131 | SK | 0.41 | 0.00 | 1.09 | 1.24 | 3.82 | 0.96 | 0.80 | 2.25 | 0.22 | 0.63 | 11.43 |
| 133 | UK | 0.01 | 0.02 | 9.47 | 0.50 | 1.90 | 0.31 | 5.61 | 0.01 | 0.95 | 6.46 | 25.23 |
| | EU27 | 34.85 | 5.89 | 93.90 | 21.03 | 50.28 | 36.37 | 131.28 | 33.75 | 32.11 | 81.29 | 520.76 |
| | EU15 | 25.06 | 5.54 | 23.73 | 10.17 | 35.16 | 30.91 | 83.49 | 17.70 | 28.38 | 70.83 | 330.99 |
| | EU12 | 9.78 | 0.35 | 70.17 | 10.86 | 15.12 | 5.46 | 47.79 | 16.06 | 3.73 | 10.46 | 189.76 |
| | EU27+CH+NO | 35.57 | 6.07 | 95.73 | 21.14 | 51.99 | 36.73 | 134.48 | 33.98 | 33.05 | 82.24 | 530.98 |

– **Billion Tonnes-km per country for the White paper Low (NSTR) Year 2030**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 3.47 | .07 | .03 | .77 | 1.90 | 1.90 | 2.47 | .48 | 1.03 | 3.83 | 15.95 |
| 102 | BE | .50 | .50 | .89 | .95 | .69 | 3.07 | 3.63 | .12 | 3.23 | 3.80 | 17.38 |
| 103 | BU | .05 | .00 | .00 | .07 | .09 | .80 | 2.85 | .03 | .11 | .66 | 4.65 |
| 104 | CH | .54 | .09 | .09 | .11 | .30 | .35 | 1.71 | .09 | .61 | .60 | 4.49 |
| 106 | CZ | .52 | .00 | 17.04 | 1.19 | .80 | 1.35 | 1.92 | 2.57 | .75 | 1.02 | 27.17 |
| 107 | DE | 5.70 | 1.05 | 5.72 | 4.86 | 7.49 | 9.11 | 22.84 | 11.63 | 11.20 | 18.32 | 97.92 |
| 108 | DK | .18 | .04 | .27 | .02 | .09 | .24 | 2.24 | .05 | .11 | .74 | 3.96 |
| 109 | EE | 2.92 | .03 | 1.48 | .81 | .05 | .03 | .02 | .39 | .08 | .02 | 5.82 |
| 110 | ES | 1.18 | 1.12 | .97 | .06 | 2.52 | .06 | 12.98 | .12 | 2.89 | 22.35 | 44.26 |
| 111 | FI | 1.96 | .06 | .54 | .16 | .50 | .57 | .12 | .22 | 1.05 | 2.09 | 7.28 |
| 112 | FR | 8.04 | 1.80 | 1.09 | .30 | 7.42 | 6.20 | 11.24 | 2.20 | 3.24 | 3.23 | 44.76 |
| 113 | GR | .02 | .32 | .00 | .00 | .20 | .01 | .46 | .00 | .07 | .45 | 1.55 |
| 115 | CR | 2.57 | .02 | .20 | 2.13 | .84 | .41 | .67 | .33 | .47 | 5.08 | 12.73 |
| 116 | IE | .03 | .10 | .07 | .00 | .13 | .01 | .04 | .00 | .02 | .22 | .61 |
| 118 | IT | .36 | .48 | .11 | .76 | .95 | 1.94 | 13.82 | .03 | .66 | 5.69 | 24.80 |
| 120 | LI | .32 | .02 | 1.11 | 1.85 | .29 | .01 | .45 | 2.18 | .01 | .04 | 6.28 |
| 121 | LU | .03 | .01 | .01 | .00 | .07 | .82 | .05 | .01 | .04 | .05 | 1.08 |
| 122 | LV | .46 | .02 | 3.21 | .21 | 1.00 | .16 | .95 | .18 | .03 | .08 | 6.30 |
| 124 | NL | .50 | 1.22 | 1.90 | .40 | 3.60 | 1.47 | 5.56 | .21 | 1.80 | 1.13 | 17.80 |
| 125 | NO | .17 | .10 | 1.45 | .03 | 1.15 | .03 | 1.04 | .11 | .24 | .53 | 4.84 |
| 126 | PL | .23 | .01 | 33.90 | .25 | 4.09 | .43 | 19.21 | 4.35 | .84 | .59 | 63.91 |
| 127 | PT | .28 | .37 | .42 | .02 | .20 | .01 | .10 | .00 | .02 | .10 | 1.52 |
| 128 | RO | 1.11 | .24 | 1.53 | 1.48 | .78 | .63 | 14.43 | 1.69 | .56 | 1.12 | 23.56 |
| 129 | SE | 3.76 | .23 | .25 | .39 | 3.73 | 2.36 | .96 | .14 | 2.18 | 6.42 | 20.43 |
| 130 | SI | .01 | .00 | .15 | .22 | 1.92 | .15 | .91 | .02 | .27 | .41 | 4.05 |
| 131 | SK | .37 | .00 | .92 | 1.05 | 3.24 | .84 | .69 | 1.90 | .19 | .61 | 9.81 |
| 133 | UK | .04 | .19 | 7.99 | .73 | 1.62 | .49 | 5.13 | .01 | 1.37 | 6.89 | 24.47 |
| | EU27 | 34.6 | 7.9 | 79.8 | 18.7 | 44.2 | 33.1 | 123.8 | 28.8 | 32.2 | 84.9 | 488.1 |
| | EU15 | 26.1 | 7.6 | 20.3 | 9.4 | 31.1 | 28.3 | 81.7 | 15.2 | 28.9 | 75.3 | 323.8 |
| | EU12 | 8.6 | 0.3 | 59.6 | 9.3 | 13.1 | 4.8 | 42.1 | 13.6 | 3.3 | 9.6 | 164.3 |
| | EU27+CH+NO | 35.3 | 8.1 | 81.3 | 18.8 | 45.6 | 33.5 | 126.5 | 29.0 | 33.1 | 86.1 | 497.4 |

– **Billion Tonnes-km per country for the White paper Low (NSTR) Year 2050**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 4.22 | .12 | .03 | .91 | 2.28 | 2.33 | 3.07 | .57 | 1.30 | 4.98 | 19.82 |
| 102 | BE | .66 | .70 | 1.07 | 1.17 | .83 | 3.71 | 4.95 | .15 | 4.13 | 5.13 | 22.51 |
| 103 | BU | .07 | .00 | .00 | .08 | .13 | .95 | 3.37 | .03 | .13 | .80 | 5.56 |
| 104 | CH | .70 | .12 | .11 | .16 | .37 | .47 | 2.06 | .10 | .75 | .89 | 5.72 |
| 106 | CZ | .65 | .01 | 20.18 | 1.41 | .96 | 1.63 | 2.36 | 3.05 | .91 | 1.29 | 32.44 |
| 107 | DE | 7.44 | 1.55 | 6.80 | 5.83 | 9.15 | 11.20 | 29.29 | 13.93 | 14.32 | 25.22 | 124.73 |
| 108 | DK | .24 | .05 | .32 | .02 | .11 | .30 | 2.93 | .06 | .15 | 1.05 | 5.23 |
| 109 | EE | 3.47 | .04 | 1.75 | .97 | .06 | .04 | .03 | .46 | .09 | .03 | 6.93 |
| 110 | ES | 1.59 | 1.46 | 1.22 | .11 | 3.30 | .07 | 15.96 | .16 | 3.72 | 26.80 | 54.40 |
| 111 | FI | 2.42 | .08 | .64 | .19 | .59 | .70 | .17 | .26 | 1.28 | 2.64 | 8.97 |
| 112 | FR | 10.63 | 2.60 | 1.32 | .44 | 9.01 | 7.59 | 14.96 | 2.65 | 4.31 | 4.92 | 58.42 |
| 113 | GR | .03 | .50 | .00 | .00 | .24 | .02 | .55 | .00 | .08 | .56 | 1.97 |
| 115 | CR | 3.05 | .03 | .24 | 2.53 | .99 | .49 | .80 | .39 | .57 | 6.17 | 15.27 |
| 116 | IE | .05 | .14 | .13 | .00 | .16 | .01 | .07 | .00 | .02 | .29 | .87 |
| 118 | IT | .52 | .64 | .13 | .92 | 1.18 | 2.58 | 17.53 | .03 | .91 | 8.37 | 32.81 |
| 120 | LI | .39 | .03 | 1.37 | 2.20 | .35 | .02 | .59 | 2.59 | .01 | .06 | 7.61 |
| 121 | LU | .04 | .01 | .02 | .00 | .08 | 1.02 | .07 | .01 | .05 | .07 | 1.36 |
| 122 | LV | .59 | .02 | 3.83 | .25 | 1.20 | .20 | 1.18 | .21 | .04 | .13 | 7.66 |
| 124 | NL | .82 | 1.93 | 2.26 | .51 | 4.35 | 1.86 | 7.07 | .25 | 2.46 | 1.81 | 23.32 |
| 125 | NO | .20 | .13 | 1.73 | .04 | 1.37 | .04 | 1.25 | .13 | .30 | .67 | 5.84 |
| 126 | PL | .28 | .01 | 40.17 | .31 | 4.90 | .54 | 23.37 | 5.18 | 1.04 | .78 | 76.60 |
| 127 | PT | .41 | .46 | .50 | .02 | .25 | .01 | .18 | .00 | .03 | .13 | 1.98 |
| 128 | RO | 1.36 | .30 | 1.82 | 1.75 | .94 | .76 | 17.15 | 2.00 | .67 | 1.36 | 28.10 |
| 129 | SE | 5.05 | .30 | .30 | .53 | 4.44 | 2.87 | 1.26 | .16 | 2.85 | 8.64 | 26.41 |
| 130 | SI | .01 | .00 | .18 | .26 | 2.34 | .19 | 1.25 | .03 | .32 | .51 | 5.08 |
| 131 | SK | .45 | .00 | 1.09 | 1.24 | 3.83 | 1.00 | .83 | 2.25 | .23 | .77 | 11.71 |
| 133 | UK | .06 | .35 | 9.49 | 1.08 | 1.94 | .74 | 6.36 | .01 | 2.01 | 9.13 | 31.17 |
| | EU27 | 44.5 | 11.3 | 94.9 | 22.7 | 53.6 | 40.8 | 155.4 | 34.4 | 41.6 | 111.6 | 610.9 |
| | EU15 | 34.2 | 10.9 | 24.2 | 11.7 | 37.9 | 35.0 | 104.4 | 18.2 | 37.6 | 99.7 | 414.0 |
| | EU12 | 10.3 | 0.4 | 70.6 | 11.0 | 15.7 | 5.8 | 50.9 | 16.2 | 4.0 | 11.9 | 197.0 |
| | EU27+CH+NO | 45.4 | 11.6 | 96.7 | 22.9 | 55.3 | 41.3 | 158.7 | 34.7 | 42.7 | 113.2 | 622.5 |

– **Billion Tonnes-km per country for the White paper High (NSTR) Year 2030**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 4.31 | .84 | .04 | .86 | 1.96 | 2.33 | 2.98 | .52 | 1.71 | 5.72 | 21.26 |
| 102 | BE | 1.33 | 1.54 | .92 | 1.09 | .75 | 3.50 | 4.79 | .28 | 4.38 | 6.07 | 24.67 |
| 103 | BU | .26 | .10 | .02 | .07 | .11 | .92 | 2.90 | .03 | .20 | .89 | 5.50 |
| 104 | CH | .67 | .25 | .09 | .14 | .31 | .42 | 1.78 | .09 | .76 | 1.09 | 5.61 |
| 106 | CZ | 1.18 | .37 | 17.07 | 1.23 | .98 | 1.75 | 2.57 | 2.60 | 1.29 | 2.60 | 31.65 |
| 107 | DE | 9.82 | 8.16 | 5.91 | 5.37 | 8.03 | 11.06 | 34.40 | 11.94 | 16.48 | 33.32 | 144.49 |
| 108 | DK | .50 | 1.02 | .30 | .04 | .19 | .33 | 2.59 | .07 | .36 | 1.86 | 7.26 |
| 109 | EE | 2.98 | .07 | 1.49 | .82 | .05 | .04 | .05 | .42 | .09 | .11 | 6.12 |
| 110 | ES | 7.07 | 5.39 | 1.23 | .95 | 3.62 | 2.34 | 19.68 | .57 | 5.27 | 31.10 | 77.23 |
| 111 | FI | 2.67 | .20 | .56 | .17 | .53 | .63 | .54 | .24 | 1.15 | 2.44 | 9.13 |
| 112 | FR | 12.27 | 6.22 | 1.15 | 1.26 | 7.87 | 7.05 | 16.33 | 2.52 | 5.78 | 11.61 | 72.05 |
| 113 | GR | .29 | .65 | .01 | .02 | .25 | .11 | .53 | .01 | .16 | .72 | 2.74 |
| 115 | CR | 3.03 | .40 | .20 | 2.15 | .90 | .57 | .88 | .36 | .79 | 6.15 | 15.44 |
| 116 | IE | .04 | .10 | .08 | .01 | .13 | .01 | .10 | .00 | .02 | .22 | .71 |
| 118 | IT | 3.43 | 5.50 | .27 | 1.95 | 1.32 | 5.12 | 20.17 | .18 | 3.73 | 17.03 | 58.70 |
| 120 | LI | .57 | .22 | 1.18 | 1.90 | .36 | .04 | .50 | 2.26 | .05 | .50 | 7.60 |
| 121 | LU | .07 | .07 | .01 | .00 | .07 | .86 | .13 | .01 | .06 | .31 | 1.61 |
| 122 | LV | .68 | .16 | 3.23 | .22 | 1.02 | .19 | .97 | .20 | .04 | .40 | 7.12 |
| 124 | NL | 2.36 | 4.17 | 1.94 | .62 | 3.67 | 1.89 | 6.09 | .36 | 2.88 | 5.23 | 29.21 |
| 125 | NO | .31 | .34 | 1.49 | .13 | 1.16 | .12 | 1.28 | .13 | .38 | .87 | 6.21 |
| 126 | PL | 1.36 | 1.12 | 33.96 | .32 | 4.29 | .93 | 20.54 | 4.43 | 1.59 | 4.24 | 72.78 |
| 127 | PT | .85 | 1.49 | .43 | .08 | .24 | .25 | .86 | .06 | .40 | 1.97 | 6.62 |
| 128 | RO | 1.35 | .73 | 1.64 | 1.58 | .96 | 1.35 | 14.70 | 1.94 | .98 | 3.61 | 28.83 |
| 129 | SE | 4.33 | .59 | .27 | .48 | 3.78 | 2.46 | 1.41 | .16 | 2.51 | 7.10 | 23.09 |
| 130 | SI | .11 | .08 | .17 | .22 | 1.98 | .34 | 1.14 | .04 | .35 | .88 | 5.30 |
| 131 | SK | .81 | .15 | .93 | 1.07 | 3.27 | 1.23 | .90 | 1.91 | .39 | 1.75 | 12.40 |
| 133 | UK | .47 | 1.24 | 8.00 | .86 | 1.64 | .59 | 5.47 | .05 | 1.61 | 7.50 | 27.44 |
| | EU27 | 62.2 | 40.6 | 81.0 | 23.3 | 48.0 | 45.9 | 161.2 | 31.2 | 52.3 | 153.3 | 699.0 |
| | EU15 | 49.8 | 37.2 | 21.1 | 13.8 | 34.1 | 38.5 | 116.1 | 17.0 | 46.5 | 132.2 | 506.2 |
| | EU12 | 12.3 | 3.4 | 59.9 | 9.6 | 13.9 | 7.3 | 45.2 | 14.2 | 5.8 | 21.1 | 192.8 |
| | EU27+CH+NO | 63.1 | 41.2 | 82.6 | 23.6 | 49.4 | 46.4 | 164.3 | 31.4 | 53.4 | 155.3 | 710.8 |

– **Billion Tonnes-km per country for the White paper High (NSTR) Year 2050**

| | | Agricultural products | Foodstuffs | Solid mineral fuels | Petroleum products | Ores and metal waste | Metal products | Crude, manufacturing, building materials | Fertilizers | Chemicals | Machinery, transport equipment | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | AT | 5.78 | 1.55 | .06 | 1.09 | 2.38 | 3.12 | 3.99 | .65 | 2.54 | 8.45 | 29.61 |
| 102 | BE | 2.19 | 2.63 | 1.13 | 1.42 | .95 | 4.52 | 7.10 | .46 | 6.25 | 9.30 | 35.95 |
| 103 | BU | .46 | .19 | .03 | .09 | .17 | 1.16 | 3.48 | .04 | .30 | 1.23 | 7.14 |
| 104 | CH | .94 | .41 | .11 | .22 | .38 | .60 | 2.19 | .11 | 1.03 | 1.80 | 7.78 |
| 106 | CZ | 1.88 | .69 | 20.24 | 1.48 | 1.29 | 2.37 | 3.55 | 3.10 | 1.90 | 4.21 | 40.71 |
| 107 | DE | 15.03 | 14.67 | 7.15 | 6.78 | 10.15 | 14.80 | 50.59 | 14.48 | 24.06 | 52.88 | 210.59 |
| 108 | DK | .84 | 1.86 | .37 | .07 | .30 | .48 | 3.58 | .09 | .61 | 3.11 | 11.31 |
| 109 | EE | 3.59 | .10 | 1.78 | .97 | .07 | .05 | .08 | .52 | .12 | .20 | 7.48 |
| 110 | ES | 12.45 | 9.33 | 1.70 | 1.75 | 5.33 | 4.29 | 28.32 | .98 | 8.11 | 42.93 | 115.19 |
| 111 | FI | 3.73 | .33 | .68 | .22 | .64 | .81 | .94 | .30 | 1.47 | 3.27 | 12.39 |
| 112 | FR | 18.42 | 10.75 | 1.43 | 2.21 | 9.84 | 9.15 | 24.33 | 3.23 | 9.00 | 20.36 | 108.73 |
| 113 | GR | .53 | 1.10 | .02 | .04 | .33 | .19 | .68 | .01 | .25 | 1.04 | 4.18 |
| 115 | CR | 3.90 | .73 | .25 | 2.57 | 1.11 | .79 | 1.18 | .44 | 1.17 | 8.13 | 20.27 |
| 116 | IE | .06 | .15 | .14 | .02 | .16 | .01 | .18 | .01 | .03 | .29 | 1.05 |
| 118 | IT | 6.17 | 9.89 | .42 | 3.12 | 1.86 | 8.44 | 29.24 | .32 | 6.58 | 29.27 | 95.31 |
| 120 | LI | .86 | .39 | 1.49 | 2.30 | .48 | .07 | .70 | 2.74 | .09 | .91 | 10.04 |
| 121 | LU | .12 | .13 | .02 | .00 | .10 | 1.09 | .21 | .01 | .10 | .55 | 2.33 |
| 122 | LV | .99 | .29 | 3.88 | .27 | 1.25 | .25 | 1.22 | .25 | .06 | .71 | 9.16 |
| 124 | NL | 4.24 | 7.37 | 2.33 | .91 | 4.48 | 2.63 | 8.06 | .54 | 4.45 | 9.37 | 44.37 |
| 125 | NO | .47 | .57 | 1.79 | .21 | 1.39 | .19 | 1.68 | .18 | .57 | 1.30 | 8.35 |
| 126 | PL | 2.37 | 2.06 | 40.28 | .43 | 5.26 | 1.48 | 25.83 | 5.32 | 2.43 | 7.51 | 92.96 |
| 127 | PT | 1.45 | 2.53 | .51 | .14 | .31 | .45 | 1.57 | .11 | .73 | 3.58 | 11.39 |
| 128 | RO | 1.81 | 1.21 | 2.01 | 1.93 | 1.27 | 2.08 | 17.65 | 2.46 | 1.46 | 5.95 | 37.82 |
| 129 | SE | 6.10 | .95 | .34 | .69 | 4.54 | 3.06 | 2.10 | .21 | 3.44 | 9.88 | 31.30 |
| 130 | SI | .19 | .15 | .21 | .27 | 2.45 | .53 | 1.68 | .05 | .48 | 1.38 | 7.40 |
| 131 | SK | 1.27 | .27 | 1.11 | 1.29 | 3.89 | 1.72 | 1.22 | 2.26 | .59 | 2.88 | 16.49 |
| 133 | UK | .85 | 2.27 | 9.52 | 1.31 | 1.98 | .92 | 6.98 | .09 | 2.44 | 10.26 | 36.64 |
| | EU27 | 95.3 | 71.6 | 97.1 | 31.4 | 60.6 | 64.5 | 224.5 | 38.7 | 78.7 | 237.7 | 999.8 |
| | EU15 | 78.0 | 65.5 | 25.8 | 19.8 | 43.3 | 54.0 | 167.9 | 21.5 | 70.1 | 204.6 | 750.3 |
| | EU12 | 17.3 | 6.1 | 71.3 | 11.6 | 17.2 | 10.5 | 56.6 | 17.2 | 8.6 | 33.1 | 249.5 |
| | EU27+CH+NO | 96.7 | 72.5 | 99.0 | 31.8 | 62.3 | 65.3 | 228.3 | 39.0 | 80.2 | 240.8 | 1,015.9 |

# Annex 4 TRANS-TOOLS output, main Flows (in billion tkm)

4-A: Reference scenario 2010 btkm flows


4-B: Reference scenario 2020 btkm flows


4-C: Reference scenario 2030 btkm flows


4-D: Reference scenario 2050 btkm flows


4-E: White paper low scenario 2030 btkm flows


4-F: White paper low scenario 2050 btkm flows

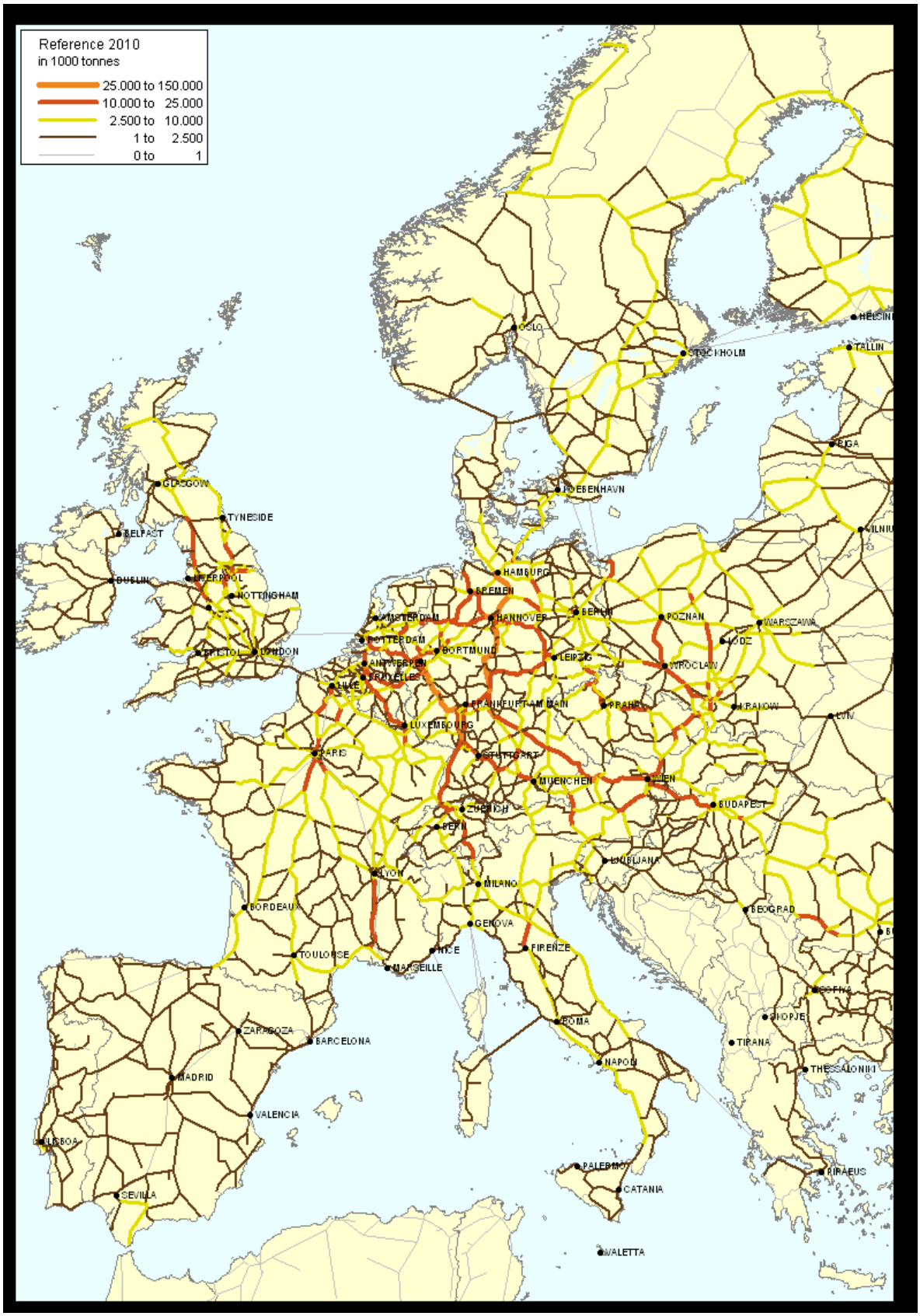

4-G: White paper high scenario 2030 btkm flows


4-I: White paper high scenario 2050 btkm flows


wp high scenario 205
in billion ton-km
40 to 314
15 to 40
5 to 15
1 to 5
0 to 1
OSLO
STOCKHOLM
RIGA
GLASGOW
TYNESIDE
BELFAST
DUBLIN
LIVERPOOL
NOTTINGHAM
WEST MIDLANDS
BRISTOL
LONDON
HAMBURG
BREMEN
AMSTERDAM
HANNOVER
BERLIN
POZNAN
WARSZAWA
ROTTERDAM
DORTMUND
LODZ
ANTWERPEN
LEIPZIG
WROCLAW
BRUXELLES
LILLE
FRANKFURT AM MAIN
PRAHA
KRAKOW
LUXEMBOURG
PARIS
STUTTGART
MUENCHEN
WIEN
BUDAPEST
ZUERICH
BERN
LJUBLJANA
LYON
MILANO
BORDEAUX
BEOGRAD
GENOVA
TOULOUSE
NICE
FIRENZE
MARSEILLE
SOFIA
SKOPJE
ROMA
ZARAGOZA
BARCELONA
TIRANA
NAPOLI
MADRID
VALENCIA
PALERMO
PIRAEUS
SEVILLA
CATANIA
VALETTA

# Annex 5 TRANS-TOOLS output, main Flows (in 1000 tonnes)

5-A: Reference scenario 2010 1000 tonnes flows



5-B: Reference scenario 2020 1000 tonnes flows

5-C: Reference scenario 2030 1000 tonnes flows

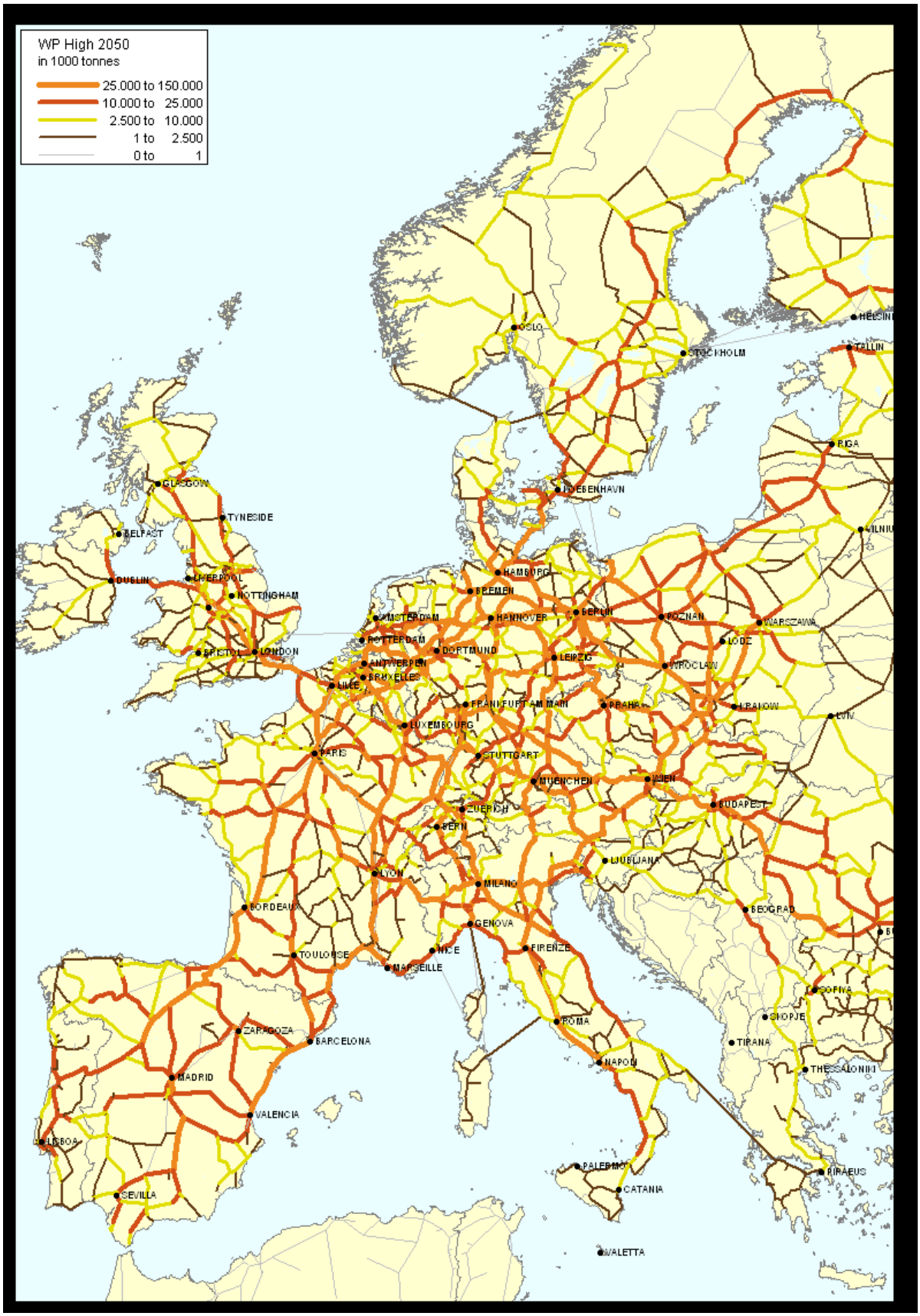
5-D: Reference scenario 2050 1000 tonnes flows


5-E: White paper low scenario 2030 1000 tonnes flows


5-F: White paper low scenario 2050 1000 tonnes flows


5-G: White paper high scenario 2030 1000 tonnes flows


5-I: White paper high scenario 2050 1000 tonnes flows


WP High 2050
in 1000 tonnes
25.000 to 150.000
10.000 to 25.000
2.500 to 10.000
1 to 2.500
0 to 1
OSLO
STOCKHOLM
TALLIN
RIGA
KOEBENHAVN
GLASGOW
TYNESIDE
BELFAST
DUBLIN
LIVERPOOL
NOTTINGHAM
HAMBURG
BREMEN
AMSTERDAM
HANNOVER
BERLIN
POZNAN
WARSZAWA
ROTTERDAM
DORTMUND
BRISTOL
LONDON
ANTWERPEN
BRUXELLES
LILLE
LEIPZIG
WROCLAW
LODZ
FRANKFURT AM MAIN
PRAHA
KRAKOW
LUXEMBOURG
PARIS
STUTTGART
MUENCHEN
WIEN
BUDAPEST
ZUERICH
BERN
LJUBLJANA
LYON
MILANO
BORDEAUX
BEOGRAD
GENOVA
TOULOUSE
NICE
FIRENZE
MARSEILLE
SOFIYA
SKOPJE
ROMA
ZARAGOZA
BARCELONA
TIRANA
NAPOLI
THESSALONIKI
MADRID
VALENCIA
LISBOA
PALERMO
PIRAEUS
SEVILLA
CATANIA
VALETTA