# RAILWAY HANDBOOK 2014

## ENERGY CONSUMPTION AND $CO_2$ EMISSIONS

International Energy Agency

INTERNATIONAL UNION OF RAILWAYS

**Railway Handbook 2014**

# Energy Consumption and $CO_2$ Emissions

## - Focus on Infrastructure -

# INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

**IEA member countries:**

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea (Republic of)
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA.

International Energy Agency
1974•2014
Secure • Sustainable • Together



**International Energy Agency**
9 rue de la Fédération
75739 Paris Cedex 15, France
***www.iea.org***

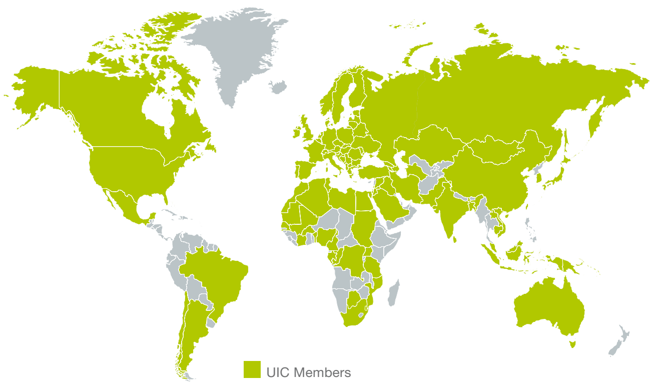
INTERNATIONAL UNION
OF RAILWAYS

# UIC: the international professional association representing the railway sector

*UIC, the international railway association which celebrated its 90th anniversary in 2012, counts 240 members across 5 continents (railway companies, infrastructure managers, rail-related transport operators, etc.). UIC's members represent over 1 million kilometres of tracks, 2,900 billion passenger-km, 10,000 billion tonne-km and a workforce of 7 million railway staff.*

## ACCORDING TO THE STATUTES, UIC'S MISSION FOCUSES MAINLY ON:

- Promoting rail transport around the world with the aim to meet current and future challenges of mobility and sustainable development.
- Promoting interoperability, creating new world standards for railways, including common standards with other transport modes.
- Developing and facilitating all forms of international cooperation among members, facilitating the sharing of best practices (benchmarking).
- Supporting members in their efforts to develop new business and new areas of activity.
- Proposing new ways to improve technical and environmental performance of rail transport, boosting competitiveness and reducing costs.




WWW.UIC.ORG

# Foreword

2014 marks the third year of collaboration between the International Energy Agency and the International Union of Railways to produce the data handbook on “Energy Consumption and $CO_2$ Emissions of World Railway Sector”.

The 2012 edition was the first to combine IEA and UIC data and provide a comprehensive picture of rail activity, energy consumption and carbon emissions in the European Union and several other countries, while the 2013 edition introduced a new section on key environmental indicators for railways and other transport modes. This second edition also had a special focus on Energy Mix, a crucial parameter to be considered as railways continue to electrify.

The positive feedback received by the IEA and UIC from stakeholders – including private, governmental and international organisations – has encouraged us to pursue this joint effort in close cooperation.

In this 2014 edition, we have worked together to update the World section and the core countries that have been present since the first edition (EU, USA, Japan, Russia, India and China).

The 2014 edition also presents a special focus on infrastructure: the analysis includes data on occupancy levels, energy consumption and emissions associated with the infrastructure and investments made on railways and roads around the world.

The conclusions are decisive: increasing investments in rail will produce important improvements both in transport efficiency and in environmental impact. In 2011, rail infrastructure carried 10 times more transport units per kilometre than road, using roughly 11 times less energy per unit than road transport.

From an emissions standpoint, every dollar invested in railway infrastructure results in one-third the emissions generated by rail traffic than would have been produced had that dollar been spent on road infrastructure. Shifting transport activity to rail would be instrumental in reaching global targets in support of a 2 degree Celsius emissions trajectory by 2050.

Global demand for transport is growing at incredibly fast rates. We hope that the new key performance indicators introduced in this edition will provide decision makers with valuable information regarding the pathways to meet this growing demand efficiently and sustainably.

The IEA and UIC will continue to collaborate in the next editions of the Handbook in our joint effort to improve transport sector data and extend global analysis even further.

Maria van der Hoeven

International Energy Agency
Executive Director

Jean-Pierre Loubinoux

International Union of Railways
Director General

## Acknowledgments

This publication has been made possible thanks to UIC railway members, who have contributed to UIC statistics on railway activity, energy consumption and $CO_2$ emissions since 2005, and to the IEA Energy Data Centre, which has collected and managed energy balances and $CO_2$ emissions data from fuel combustion.

The Handbook has been coordinated by John Dulac, Pierpaolo Cazzola (IEA) and Veronica Aneris (UIC).

A special mention goes to the cooperation of UIC and IEA staff, and in particular to Nicholas Craven and Andrea Braschi (UIC).

A special thanks to the Sustainable Development Foundation for its technical support, especially to Raimondo Orsini, Daniele Arena, Valeria Gentili, Stefania Grillo and Luca Refrigeri.

Infographic design: Laboratorio Linfa
www.laboratoriolinfa.com

Printed on Fedrigoni Symbol Matt Plus

**Railway Handbook 2014**

# Energy Consumption and $CO_2$ Emissions

# Index

# Index of Figures

World



EU27



USA



Japan

# Index of tables

# Introduction

The 2014 edition of the Railway Handbook on Energy Consumption and $CO_2$ emissions is the third publication that sees the collaboration of IEA and UIC in collecting activity, energy and $CO_2$ emissions data, elaborating and presenting it. The previous editions can be downloaded for free from the UIC website.

This edition contains updates to the World and European Union sections, as well as several countries that can be considered the most relevant from the point of view of transport activity: USA, Japan, Russia, India and China.

This year's Handbook also contains a section with a special focus on infrastructure, in particular on road and rail, including: the amount of existing infrastructure, its impact on land use, respective occupancy levels, energy consumption and $CO_2$ emissions, and the investments connected to constructing, operating and maintaining transport infrastructure.

As in previous publications, this Handbook combines IEA statistical data (CO2 Emissions from Fuel Combustion – IEA, 2013a – and World Energy Balances – IEA, 2013b) and rail data estimates from the IEA Mobility Model together with UIC statistics (UIC, 2013a) and the UIC Environmental Performance Database (UIC, 2013b). Further data, particularly on transport activity, comes from national statistics institutes and international organisations (e.g. OECD and Eurostat).

The data collected in this handbook opens several insights into the energy and emissions performance of the transport sector, and in particular railways. Worldwide, only 0.6% of the total energy consumed in 2011 and 1% of global $CO_2$ emissions can be attributed to rail, compared to 20% of energy and 16.5% of emissions that can be attributed to road transport.
Moreover, rail energy and emissions intensities continue to improve. The use of coal as a fuel in world railways has been reduced from 25% in 1990 to 6% in 2011, while the use of electricity more than doubled since 1990 to 35% in 2011. In this context and timeframe, it is interesting to note that renewable electricity production also doubled, although renewables in the world electricity mix only grew from 18% to 20% since 1990.

The effort of railways to improve their environmental impact is consistent: specific energy consumption and $CO_2$ emissions for passenger transport have both been halved since 1990.

On a European level, while emissions from the overall transport sector increased by 25% between 1990 and 2011, railway emissions dropped by 42%. This was possible in part thanks to the decrease in the use of diesel (down by 31%) in favour of the use of electricity (up by 14%), as well as because of increased use of renewables in the European electricity mix (from 14% to 22%).

The special focus on infrastructure in this Handbook shows that while paved road lane kilometres doubled since 1975, global railway track length decreased by nearly 10%. High-speed railways are an exception to this trend, having doubled in length between 2009 and 2013. China now holds more than 50% of global high-speed lines.

The special focus section also gives an insight on the efficiency of railway infrastructure compared to roads: rail infrastructure carries ten times more transport units per kilometre than roadways, while using nearly 40 times less land than roads.

The projections shown in this Handbook also illustrate the strong role for rail in meeting global climate and economic objectives: on average, every dollar spent on rail infrastructure results in between three and ten times less $CO_2$ emissions compared to each dollar spent on road.

## Part I:
# The Railway Sector
# Main data

# World

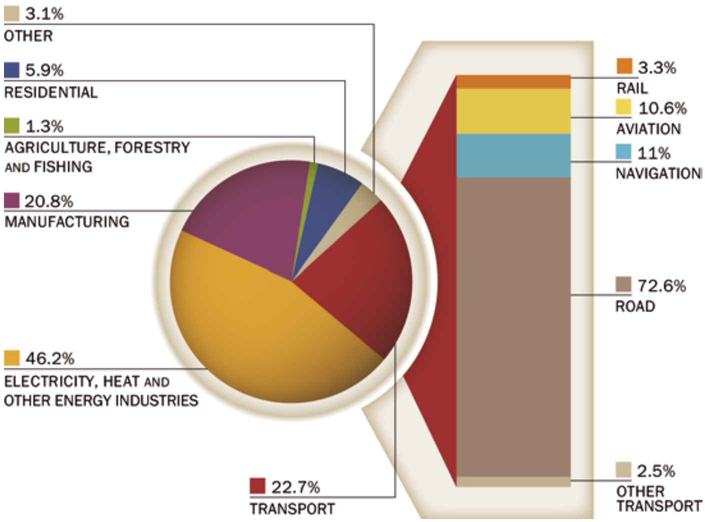


## Key Facts[1]

- The amount of pkm transported by rail in the world grew by 130% since 1975. China and India were the major contributors, with a sevenfold increase in railway activity, while EU27 activity grew by 4% in the 1990-2011 period (Fig. 6).
- In the period 1975-2011, global rail freight tkm grew by 76%, while in China and Latin America it grew by more than 500% in that period. Rail freight activity in Europe decreased by 11% (Fig. 7).
- The transport sector consumed 27.6% of global energy use. 2.2% of this energy was consumed by rail, which means that 0.6% of the world's energy was consumed by railways (Fig. 3).
- Railway specific energy consumption decreased by around 50% between 1975 and 2011, both for passenger and freight activity (Fig. 10).
- The use of coal in railways decreased significantly, going from 25% of total energy sources in 1990 to 6% in 2011. At the same time, the use of electricity doubled (Fig. 8).
- The transport sector was responsible for 22.7% of the total energy-related $CO_2$ emissions, of which 3.3% was due to rail activity. Railways therefore generated less than 1% of total energy-related $CO_2$ emissions (Fig. 1). At the same time, railways transported more than 9% of the world's passengers and freight activity (Table 1).
- Transport sector $CO_2$ emissions increased by 53% between 1990 and 2011: in the same timeframe, the share of railway $CO_2$ emissions in transport decreased from 4.2% to 3.3% (Fig. 5).
- Railway specific $CO_2$ emissions dropped by 54% for passenger activity and 40% for freight between 1975 and 2011 (Fig. 11).

[1] If not otherwise specified, data is related to the year 2011

Fig. 1: **Share of $CO_2$ emissions from fuel combustion by sector, 2011**




Note: Emissions from rail electrical traction are reallocated from electricity, heat and other energy industries to the transport sector. See Methodology Notes.

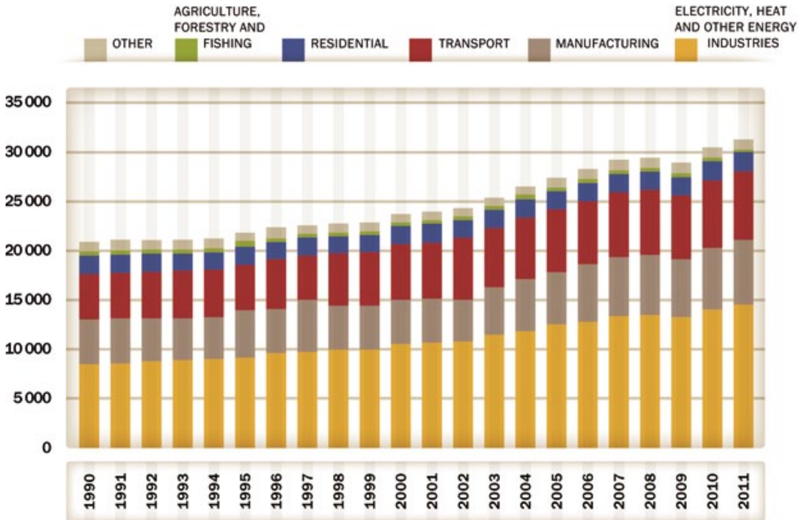
Source: Elaboration by Susdef based on IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

Table 1: **World transport modal share, 2011**

| | Passenger PKM | Freight TKM | Total TU |
|---|---|---|---|
| ROAD | 83.5% | 10.4% | 34.8% |
| NAVIGATION | 0.3% | 78% | 52.2% |
| RAIL | 6.4% | 10.8% | 9.3% |
| AVIATION | 9.8% | 0.8% | 3.7% |

Source: IEA Mobility Model and UNCTAD (2013)

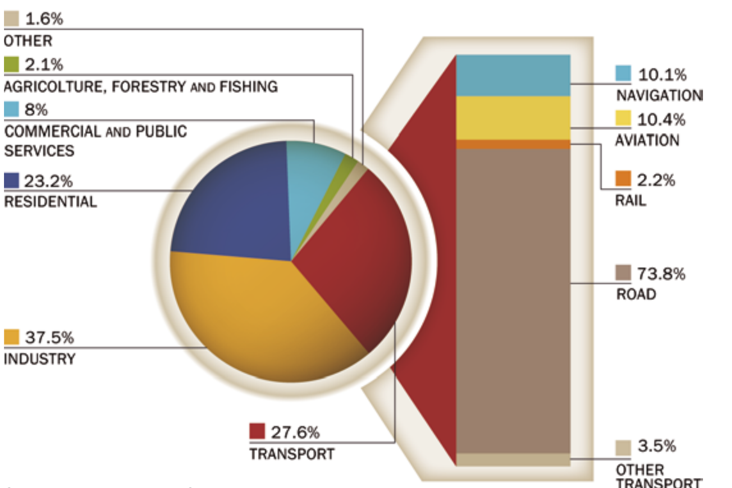
Fig. 2: **Total $CO_2$ emissions from fuel combustion by sector, 1990-2011 (million $tCO_2$)**




Note: Emissions from rail electrical traction are included in the transport sector. See Methodology Notes.

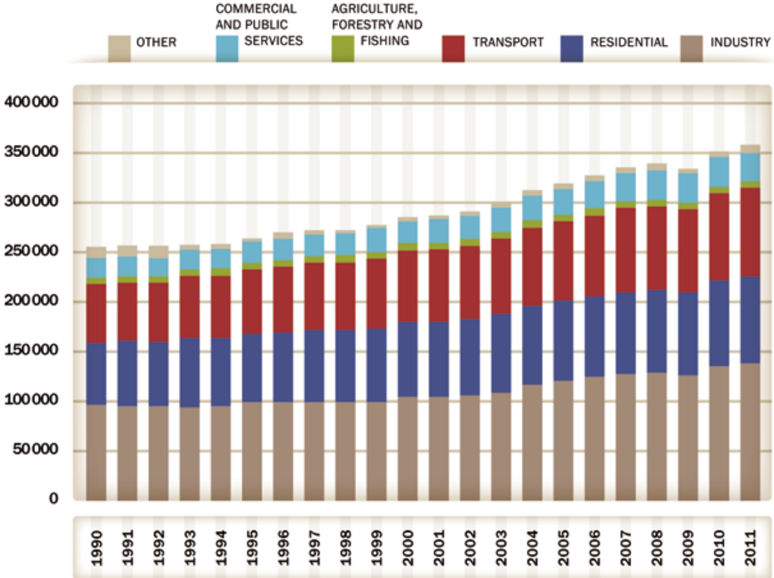
Source: Elaboration by Susdef based on IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

Fig. 3: **Share of final energy consumption by sector, 2011**



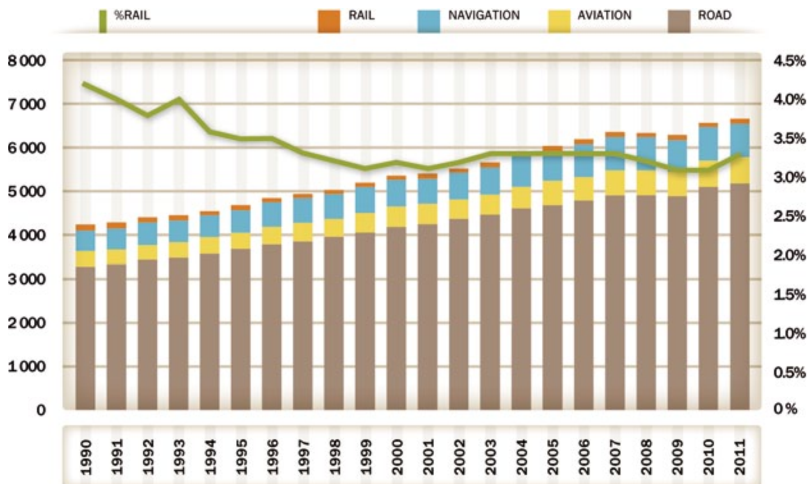

Source: Elaboration by Susdef based on IEA (2013b)

Fig. 4: **Total final energy consumption by sector, 1990-2011 (PJ)**



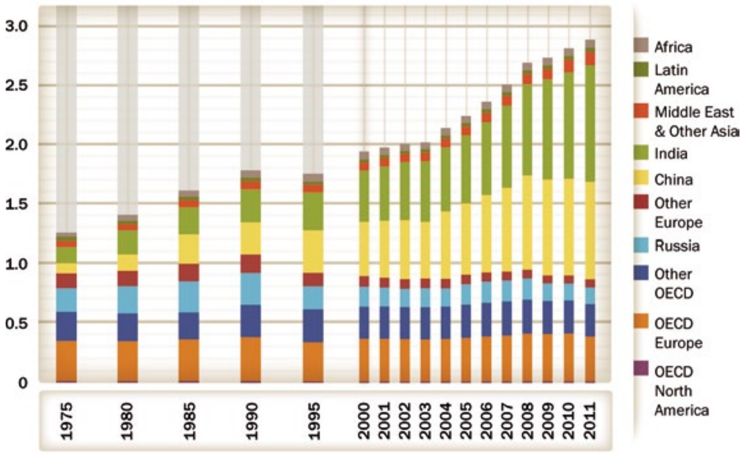

Source: IEA (2013b)

Fig. 5: **Transport sector $CO_2$ emissions by mode, 1990-2011 (million $tCO_2$ - left, share of rail over total - right)**



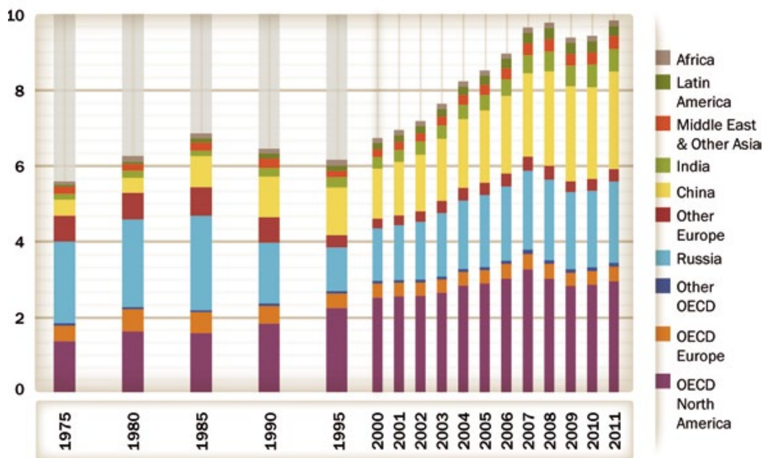

Source: IEA (2013a)

Fig. 6: **Railway passenger transport activity by geographic area, 1975-2011 (trillion pkm)**



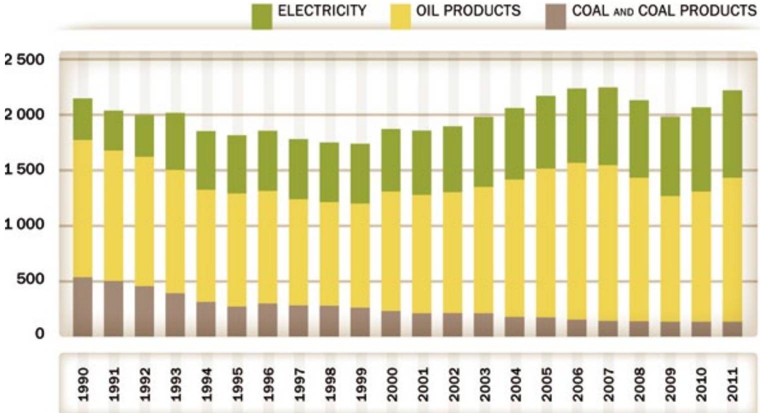

Source: Elaboration by IEA based on UIC (2013a)

Fig. 7: **Railway freight transport activity by geographic area, 1975-2011 (trillion tkm)**



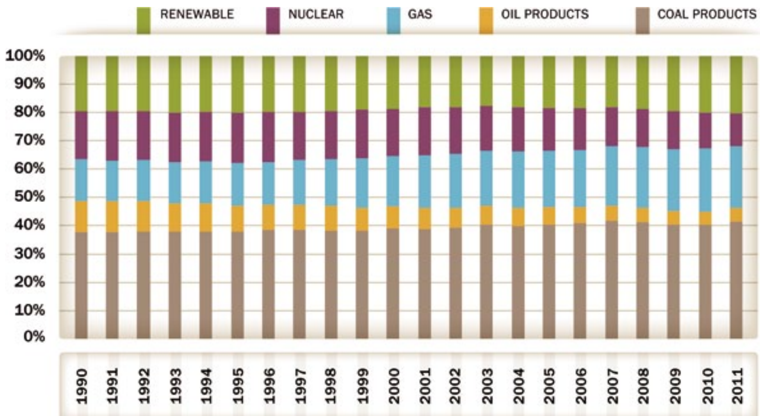

Source: Elaboration by IEA based on UIC (2013a)

Fig. 8: **Railway final energy consumption by fuel, 1990-2011 (PJ)**




Source: IEA (2013b)

Fig. 9: **World electricity production mix evolution, 1990-2011**



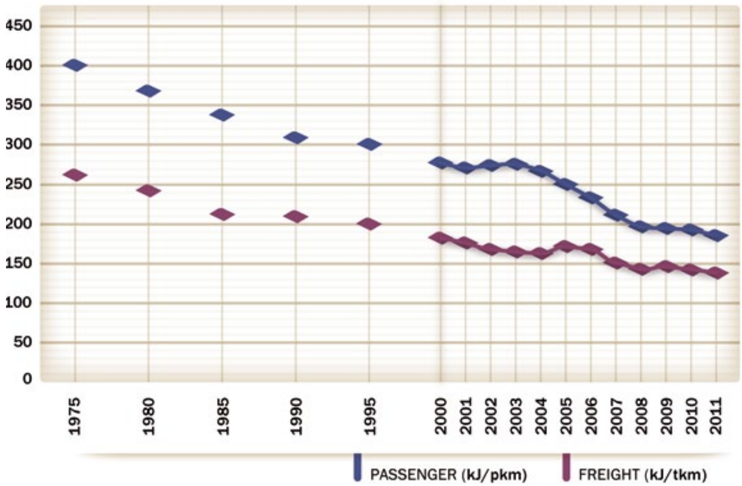

Source: IEA (2013b)

Table 2: **World electricity production mix, 2000-2011**

| | 2000 | 2011 |
|---|---|---|
| COAL PRODUCTS | 39% | 41% |
| OIL PRODUCTS | 8% | 5% |
| GAS | 18% | 22% |
| NUCLEAR | 17% | 12% |
| RENEWABLE | 18% | 20% |

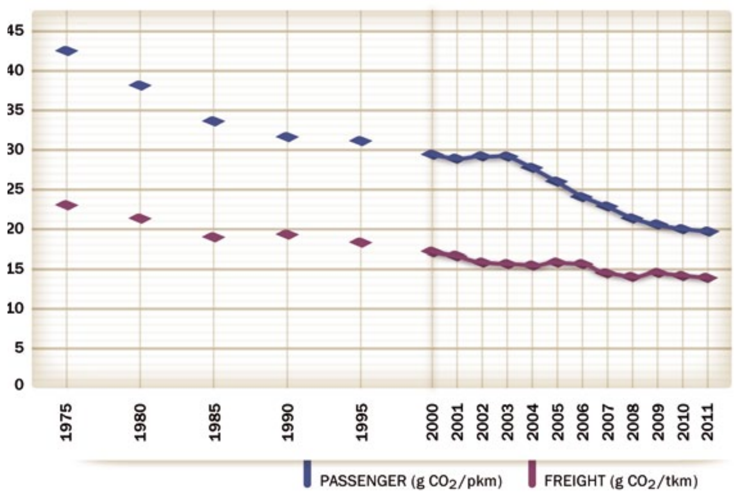
Source: IEA (2013b)

Fig. 10: **Railway specific energy consumption, 1975-2011**




Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2013a)

Fig. 11: **Railway specific $CO_2$ emissions, 1975-2011**




Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2013a)

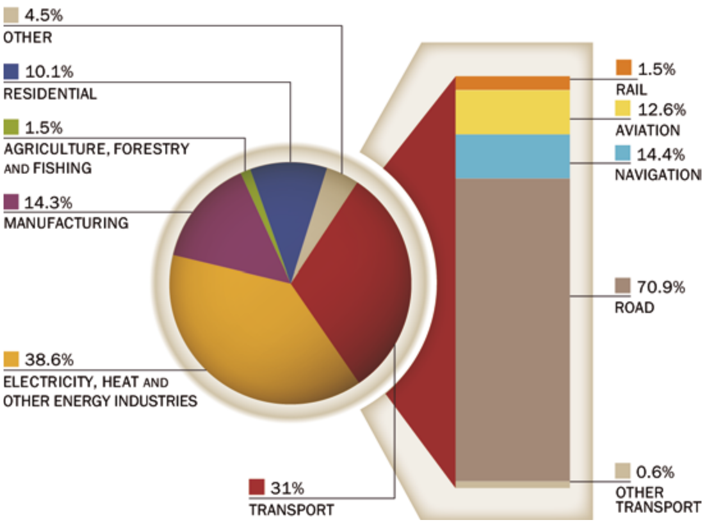
# Europe (EU27)

## Key Facts[1]

- Both passengers and freight transport activity increased by more than 20% between 1995 and 2011; in that period, rail activity increased by 5.5%, dropping its share from 8.7% to 7.5% (Fig. 17).
- Rail electric traction increased its share from 2005 to 2011, reaching 86% of train-km for freight and 81% for passenger service (Fig. 19).
- The transport sector increased its energy consumption by 29% from 1990 to 2011 (Fig. 15). In 2011 rail was responsible only of 0.6% of the total energy consumed (Fig. 14).
- Railway specific energy consumption dropped by 17% for passenger service and by 23% for freight in the 1990-2011 timeframe (Fig. 24).
- The use of diesel energy decreased by 31% in European railways between 1990 and 2011, while the use of electric energy increased by 14% (Fig. 21).
- In the split of energy sources used by railways, considering also diesel traction, railways in 2011 used 14% of renewables, meaning that railways have already met the 2020 EU target for transport sector (10% share of renewables) (Fig. 23 and Table 5).
- Transport emissions represented 31% of total emissions of which 1.5% were generated by rail (Fig. 12), with a rail market share of 8.5% (Table 3).
- Total transport emissions increased by 25% in the 1990-2011 period, while rail emissions dropped by 42% (Fig. 16).
- Railway specific $CO_2$ emissions dropped by 32% for passengers and 43% for freight between 1990 and 2011 (Fig. 25).

[1] If not otherwise specified, data is related to the year 2011

Fig. 12: **Share of $CO_2$ emissions from fuel combustion by sector, 2011**




Note: Emissions from rail electrical traction are reallocated from electricity, heat and other energy industries to the transport sector. See Methodology Notes.

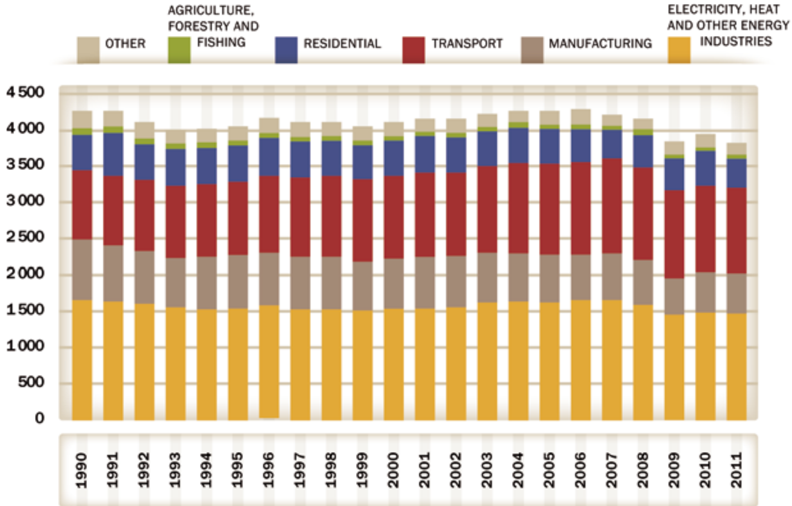
Source: Elaboration by Susdef based on UIC (2013b), IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

Table 3: **EU27 Transport modal share, 2011**

| | Passenger PKM | Freight TKM | Total TU |
|---|---|---|---|
| ROAD | 83.6% | 46.9% | 70.3% |
| AVIATION | 8.8% | 0.1% | 5.7% |
| NAVIGATION | 0.6% | 41.9% | 15.5% |
| RAIL | 7% | 11.1% | 8.5% |

Source: Elaboration by Susdef based on EC (2013) and UIC (2013a)

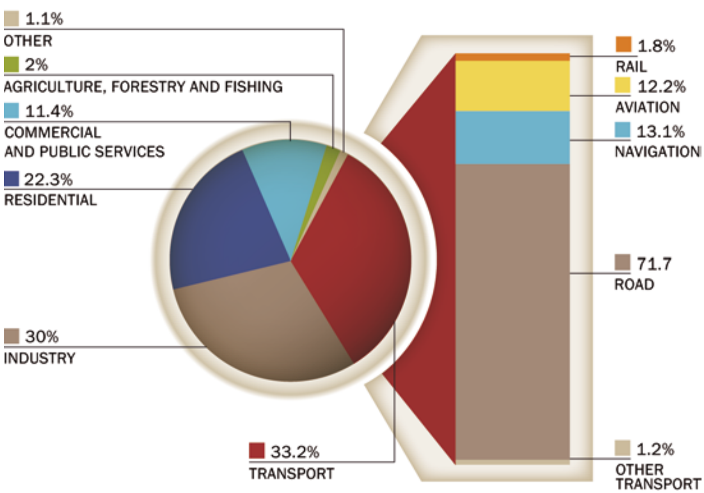
Fig. 13: **Total $CO_2$ emissions from fuel combustion by sector, 1990-2011 (million $tCO_2$)**




Note: Emissions from rail electrical traction are included in the transport sector. See Methodology Notes.

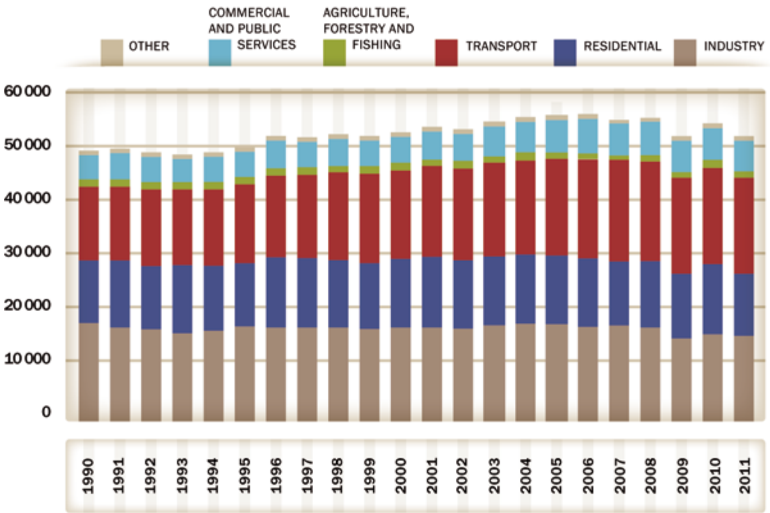
Source: Elaboration by Susdef based on IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

Fig. 14: **Share of final energy consumption by sector, 2011**



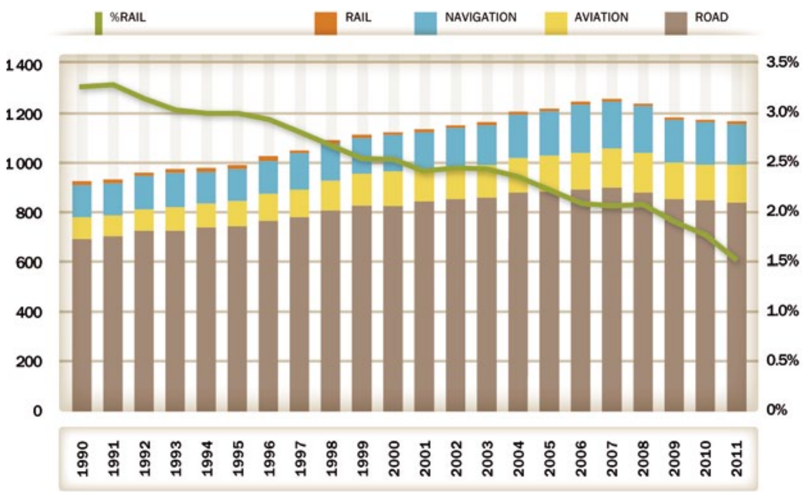

Source: Elaboration by Susdef based on IEA (2013b)

Fig. 15: **Total final energy consumption by sector, 1990-2011 (PJ)**



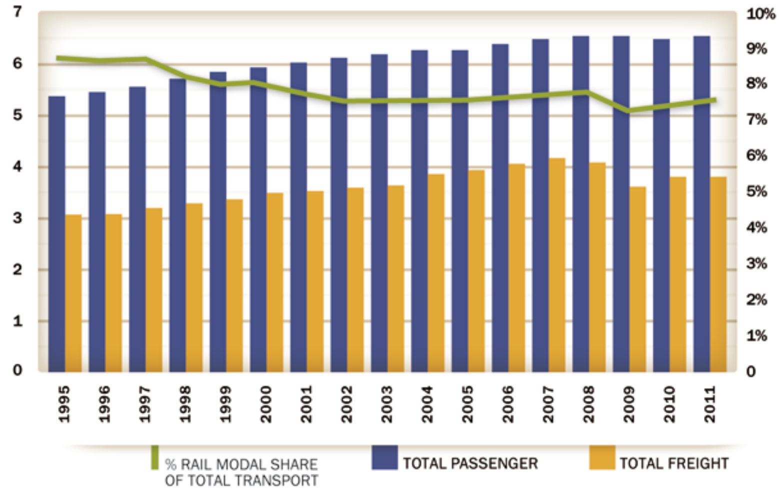

Source: Elaboration by Susdef based on IEA (2013b)

Fig. 16: **Transport sector $CO_2$ emissions by mode, 1990-2011 (million $tCO_2$ - left, share of rail over total - right)**



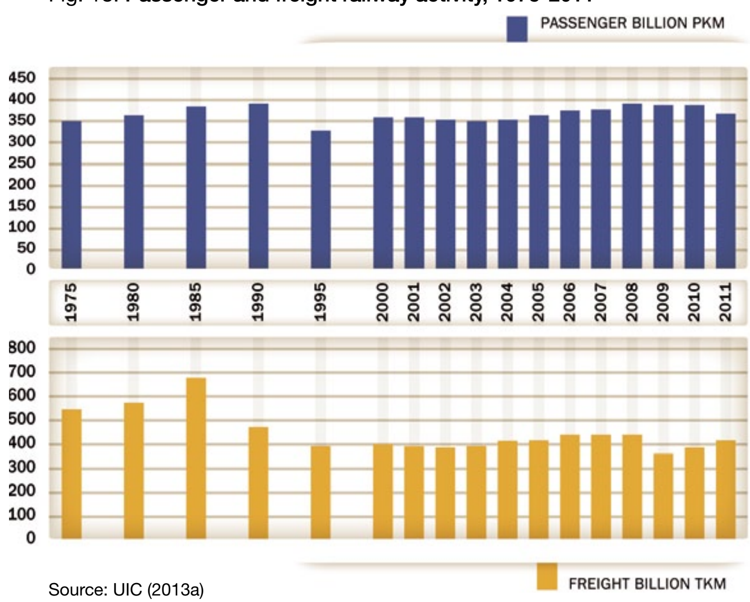

Source: IEA (2013a)

Fig. 17: **Passenger and freight transport activity – all modes, 1995-2011 (trillion pkm and tkm)**



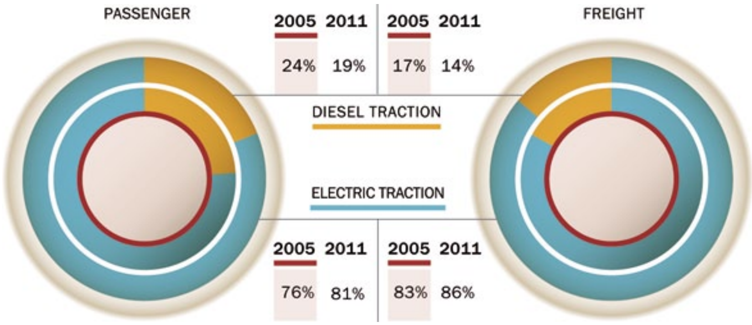

Source: Elaboration by Susdef based on EC (2013) and UIC (2013a)

Fig. 18: **Passenger and freight railway activity, 1975-2011**



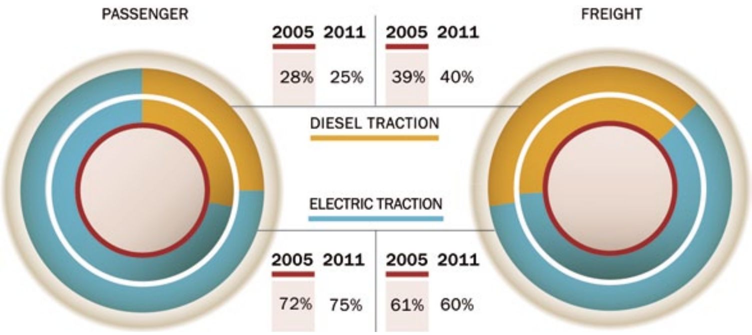

Source: UIC (2013a)

Fig. 19: **Passenger and freight railway activity (train-km) split by traction type, 2005 inside – 2011 outside**



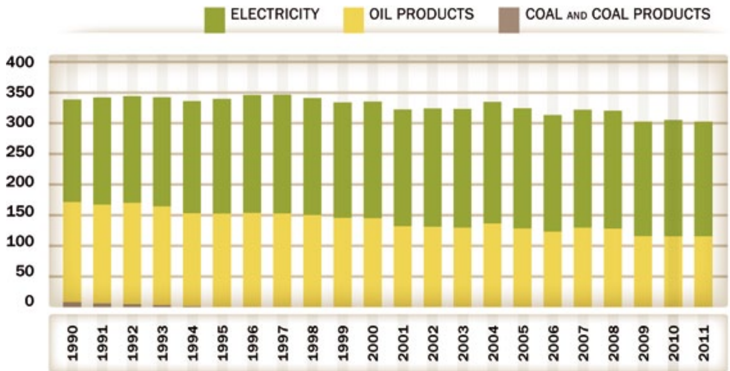

Source: Elaboration based on UIC (2013b)

Fig. 20: **Passenger and freight railway energy consumption split by traction type, 2005 inside – 2011 outside**



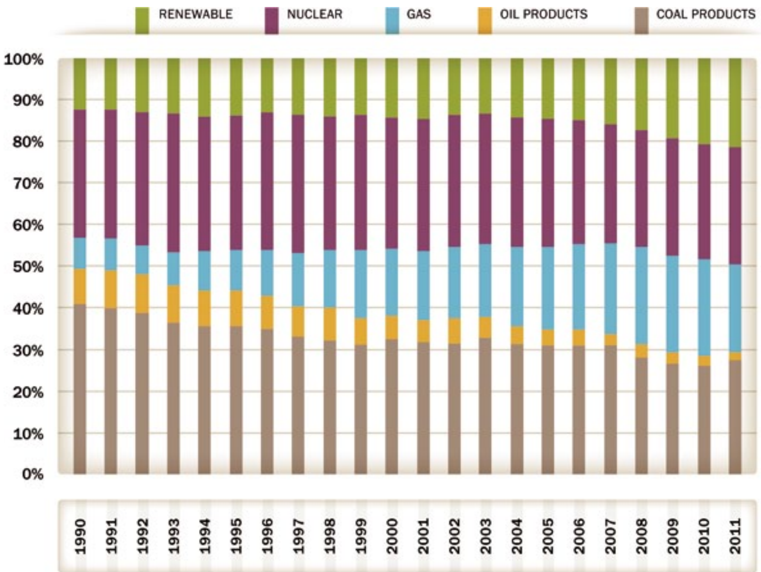

Source: Elaboration based on UIC (2013b)

Fig. 21: **Railway final energy consumption by fuel, 1990-2011 (PJ)**




Source: IEA (2013b)

Fig. 22: **EU27 electricity production mix evolution, 1990-2011**



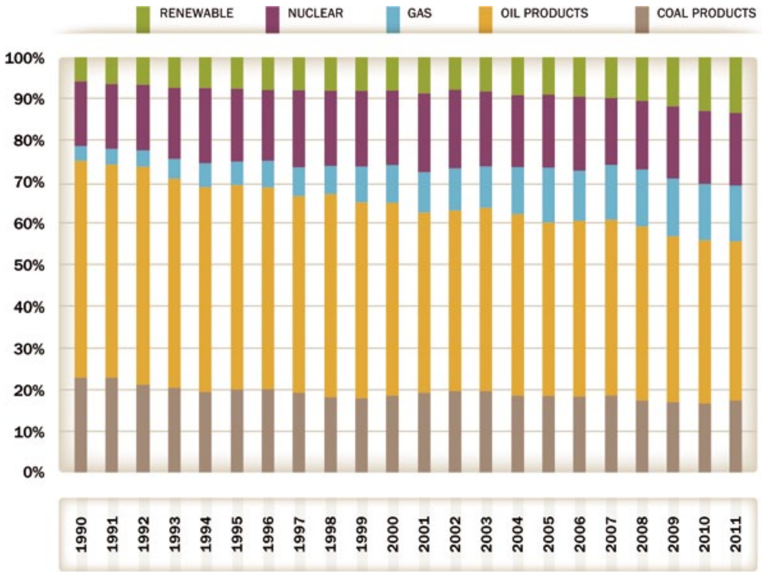

Source: IEA (2013b)

Table 4: **EU27 electricity production mix, 2000-2011**

| | 2000 | 2011 |
|---|---|---|
| COAL PRODUCTS | 32% | 27% |
| OIL PRODUCTS | 6% | 2% |
| GAS | 16% | 21% |
| NUCLEAR | 32% | 28% |
| RENEWABLE | 14% | 22% |

Source: IEA (2013b)

Fig. 23: **EU27 railway energy sources mix evolution, 1990-2011**



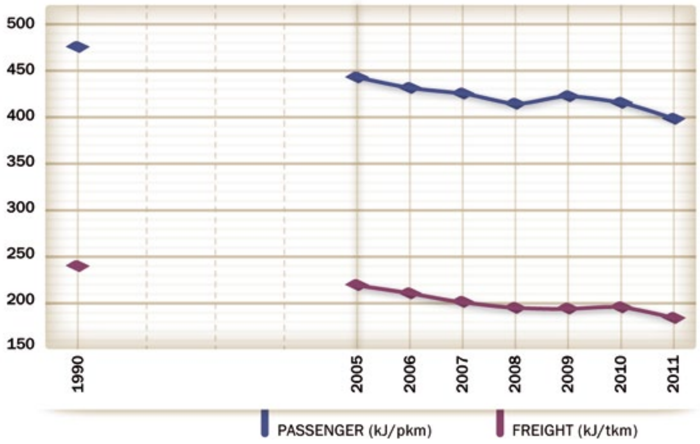

Source: Elaboration by Susdef based on IEA (2013b)

Table 5: **EU27 railway energy sources mix, 2000-2011**

| | 2000 | 2011 |
|---|---|---|
| COAL PRODUCTS | 18% | 17% |
| OIL PRODUCTS | 47% | 39% |
| GAS | 9% | 13% |
| NUCLEAR | 18% | 17% |
| RENEWABLE | 8% | 14% |

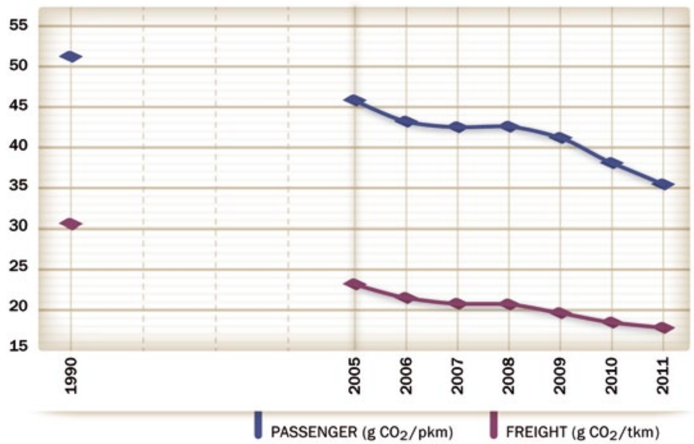
Source: Elaboration by Susdef based on IEA (2013b)

Fig. 24: **Railway specific energy consumption, 1990-2011**




Source: UIC (2013b)

Fig. 25**: Railway specific $CO_2$ emissions, 1990-2011**

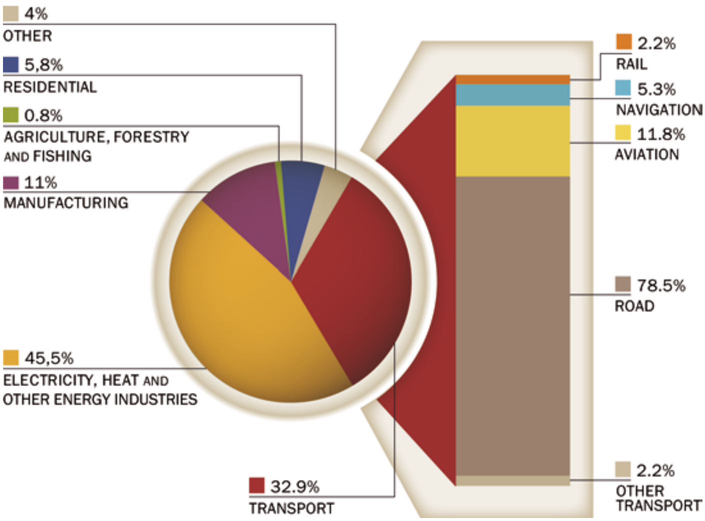



Source: UIC (2013b)

# USA



Fig. 26: **Share of $CO_2$ emissions from fuel combustion by sector, 2011**




Note: Emissions from rail electrical traction are reallocated from electricity, heat and other energy industries to the transport sector. See Methodology Notes.

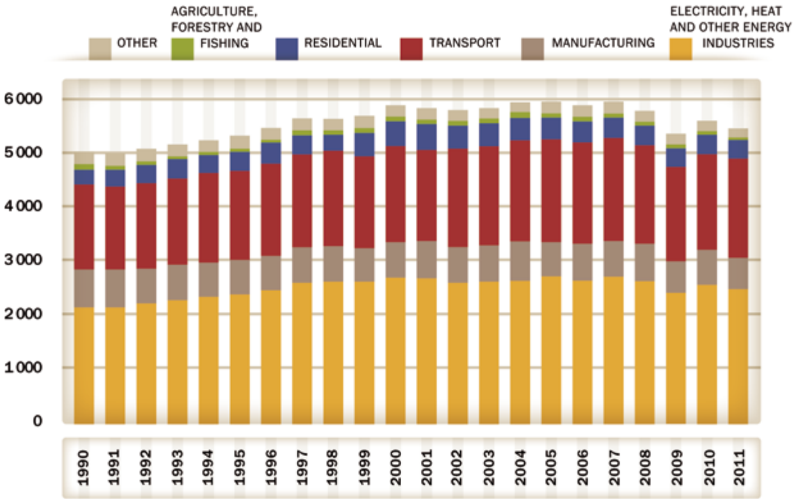
Source: Elaboration by Susdef based on IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

Table 6: **Transport modal share, 2011**

| | Passenger PKM | Freight TKM | Total TU |
|---|---|---|---|
| ROAD | 87.9% | 35.3% | 67.1% |
| AVIATION | 12% | 0.4% | 7.4% |
| NAVIGATION | 0% | 14.4% | 5.7% |
| RAIL | 0.1% | 49.9% | 19.8% |

Source: UIC (2013a) and NTS (2014)

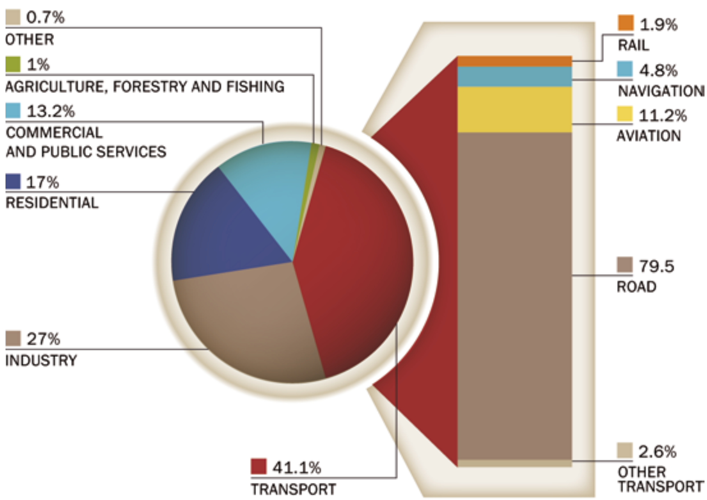
Fig. 27: **Total $CO_2$ emissions from fuel combustion by sector, 1990-2011 (million $tCO_2$)**




Note: Emissions from rail electrical traction are included in the transport sector. See Methodology Notes.

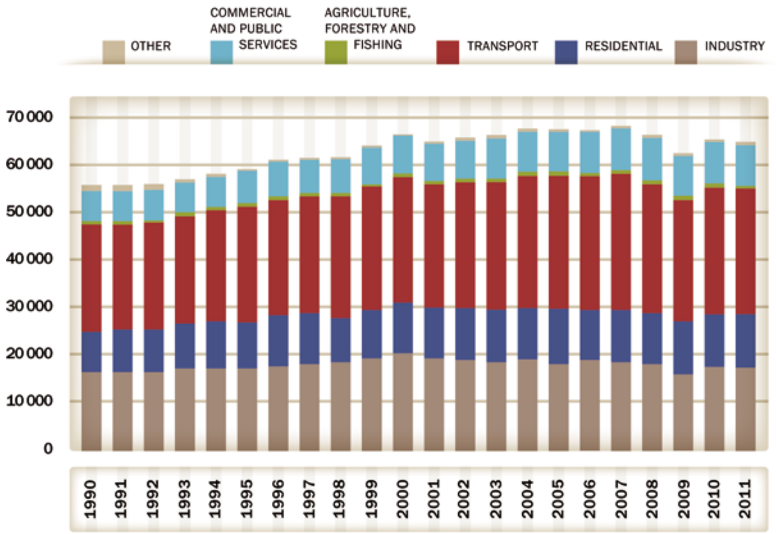
Source: Elaboration by Susdef based on IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

Fig. 28: **Share of final energy consumption by sector, 2011**



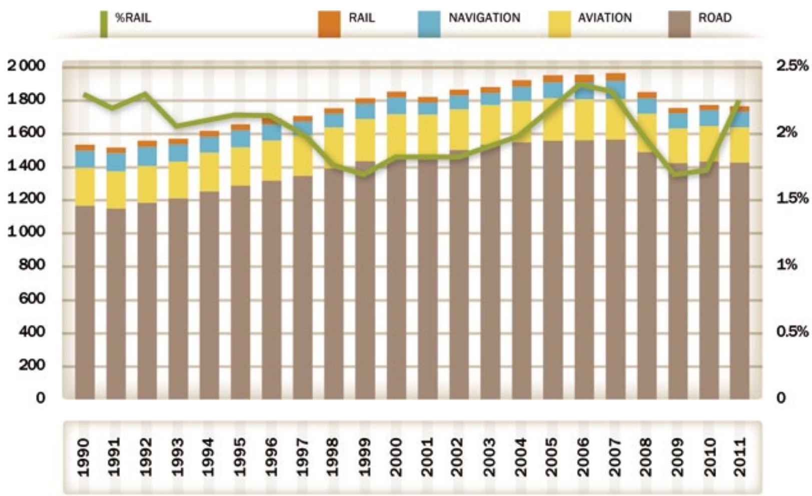

Source: Elaboration by Susdef based on IEA (2013b)

Fig. 29: **Total final energy consumption by sector, 1990-2011 (PJ)**



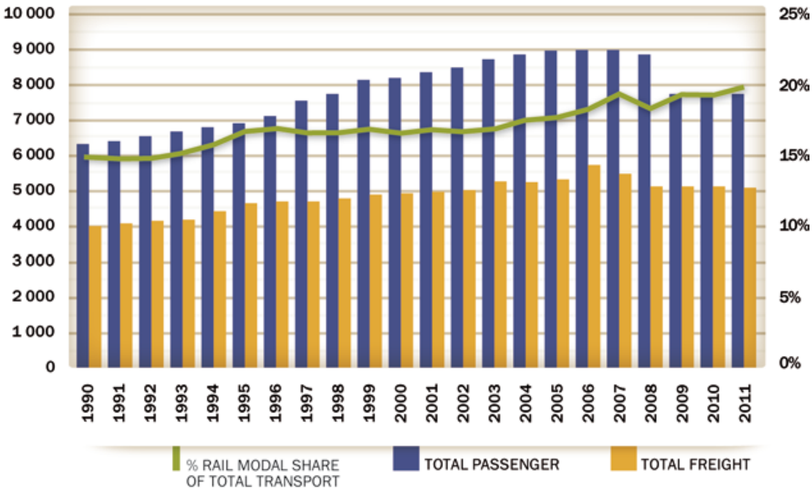

Source: Elaboration by Susdef based on IEA (2013b)

Fig. 30: **Transport sector $CO_2$ emissions by mode, 1990-2011 (million $tCO_2$ - left, share of rail over total - right)**



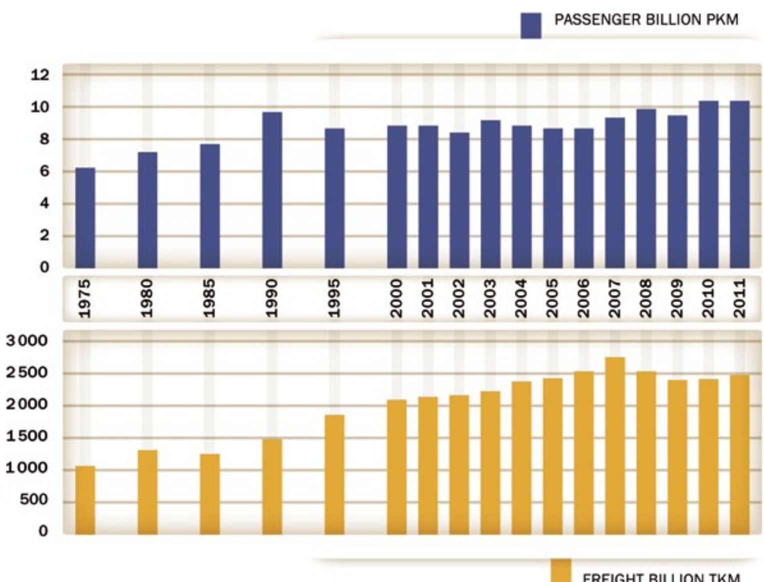

Source: IEA (2013a)

Fig. 31: **Passenger and freight transport activity - all modes, 1990-2011 (billion pkm and tkm)**



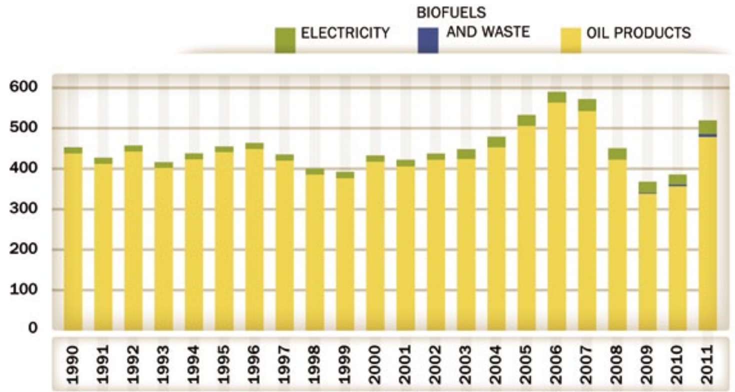

Source: Elaboration by IEA based on UIC (2013a) and NTS (2014)

Fig. 32: **Passenger and freight railway activity, 1975-2011**



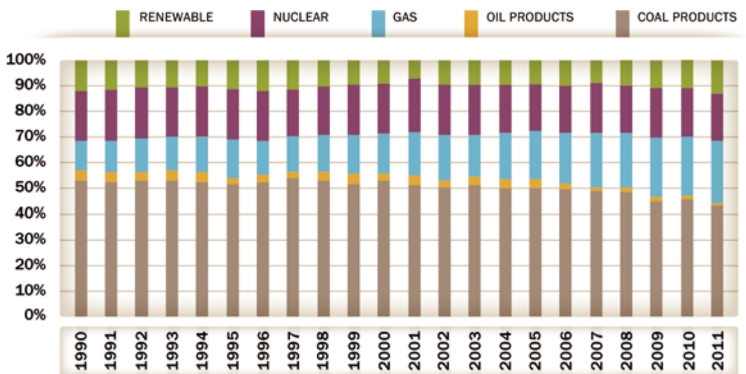

Source: Elaboration by IEA based on UIC (2013a)

Fig. 33: **Railway final energy consumption by fuel, 1990-2011 (PJ)**




Source: IEA (2013b)

Fig. 34: **National electricity production mix evolution, 1990-2011**



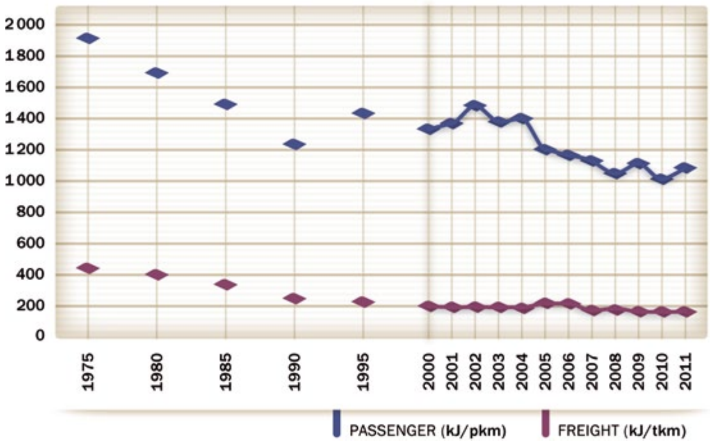

Source: IEA (2013b)

Table 7: **National electricity production mix, 2000-2011**

| | 2000 | 2011 |
|---|---|---|
| COAL PRODUCTS | 53% | 43% |
| OIL PRODUCTS | 3% | 1% |
| GAS | 16% | 24% |
| NUCLEAR | 20% | 19% |
| RENEWABLE | 8% | 13% |

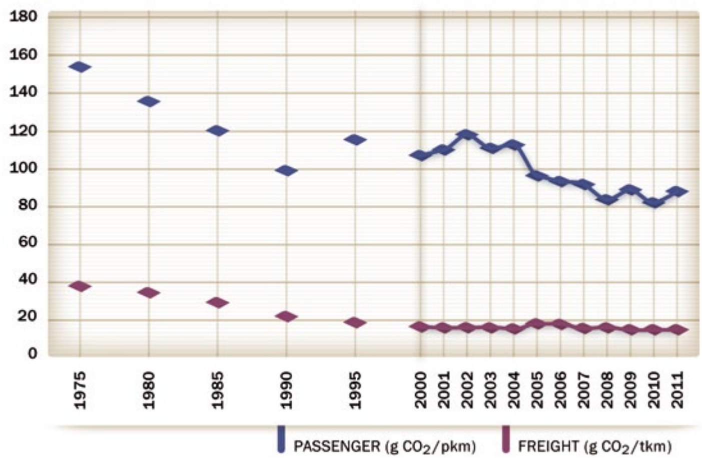
Source: IEA (2013b)

Fig. 35: **Railway specific energy consumption, 1975-2011**




Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2013a)

Fig. 36: **Railway specific $CO_2$ emissions, 1975-2011**

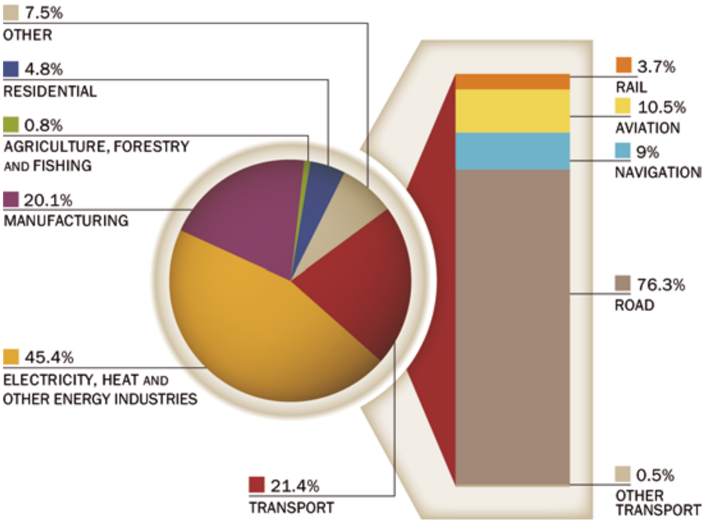



Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2013a)

# Japan



Fig. 37: **Share of $CO_2$ emissions from fuel combustion by sector, 2011**




Note: Emissions from rail electrical traction are reallocated from electricity, heat and other energy industries to the transport sector. See Methodology Notes.

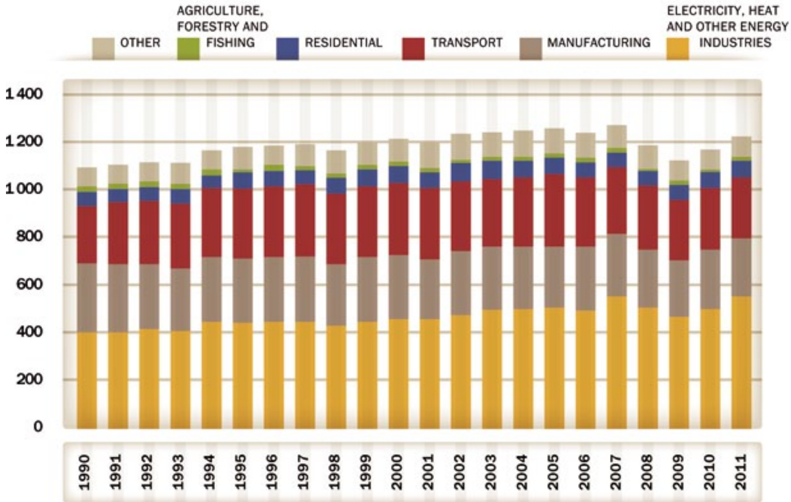
Source: Elaboration by Susdef based on IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

Table 8: **Transport modal share, 2011**

| | Passenger PKM | Freight TKM | Total TU |
|---|---|---|---|
| ROAD | 73.6% | 61.4% | 70% |
| AVIATION | 5.8% | 0.2% | 4.1% |
| NAVIGATION | 0.2% | 34.4% | 10.4% |
| RAIL | 20.4% | 4% | 15.5% |

Source: Elaboration by IEA based on OECD (2014), UIC (2013a), JSB (2013) and JMLIT (2014)

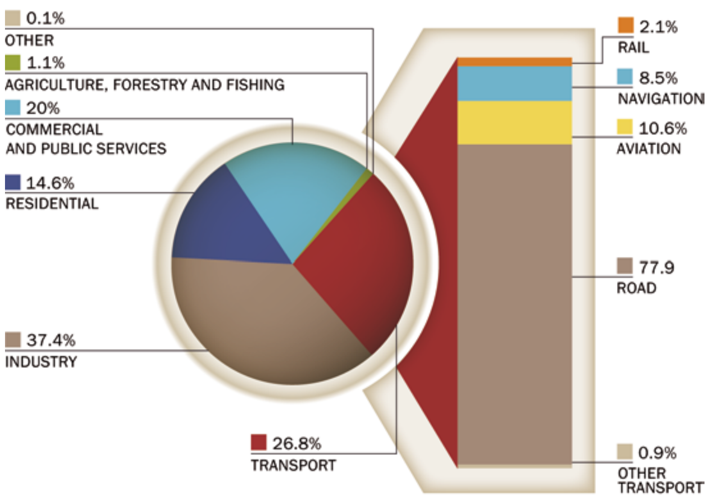
Fig. 38: **Total $CO_2$ emissions from fuel combustion by sector, 1990-2011 (million $tCO_2$)**




Note: Emissions from rail electrical traction are included in the transport sector.
See Methodology Notes.

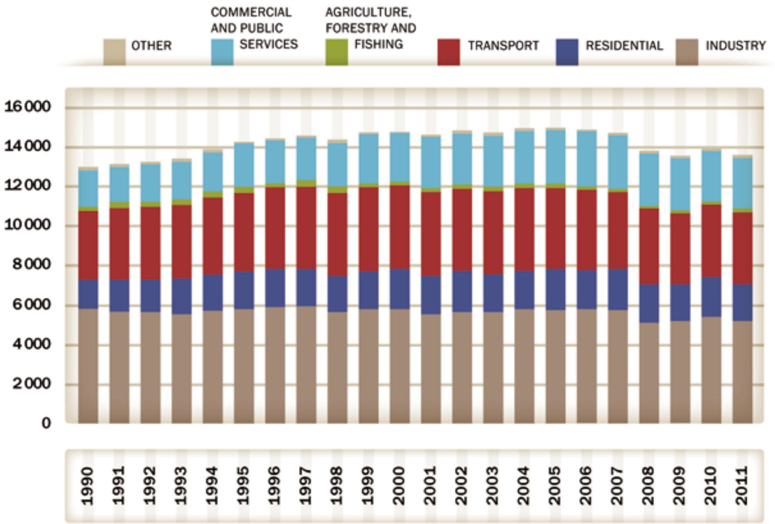
Source: Elaboration by Susdef based on IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

Fig. 39: **Share of final energy consumption by sector, 2011**



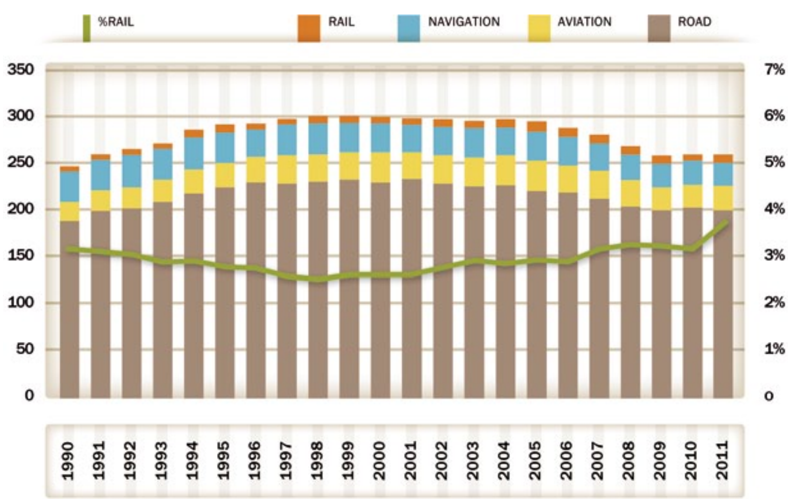

Source: Elaboration by Susdef based on IEA (2013b)

Fig. 40: **Total final energy consumption by sector, 1990-2011 (PJ)**



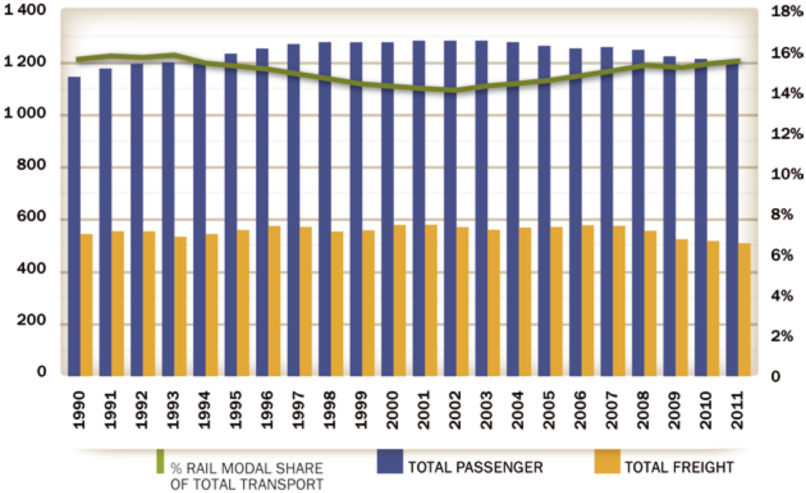

Source: Elaboration by Susdef based on IEA (2013b)

Fig. 41: **Transport sector $CO_2$ emissions by mode, 1990-2011 (million $tCO_2$ - left, share of rail over total - right)**



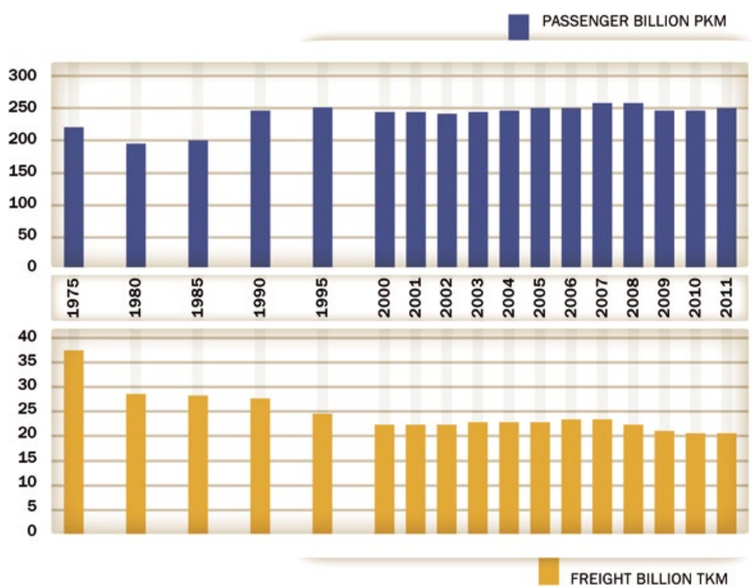

Source: IEA (2013a)

Fig. 42: **Passenger and freight transport activity – all modes, 1990-2011 (billion pkm and tkm)**



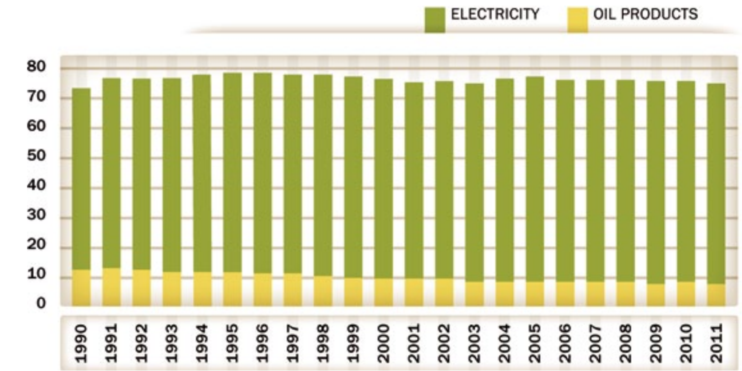

Source: Elaboration by IEA based on OECD (2014), UIC (2013a), JSB (2013) and JMLIT (2014)

Fig. 43: **Passenger and freight railway activity, 1975-2011**



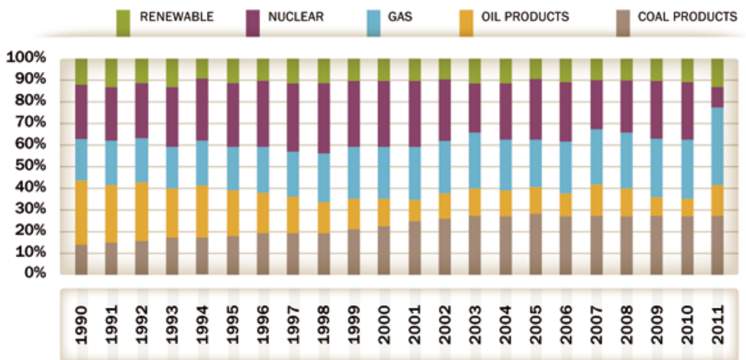

Source: Elaboration by IEA based on UIC (2013a)

Fig. 44: **Railway final energy consumption by fuel, 1990-2011 (PJ)**




Source: IEA (2013b)

Fig. 45: **National electricity production mix evolution, 1990-2011**



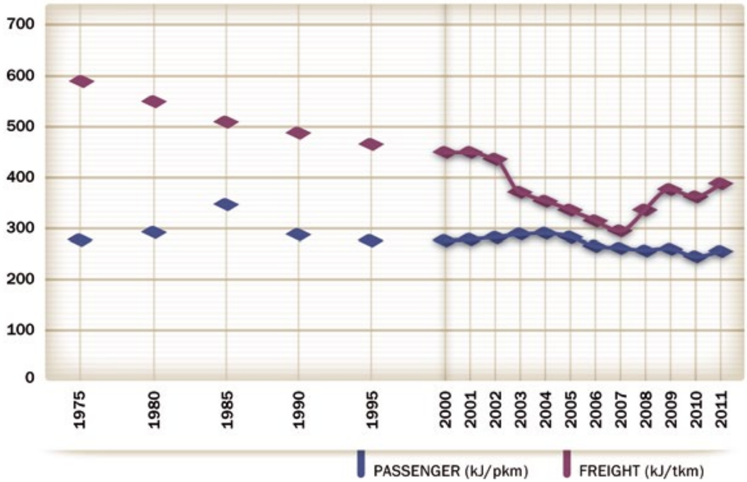

Source: IEA (2013b)

Table 9: **National electricity production mix, 2000-2011**

| | 2000 | 2011 |
|---|---|---|
| COAL PRODUCTS | 22% | 27% |
| OIL PRODUCTS | 13% | 15% |
| GAS | 24% | 36% |
| NUCLEAR | 31% | 9% |
| RENEWABLE | 10% | 13% |

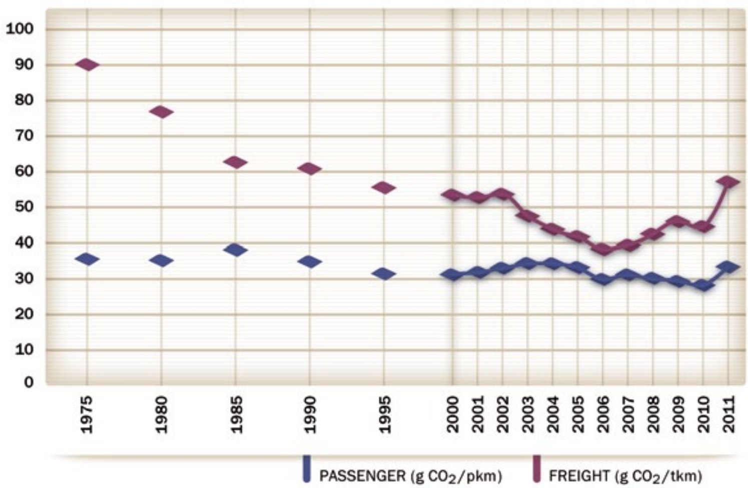
Source: IEA (2013b)

Fig. 46: **Railway specific energy consumption, 1975-2011**




Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2013a)

Fig. 47: **Railway specific $CO_2$ emissions, 1975-2011**

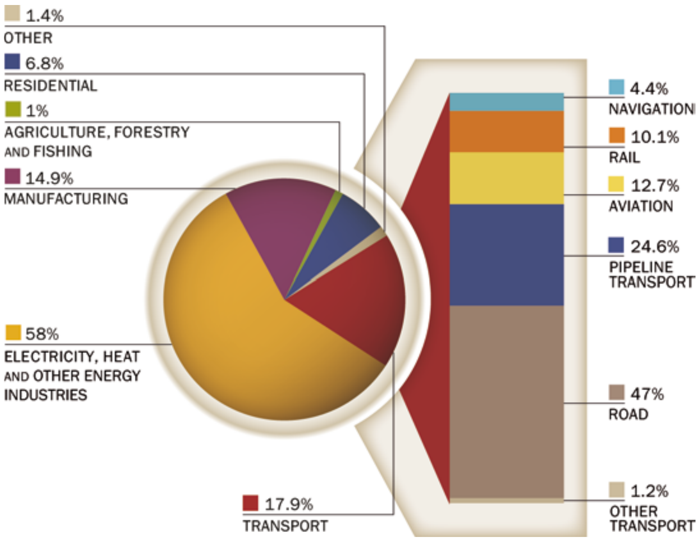



Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2013a)

# Russian Federation



Fig. 48: **Share of $CO_2$ emissions from fuel combustion by sector, 2011**




Note: Emissions from rail electrical traction are reallocated from electricity, heat and other energy industries to the transport sector. See Methodology Notes.

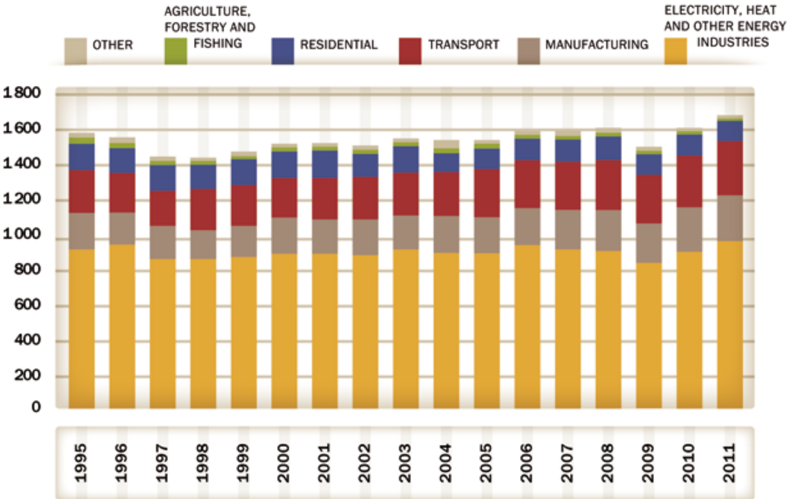
Source: Elaboration by Susdef based on IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

Table 10: **Transport modal share, 2011**

| | Passenger PKM | Freight TKM | Total TU |
|---|---|---|---|
| ROAD | 31.1% | 9.2% | 12.6% |
| AVIATION | 37.4% | 0.2% | 6% |
| NAVIGATION | 0.1% | 2.5% | 2.1% |
| RAIL | 31.4% | 88.1% | 79.3% |

Source: OECD (2014), UIC (2013a) and Rosstat (2014)

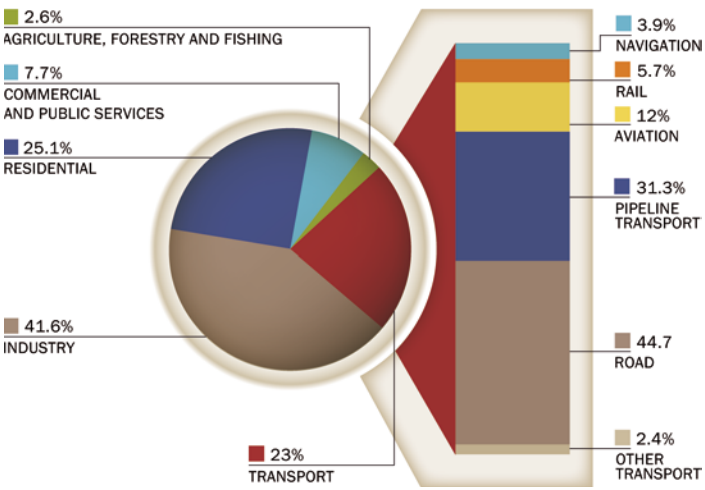
Fig. 49: **Total $CO_2$ emissions from fuel combustion by sector, 1995-2011 (million $tCO_2$)**




Note: Emissions from rail electrical traction are included in the transport sector. See Methodology Notes.

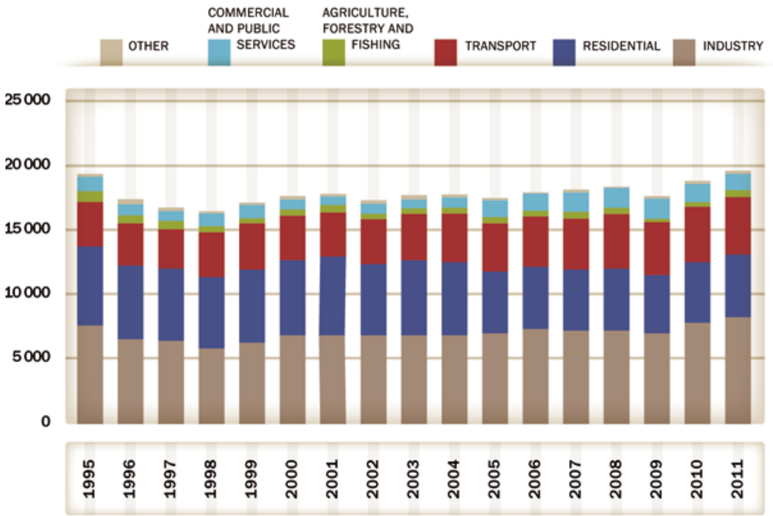
Source: Elaboration by Susdef based on IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

Fig. 50: **Share of final energy consumption by sector, 2011**



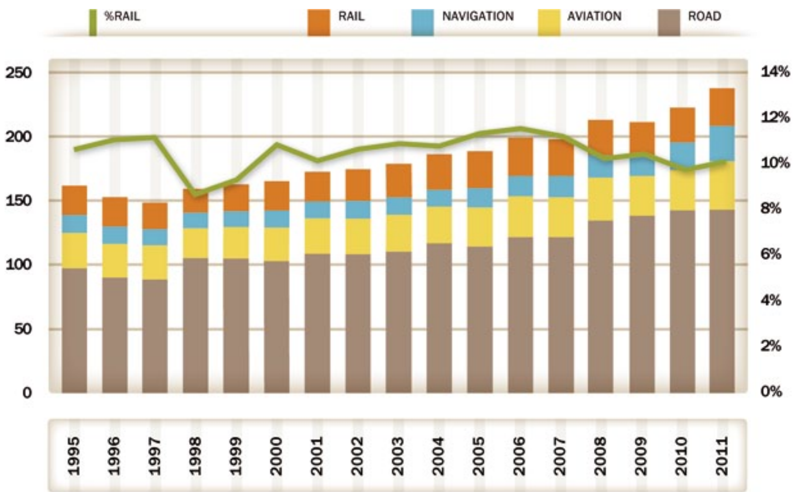

Source: Elaboration by Susdef based on IEA (2013b)

Fig. 51: **Total final energy consumption by sector, 1995-2011 (PJ)**



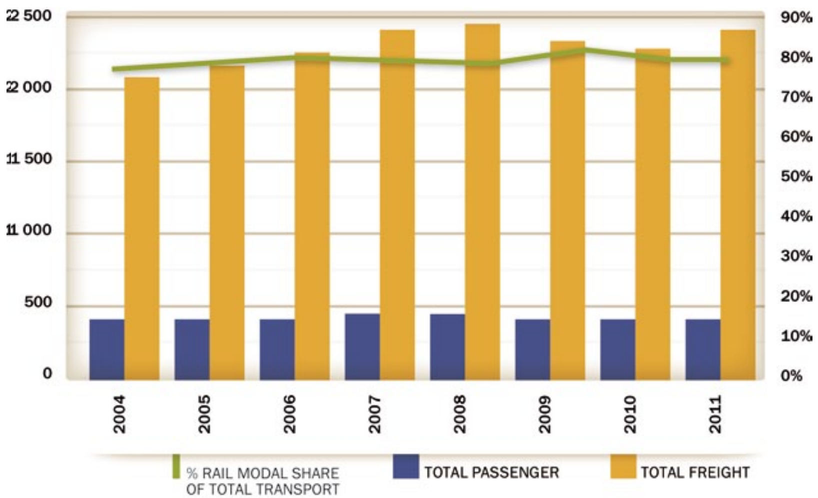

Source: Elaboration by Susdef based on IEA (2013b)

Fig. 52: **Transport sector $CO_2$ emissions by mode, 1995-2011 (million $tCO_2$ - left, share of rail over total - right)**



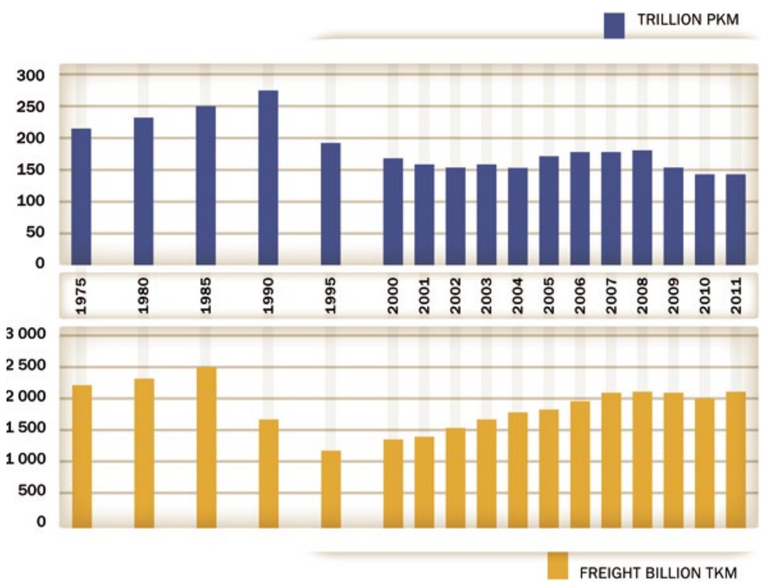

Source: IEA (2013a)

Fig. 53: **Passenger and freight transport activity – all modes, 2004-2011 (billion pkm and tkm)**



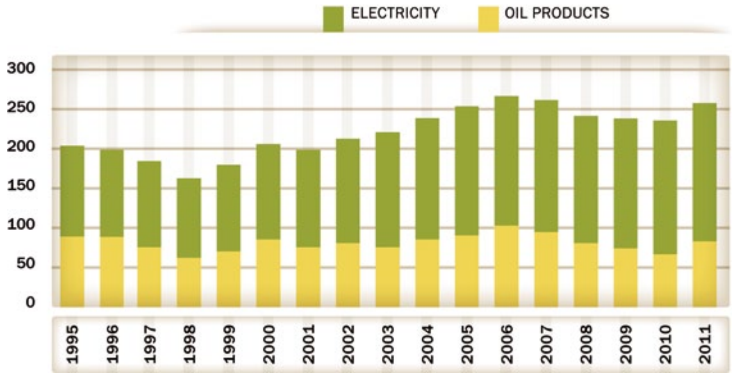

Source: OECD (2014), UIC (2013a) and Rosstat (2014)

Fig. 54: **Passenger and freight railway activity, 1975-2011**



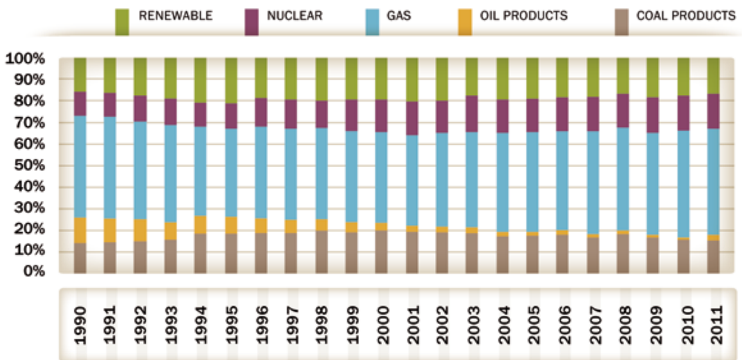

Source: Elaboration by IEA based on UIC (2013a)

Fig. 55: **Railway final energy consumption by fuel, 1990-2011 (PJ)**




Source: IEA (2013b)

Fig. 56: **National electricity production mix evolution, 1990-2011**



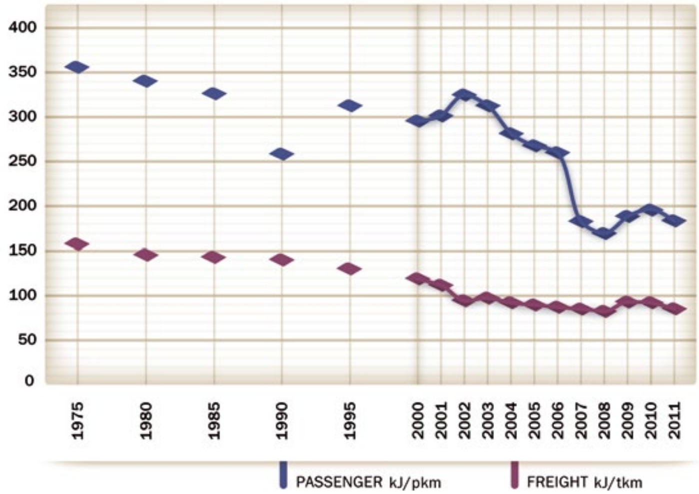

Source: IEA (2013b)

Table 11: **National electricity production mix, 2000-2011**

| | 2000 | 2011 |
|---|---|---|
| COAL PRODUCTS | 20% | 16% |
| OIL PRODUCTS | 4% | 3% |
| GAS | 42% | 49% |
| NUCLEAR | 15% | 16% |
| RENEWABLE | 19% | 16% |

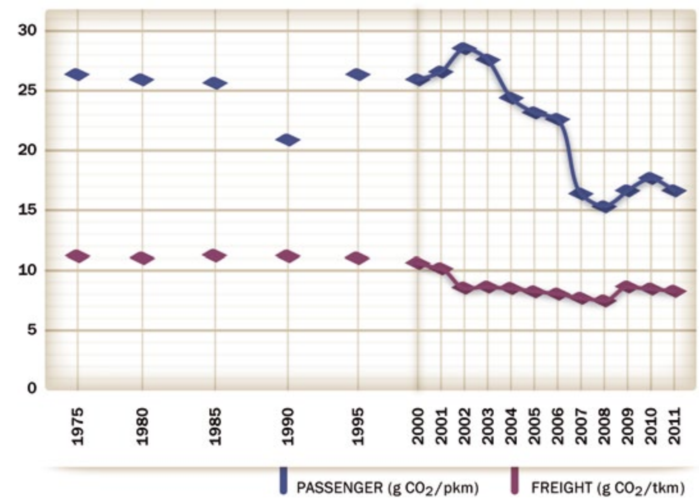
Source: IEA (2013b)

Fig. 57: **Railway specific energy consumption, 1975-2011**




Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2013a)

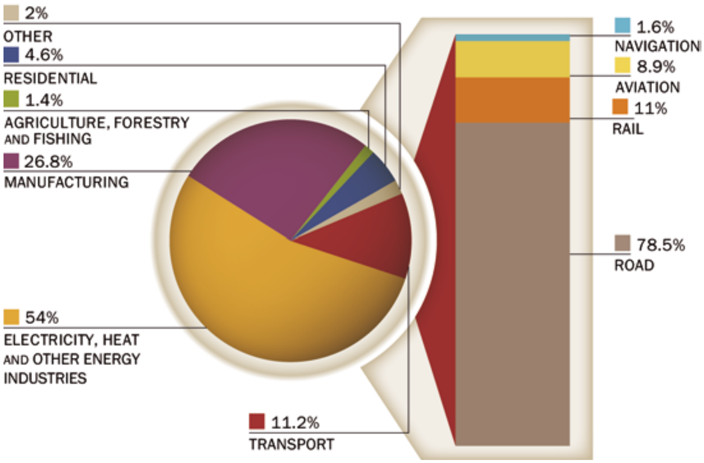
Fig. 58: **Railway specific $CO_2$ emissions, 1975-2011**




Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2013a)

# India

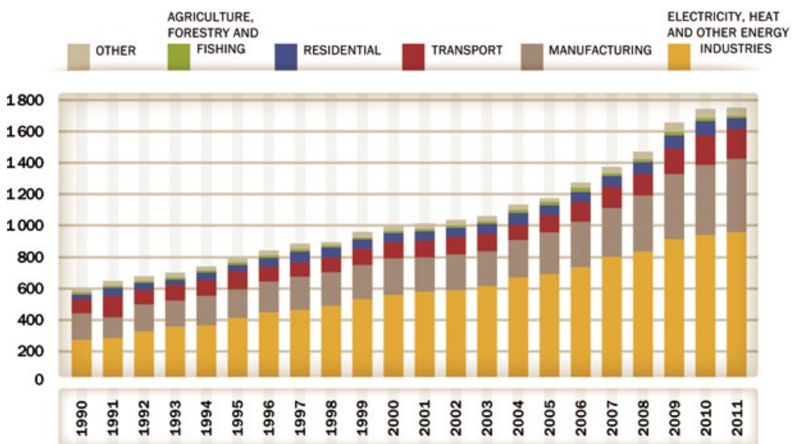
Fig. 59: **Share of $CO_2$ emissions from fuel combustion by sector, 2011**




Note: Emissions from rail electrical traction are reallocated from electricity, heat and other energy industries to the transport sector. See Methodology Notes.

Source: Elaboration by Susdef based on IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

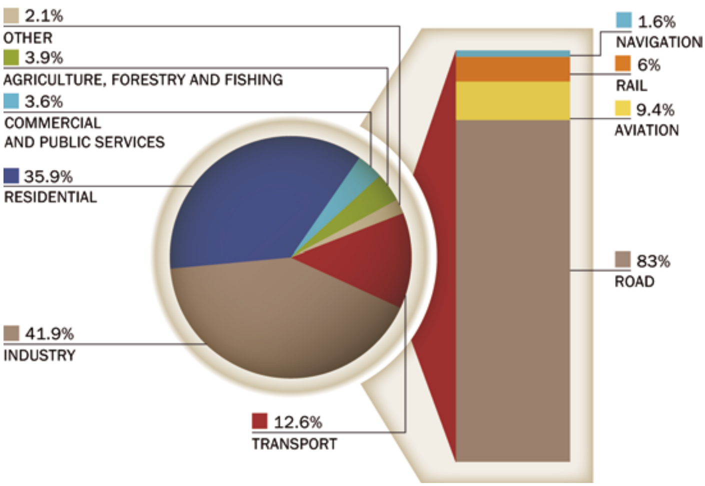
Fig. 60: **Total $CO_2$ emissions from fuel combustion by sector, 1990-2011 (million $tCO_2$)**




Note: Emissions from rail electrical traction are included in the transport sector. See Methodology Notes.

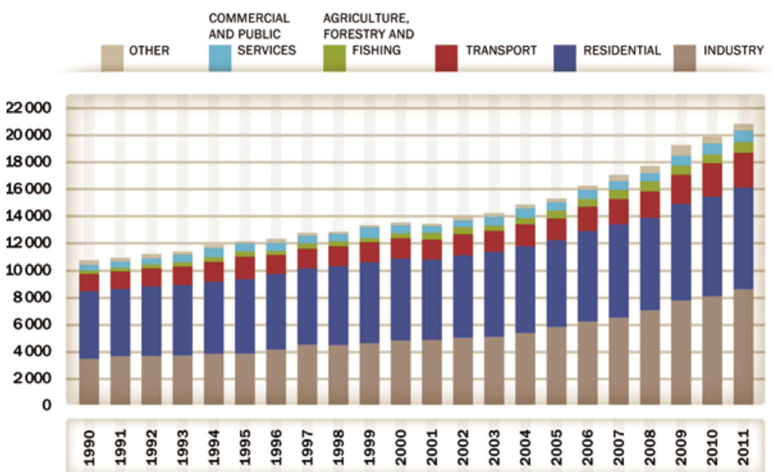
Source: Elaboration by Susdef based on IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

Fig. 61: **Share of final energy consumption by sector, 2011**



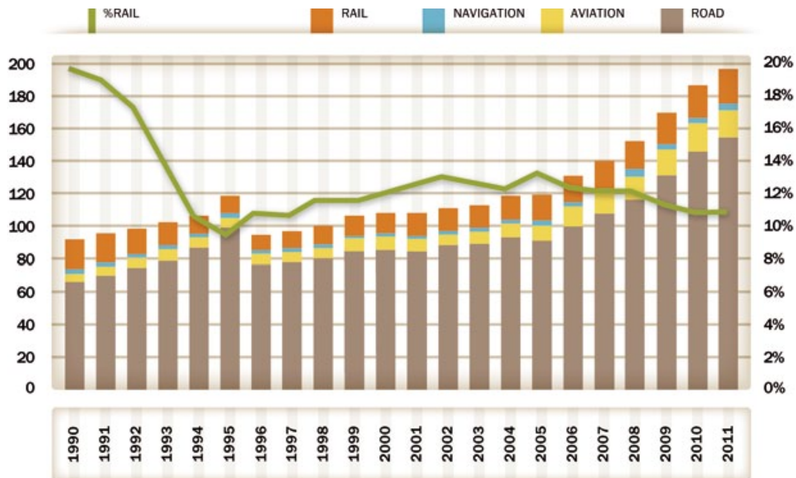

Source: Elaboration by Susdef based on IEA (2013b)

Fig. 62: **Total final energy consumption by sector, 1990-2011 (PJ)**



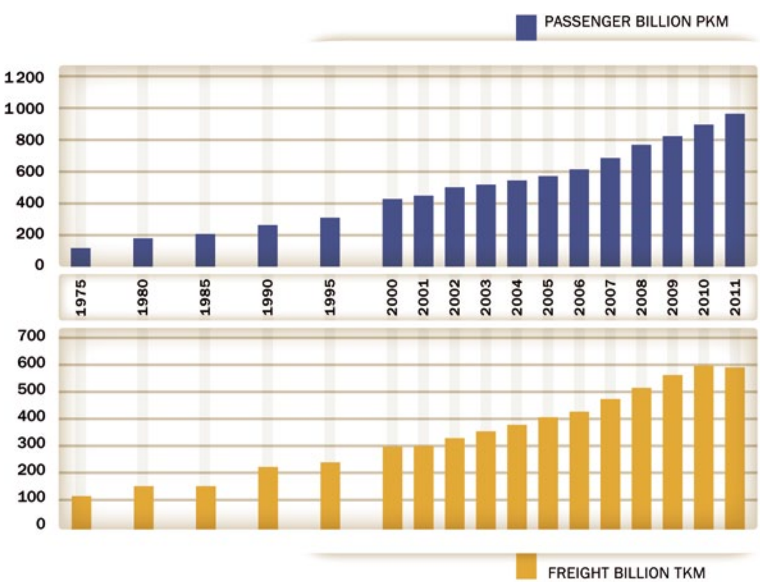

Source: Elaboration by Susdef based on IEA (2013b)

Fig. 63: **Transport sector $CO_2$ emissions by mode, 1990-2011 (million $tCO_2$ - left, share of rail over total - right)**



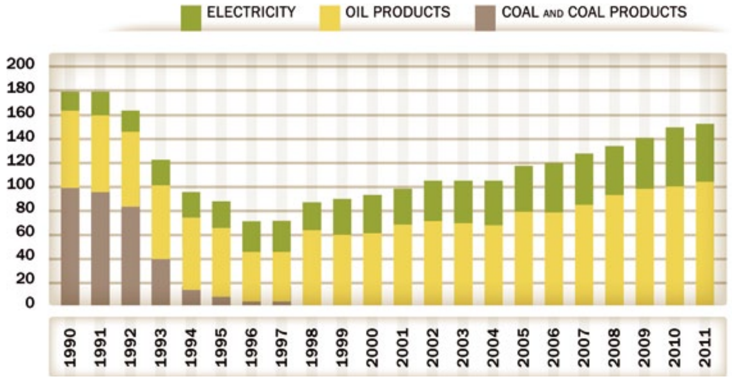

Source: IEA (2013a)

Fig. 64: **Passenger and freight railway activity, 1975-2011**



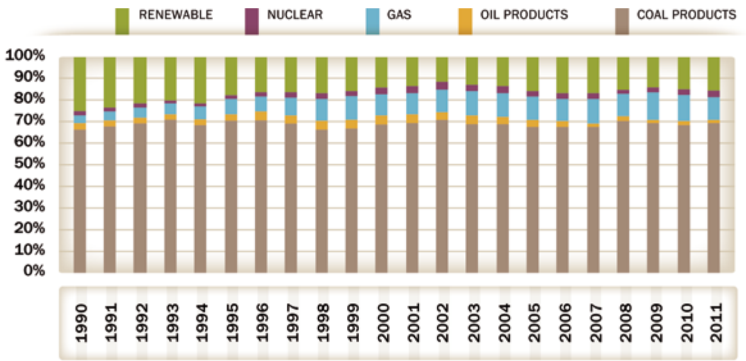

Source: Elaboration by IEA based on UIC (2013a)

Fig. 65: **Railway final energy consumption by fuel, 1990-2011 (PJ)**




Source: IEA (2013b)

Fig. 66: **National electricity production mix evolution, 1990-2011**



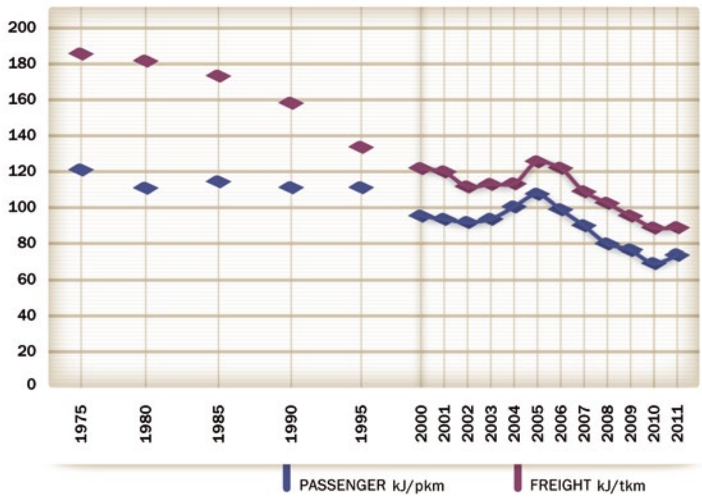

Source: IEA (2013b)

Table 12: **National electricity production mix, 2000-2011**

| | 2000 | 2011 |
|---|---|---|
| COAL PRODUCTS | 69% | 70% |
| OIL PRODUCTS | 4% | 1% |
| GAS | 10% | 11% |
| NUCLEAR | 3% | 3% |
| RENEWABLE | 14% | 15% |

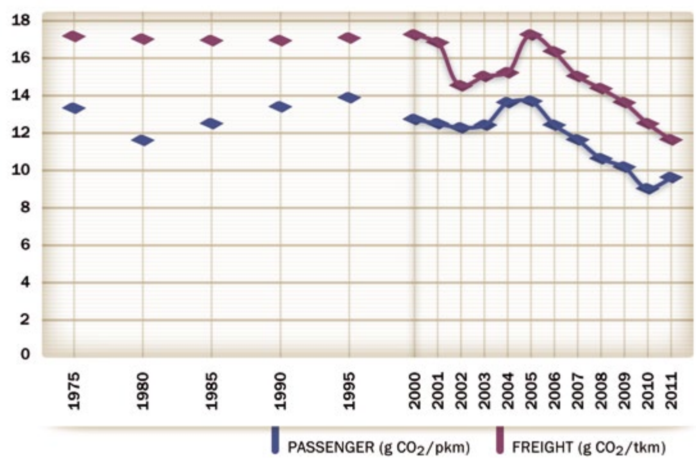
Source: IEA (2013b)

Fig. 67: **Railway specific energy consumption, 1975-2011**




Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2013a)

Fig. 68: **Railway specific $CO_2$ emissions, 1975-2011**

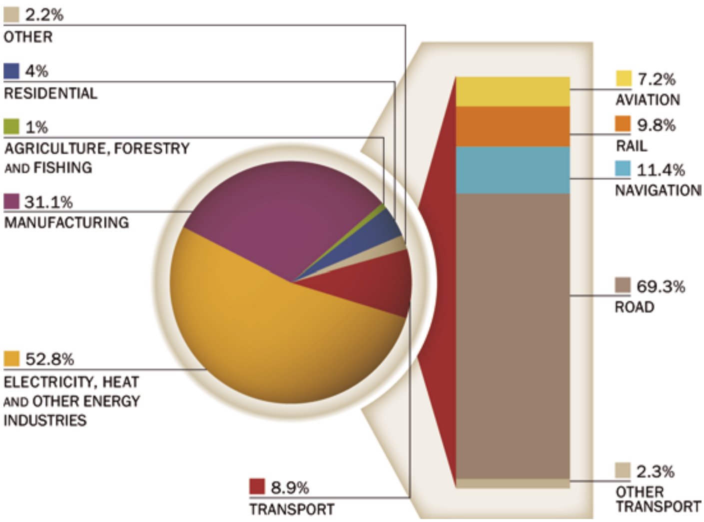



Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2013a)

# People's Republic of China



Fig. 69: **Share of $CO_2$ emissions from fuel combustion by sector, 2011**




Note: Emissions from rail electrical traction are reallocated from electricity, heat and other energy industries to the transport sector. See Methodology Notes.

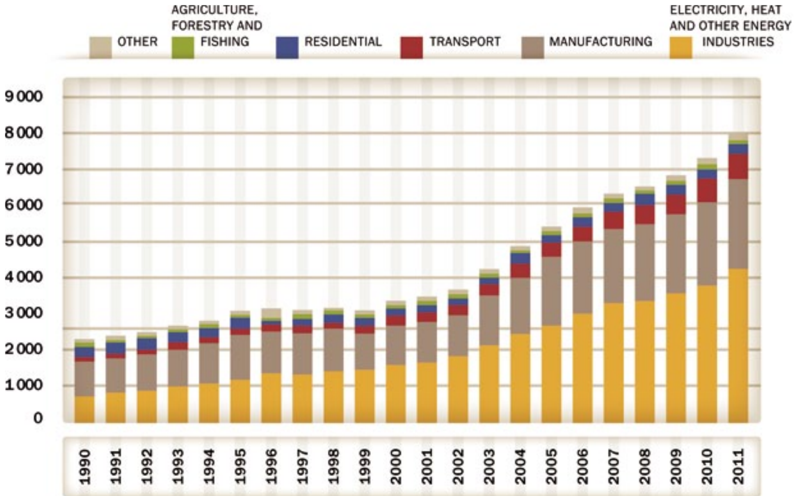
Source: Elaboration by Susdef based on IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

Table 13: **Transport modal share, 2011**

| | Passenger PKM | Freight TKM | Total TU |
|---|---|---|---|
| ROAD | 54.1% | 32.9% | 36.4% |
| NAVIGATION | 0.2% | 48.2% | 40.3% |
| RAIL | 31% | 18.8% | 20.8% |
| AVIATION | 14.7% | 0.1% | 2.5% |

Source: UIC (2013a) and CNBS (2013)

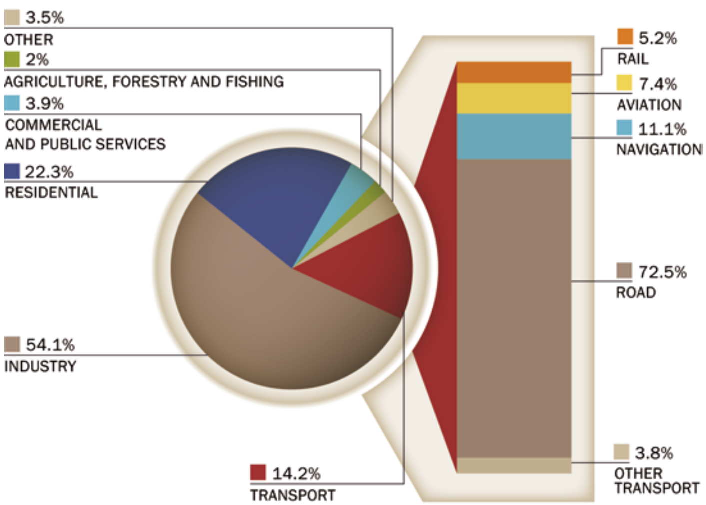
Fig. 70: **Total $CO_2$ emissions from fuel combustion by sector, 1990-2011 (million $tCO_2$)**




Note: Emissions from rail electrical traction are included in the transport sector. See Methodology Notes.

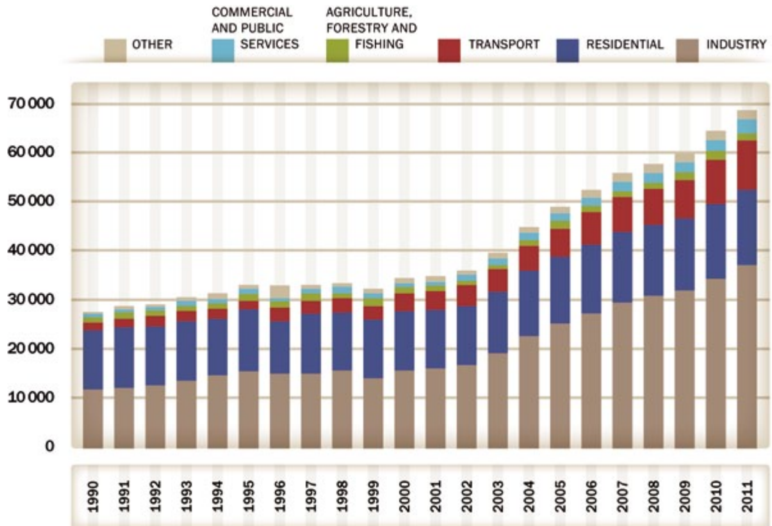
Source: Elaboration by Susdef based on IEA (2013a), IEA (2013b), IPCC (2006) and IEA (2008)

Fig. 71: **Share of final energy consumption by sector, 2011**



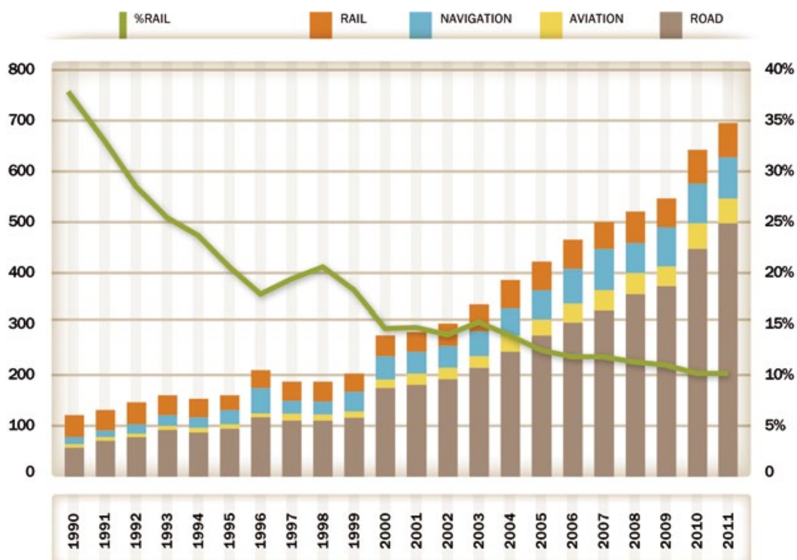

Source: Elaboration by Susdef based on IEA (2013b)

Fig. 72: **Total final energy consumption by sector, 1990-2011 (PJ)**



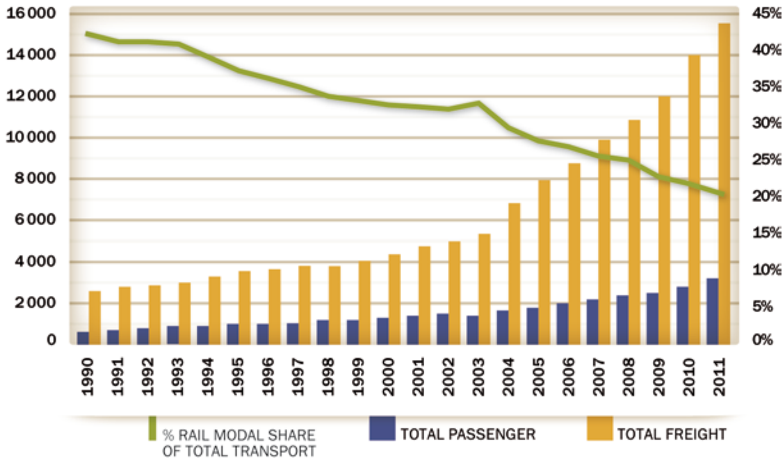

Source: Elaboration by Susdef based on IEA (2013b)

Fig. 73: **Transport sector $CO_2$ emissions by mode, 1990-2011 (million $tCO_2$ - left, share of rail over total - right)**



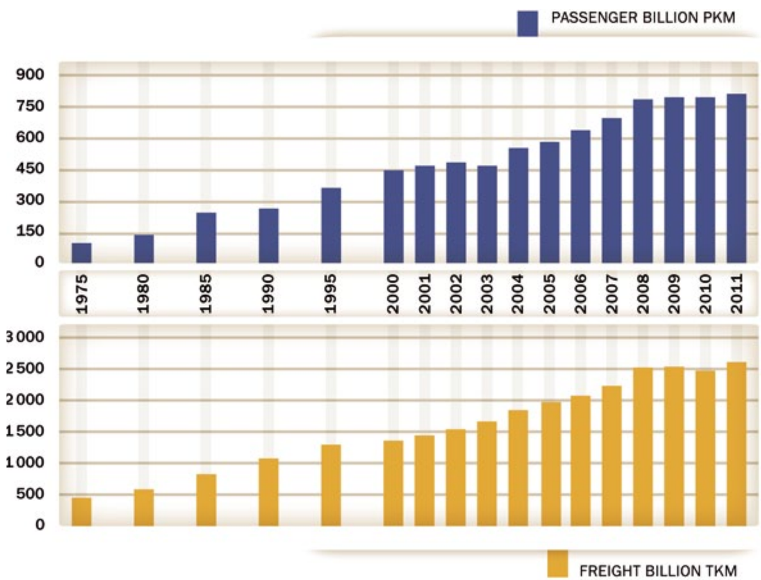

Source: IEA (2013a)

Fig. 74: **Passenger and freight transport activity - all modes, 1990-2011 (billion pkm and tkm)**



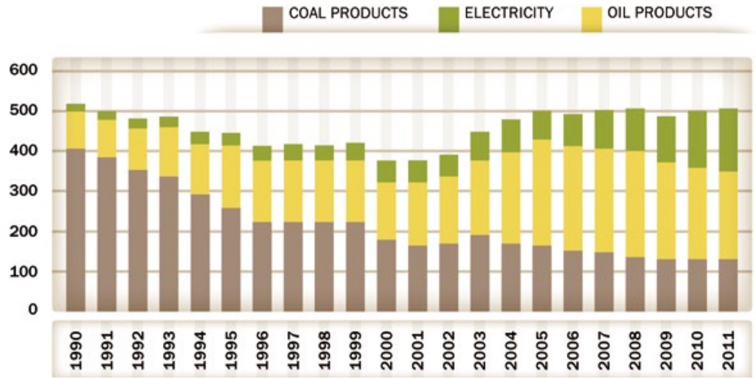

Source: UIC (2013a) and CNBS (2013)

Fig. 75: **Passenger and freight railway activity, 1975-2011**



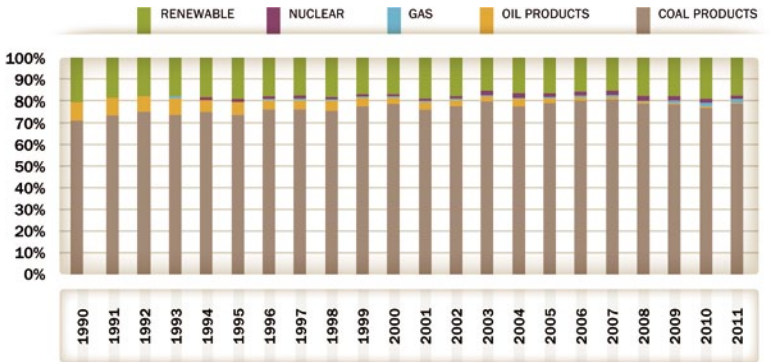

Source: Elaboration by IEA based on UIC (2013a)

Fig. 76: **Railway final energy consumption by fuel, 1990-2011 (PJ)**




Source: IEA (2013b)

Fig. 77: **National electricity production mix evolution, 1990-2011**



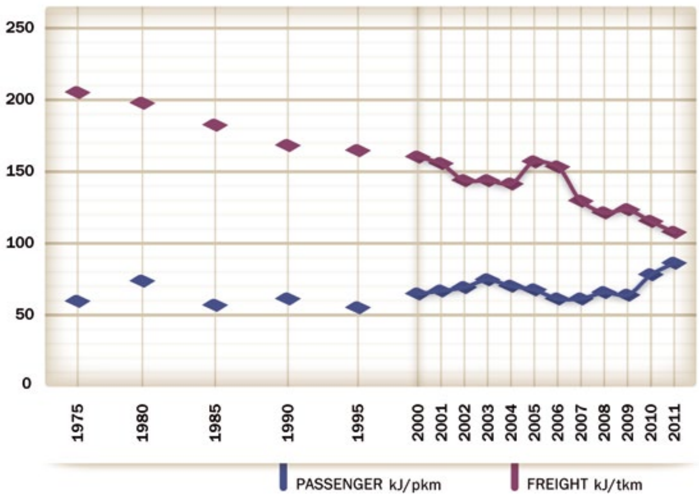

Source: IEA (2013b)

Table 14: **National electricity production mix, 2000-2011**

| | 2000 | 2011 |
|---|---|---|
| COAL PRODUCTS | 78% | 79% |
| OIL PRODUCTS | 3% | 0% |
| GAS | 1% | 2% |
| NUCLEAR | 1% | 2% |
| RENEWABLE | 17% | 17% |

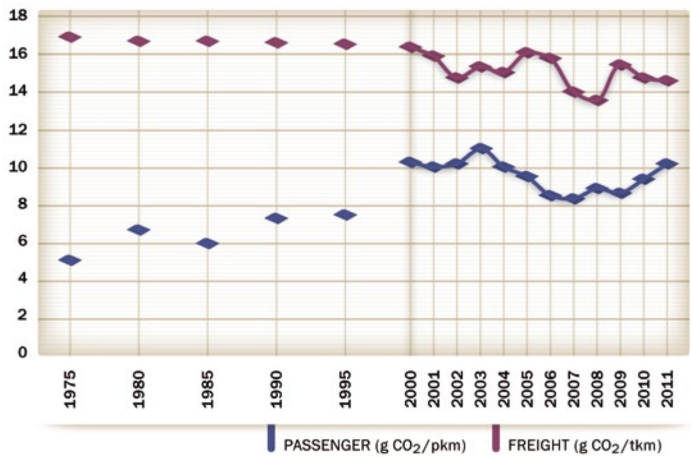
Source: IEA (2013b)

Fig. 78: **Railway specific energy consumption, 1975-2011**




Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2013a)

Fig. 79: **Railway specific $CO_2$ emissions, 1975-2011**




Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2013a)

# Part II: Focus on Infrastructure

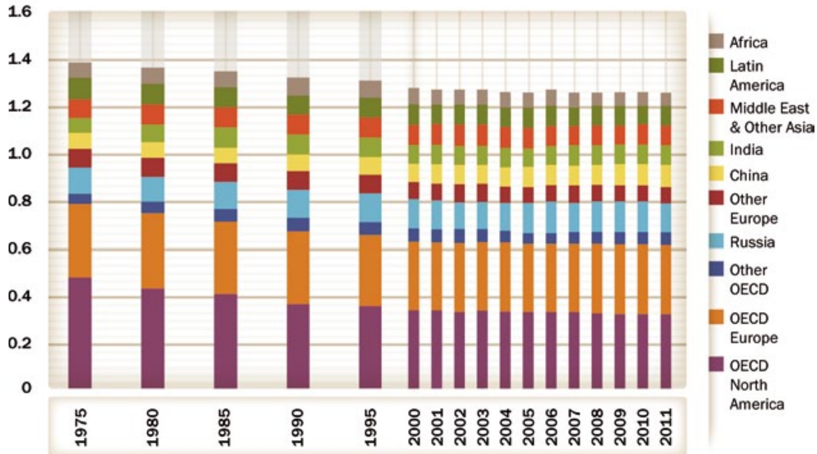
# Key Facts

- Worldwide railway track length decreased by 9% from 1975 to 2011 (Fig. 80), while road paved lanes more than doubled (Fig. 81).
- High-speed infrastructure increased fourfold between 2000 and 2013 and more than doubled from 2009 to 2013 (Fig. 86).
- China held about 50% of high-speed lines worldwide in 2013; the closest second was Japan with 12% of high-speed lines (Fig. 87).
- Rail average occupancy levels (transport units per infrastructure-km) in 2011 were more than ten times average road occupancy levels. While road occupancy has been more or less constant since 2000, rail occupancy levels increased by nearly 50% (Fig. 90).

  Worldwide, road infrastructure uses 37 times more land than rail infrastructure (Fig. 93), while only carrying 3.5 times more transport units than rail (Table 1).
- The average energy intensity (in kJ/tu) of road activity in 2011 was 11 times higher than the energy intensity of rail (Fig. 96); the $CO_2$ emission intensity (in gCO2/tu) of road was 9 times that of rail (Fig. 97).
- On average, between 1995 and 2011in select ITF countries, road spending in percentage of GDP was more than 3 times higher than rail spending (Fig. 100).
- As a general average, annuitized rail costs per infrastructural km are as much as 3 to 16 times more expensive than roadways; yet, railway emissions for every dollar spent are 3 to 14 times less than for roads, making rail investments more than 10 times more effective than roads in terms of resulting emissions (Fig. 106).

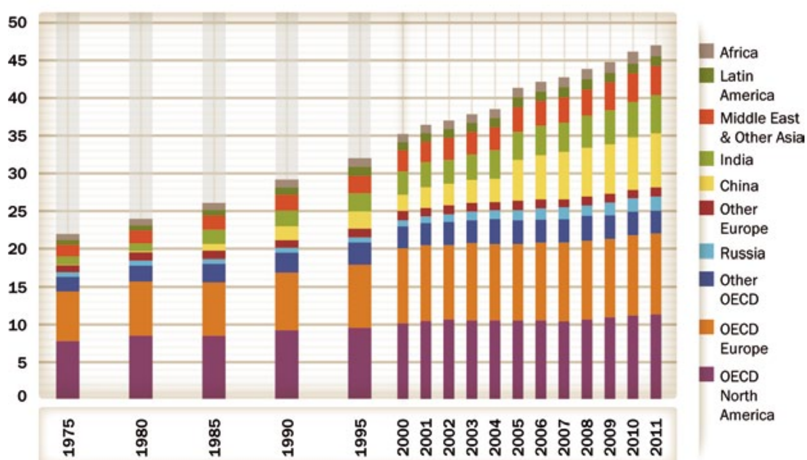
# Rail and Road Infrastructure

Fig. 80: **Length of railway tracks in operation by geographic area, 1975-2011(million track-km)**



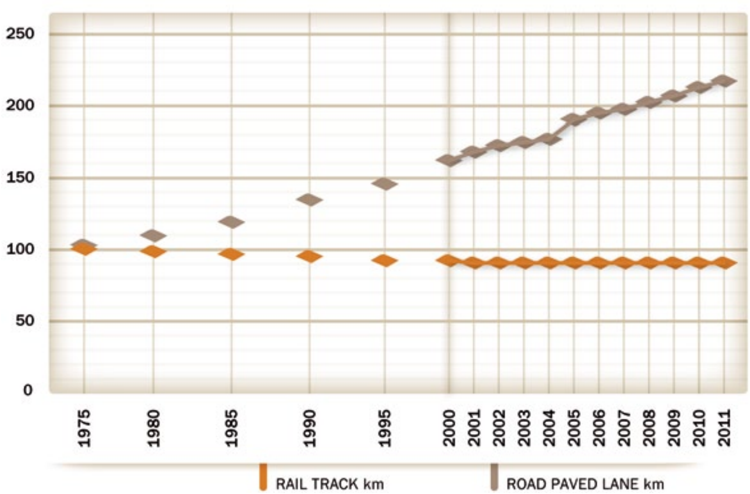

Source: Elaboration by IEA based on UIC (2013a)

Fig. 81: **Length of paved lanes by geographic area, 1975-2011 (million lane-km)**




Source: Elaboration by IEA based on IRF (2013)

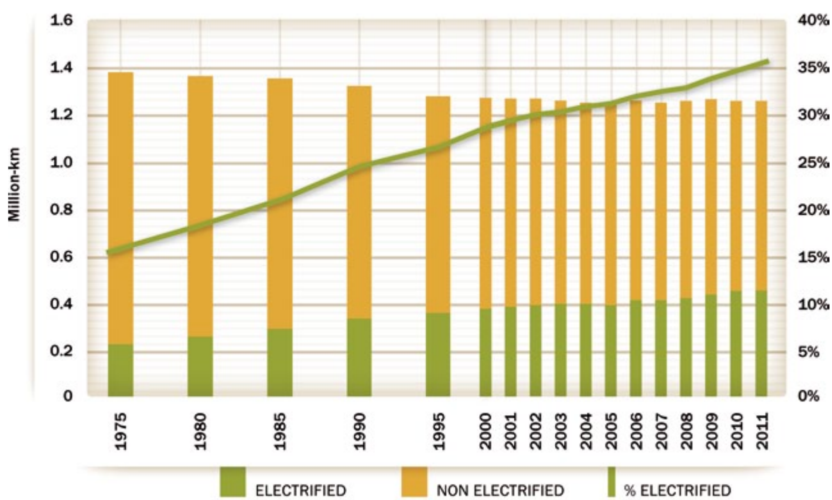
Fig. 82: **Evolution of road paved lane-km and railway track-km worldwide, 1975-2011**




Year 1975=100

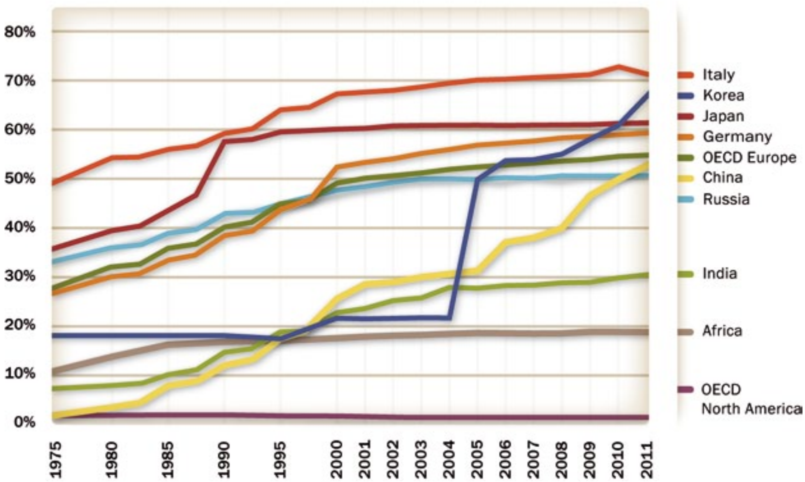
Source: Elaboration by Susdef based on IEA (2013c) and UIC (2013a)

Fig. 83: **Length and share of electrified versus non-electrified railway tracks, 1975-2011**



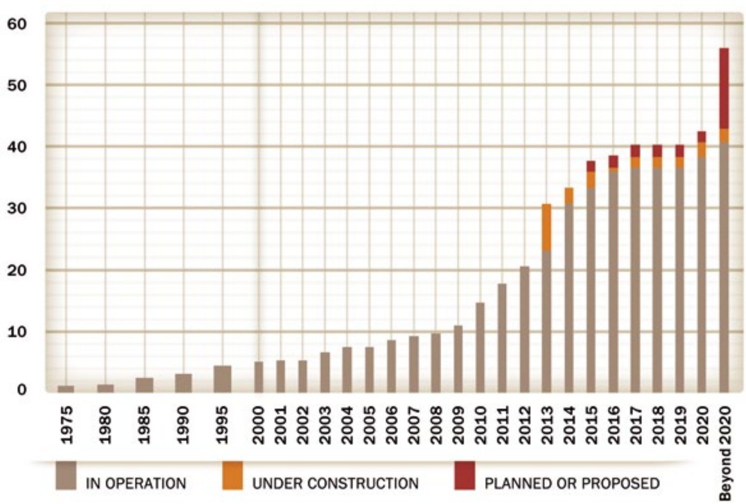

Source: Elaboration by IEA based on UIC (2013a)

Fig. 84: **Share of electrified railway lines in selected countries and geographic areas, 1975-2011**



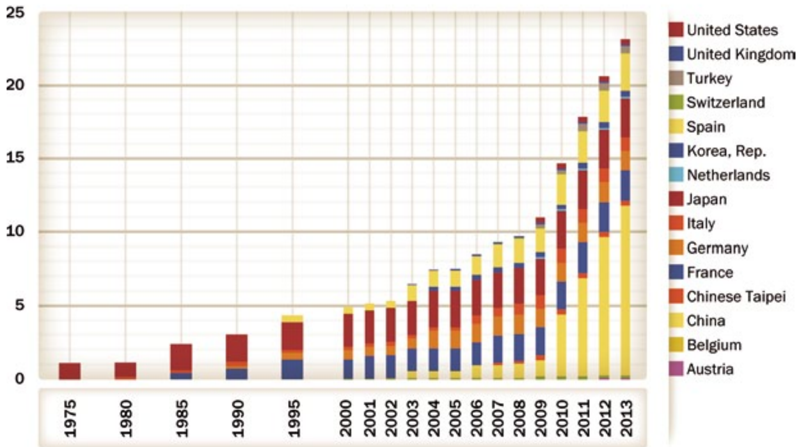

Source: Elaboration by IEA based on UIC (2013a)

Fig. 85: **High-speed lines in operation and forecasted, 1975-2020 and beyond (thousand km)**



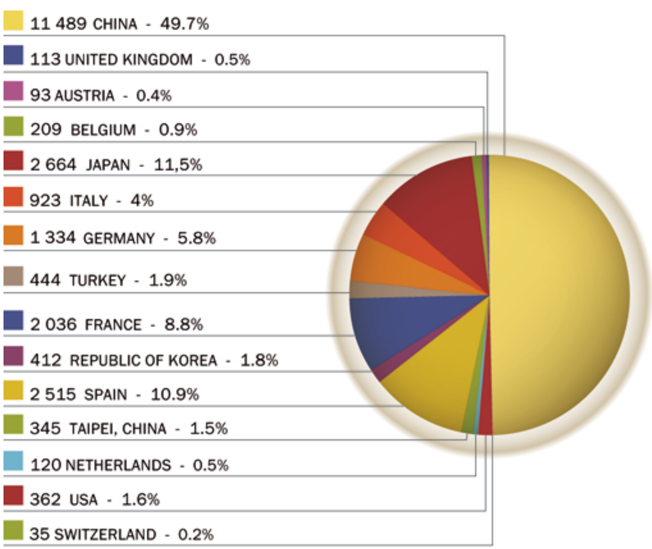

Source: Elaboration by IEA based on UIC (2013a)

Fig. 86: **High-speed lines in operation by country, 1975-2013 (thousand km)**




Source: Elaboration by IEA based on UIC (2013a)

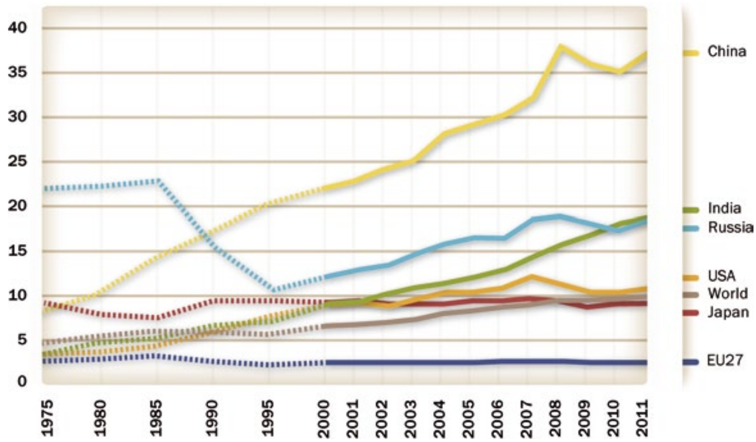
Fig. 87: **High-speed lines in operation by country (km) and share of world total (%), 2013**




Source: Elaboration by IEA based on UIC (2013a)

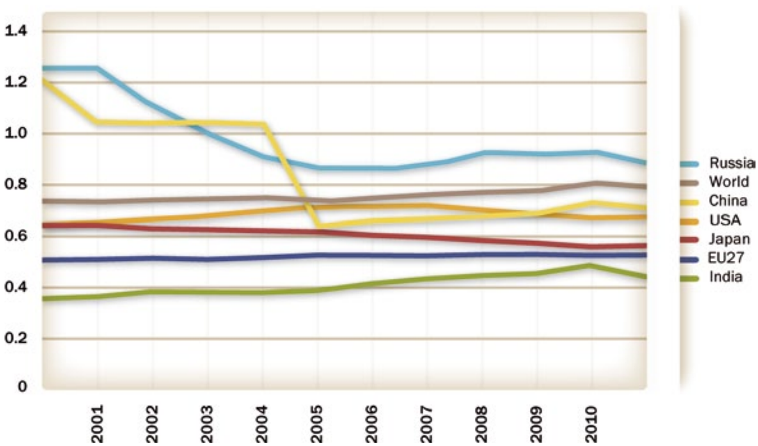
# Occupancy Level

Fig. 88: **Rail average occupancy level, 1975-2011 (million transport units per track-km)**



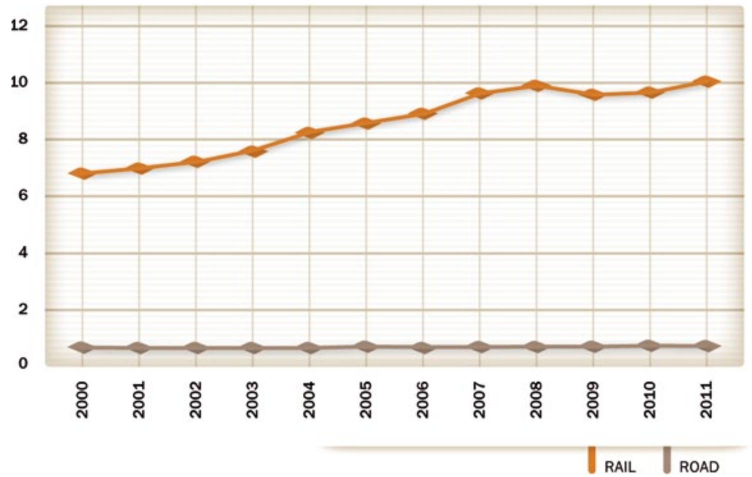

Source: IEA Mobility Model based on UIC (2013a)

Fig. 89: **Road average occupancy level, 2000-2011 (million transport units per paved lane-km)**




Source: IEA Mobility Model based on IRF (2013)

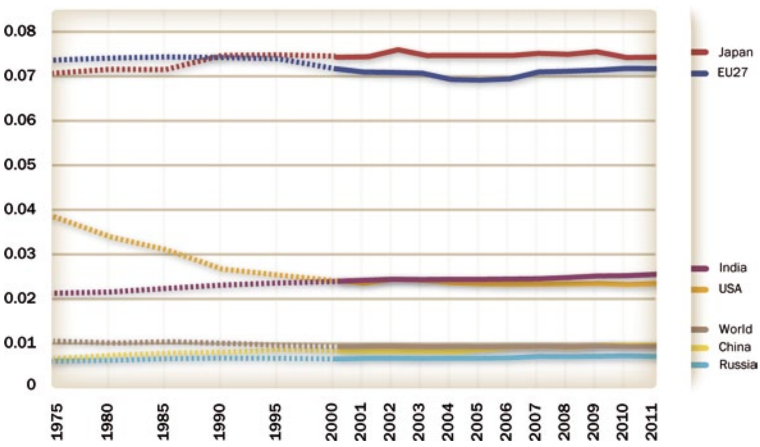
Fig. 90: **Worldwide evolution of paved roads and railway tracks occupancy level, 2000-2011 (million transport units per paved lane-km or rail track-km)**




Source: IEA Mobility Model based on UIC (2013a) and IRF (2013)

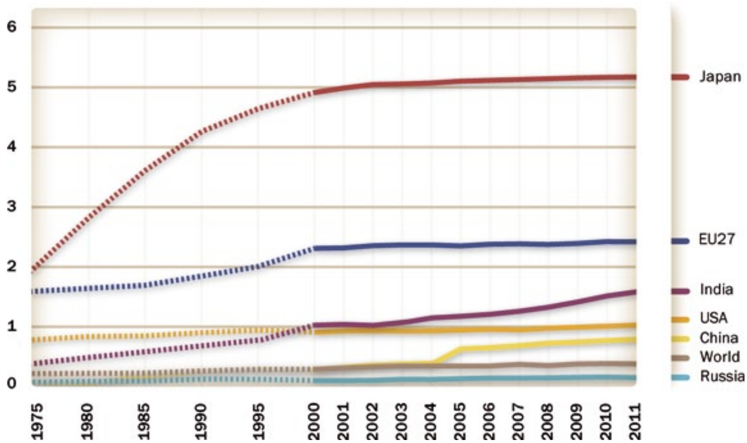
# Land Use

Fig. 91: **Rail land use, 1975-2011 (track-km of infrastructure per km² of land)**



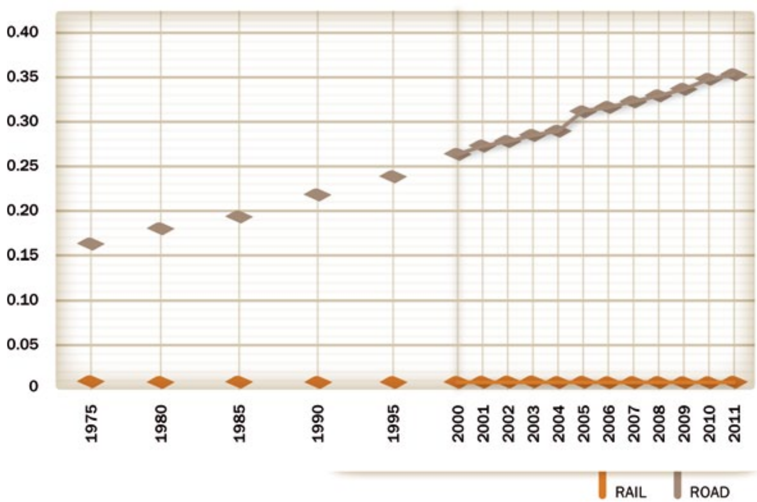

Source: IEA Mobility Model based on UIC (2013a) and FAO (2013)

Fig. 92: **Road land use, 1975-2011 (lane-km of infrastructure per km² of land)**



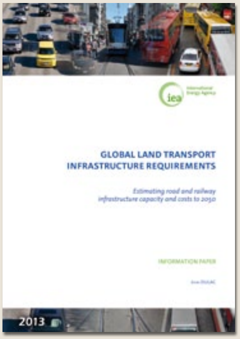

Source: IEA Mobility Model based on IRF (2013) and FAO (2013)

Fig. 93: **Worldwide evolution of paved roads and railway tracks land use, 1975-2011 (paved lane-km or rail track-km per km² of land)**




Source: IEA Mobility Model based on UIC (2013a), IRF (2013) and FAO (2013)

## IEA Global Land Transport Infrastructure Projections



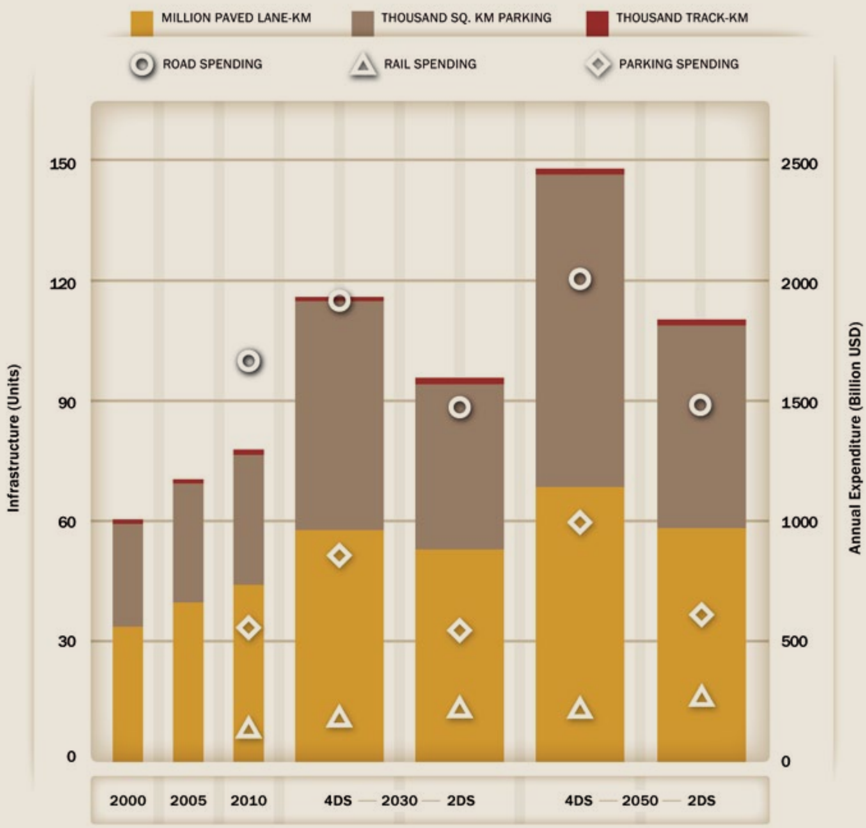

Over the next four decades, global passenger and freight travel is expected to double over 2010 levels in a business-as-usual scenario (IEA 4°C scenario, 4DS). In order to accommodate this growth, the International Energy Agency estimates that the world will need to add nearly 25 million paved road lane-kilometres and 335 000 rail track kilometres by 2050.

In addition, it is expected that more than 45 000 square kilometres of new parking spaces will be added to accommodate private motorized vehicle growth. These infrastructure additions, when combined with operations, maintenance and repairs, are expected to cost as much as USD 45 trillion by 2050. When repairs and maintenance are included for existing land transport infrastructure, global infrastructure spending could reach as much as USD 120 trillion by 2050.

If countries were to pursue “avoid and shift” policies (IEA 2°C scenario, 2DS), including greater investments in rail and bus rapid transit infrastructure, roadway additions to 2050 could decrease by more than 10 million lane-kilometres over 4DS projections. While expenditures on rail and bus infrastructure would increase marginally, net transport infrastructure investments to 2050 would decrease by nearly USD 20 trillion over the next 40 years.

For more information on IEA land transport infrastructure projections, please visit: www.iea.org/transport-infrastructure

Fig. 94: **Projection of paved lanes, parking and railways extension and spending**




Source: IEA, 2013c

## Transport activity and occupancy constraints

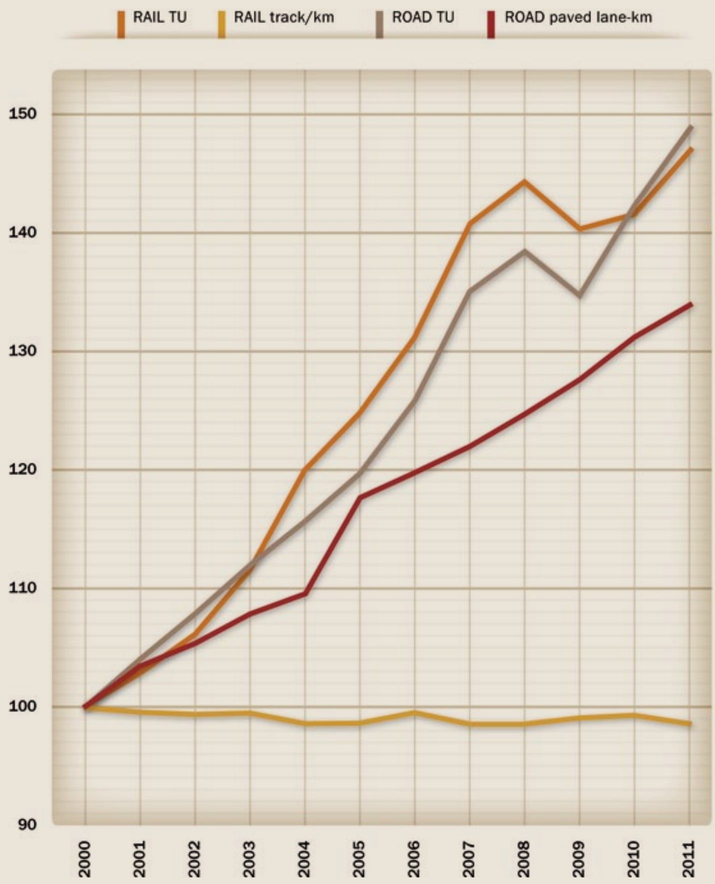
The IEA Mobility Model estimates average annual occupancy levels in transport units per road lane-km and per rail track-km for select countries. Globally, both road and rail passenger and freight travel activity (in passenger and tonne kilometres) grew by nearly 50% between 2000 and 2011. At the same time, global rail infrastructure (in track-km) remained nearly constant, while total road paved lane-km increased by roughly 33%.

While IEA estimates on average annual occupancy levels do not indicate specific congestion levels along infrastructure at any given point in time, they do illustrate the different relationship between travel growth and infrastructural carrying capacity for road and rail transport. Historically, rail has undertaken more activity per unit of infrastructure compared to road, with more than five times the transport units carried per track-km in 2000 than along a road lane-km. Yet, global rail activity (in transport units) grew at roughly the same pace as road travel since 2000, increasing this margin to a more than 7-fold difference in transport units carried per infrastructural kilometre in 2011.

In the future, this relationship may have significant consequences on infrastructure demand to continue meeting carrying capacity for travel activity growth. The IEA estimates that global rail and road activity both will double by 2050. To support this growth, the IEA Mobility Model expects that road paved lane-km will need to increase by nearly 60% over 2010 levels by 2050 in a business-as-usual scenario. By contrast, rail track-km are only expected to grow by 25%.

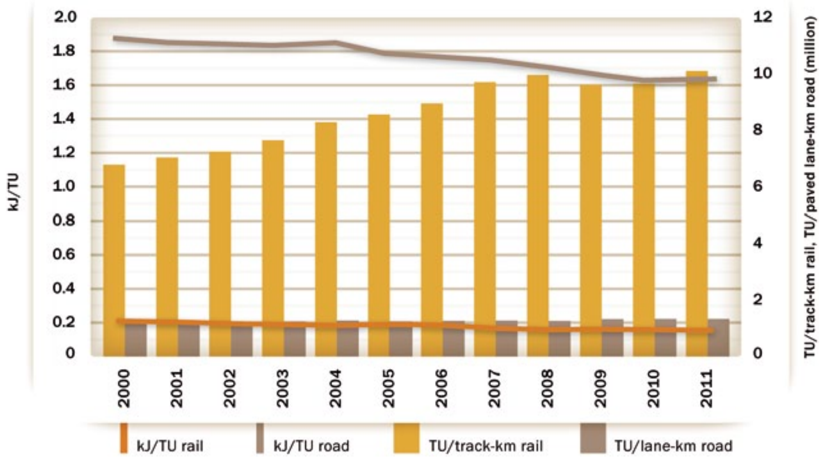
In order to reach a 2°C climate target, the IEA recommends an “avoid, shift and improve” approach with increased investments in rail infrastructure. “Applying more efficient technology and fuels is critical but may not be enough […]. It is imperative to investigate the potential for contributions from reducing the growth rate in travel demand and influencing the modes used” (IEA, 2014).

Fig. 95: **Evolution of road and rail activity and infrastructure length, 2000-2011 (Year 2000=100)**



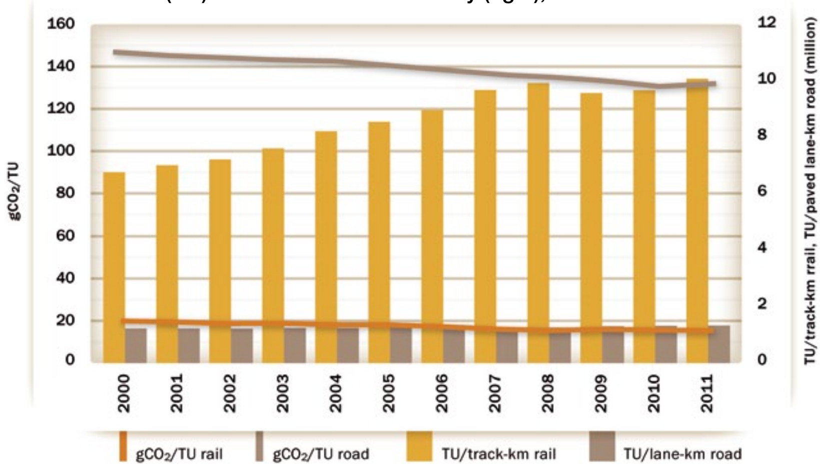
# Energy/$CO_2$ and Infrastructure

Fig. 96: **Worldwide evolution of road and rail energy intensity (left) and infrastructure intensity (right), 2000-2011**




Source: Elaboration by IEA and Susdef based on EC (2013), IEA (2013b), UIC (2013b) and IEA Mobility Model

Fig. 97: **Worldwide evolution of road and rail $CO_2$ emissions intensity (left) and infrastructure intensity (right), 2000-2011**

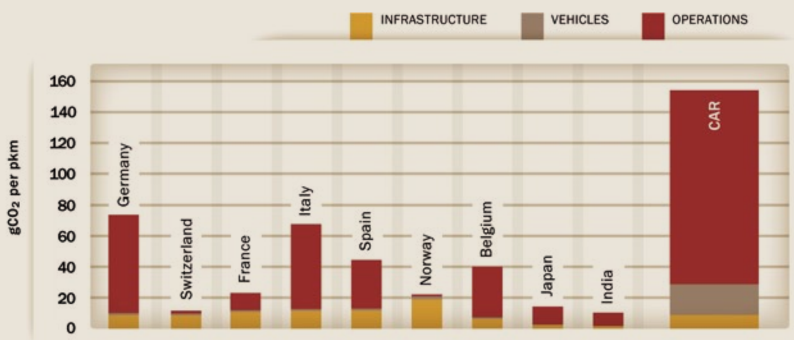



Source: Elaboration by IEA and Susdef based on EC (2013), IEA (2013a), UIC (2013b) and IEA Mobility Model

# Carbon Footprint of Railway Infrastructure

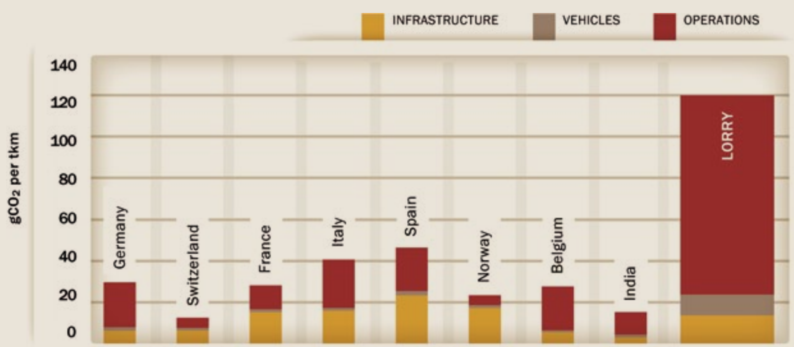
A 2011 study by Matthias Tuchschmid, IFEU and Öko-Institut, commissioned by UIC (Tuchschmid 2013), researched the carbon footprint of the construction of railway infrastructure and rolling stock, defining a methodology and calculating the carbon footprint for several example countries. The results show that the construction of rail infrastructure can have a significant impact (between 1 and 25 $gCO_2$ per pkm or tkm). However, the environmental advantage of railways compared to road persists even when taking into account the carbon footprint of the construction of infrastructure.

Fig. 98: **Carbon Footprint of passenger rail transport in select countries**




Source: Tuchschmid (2011)

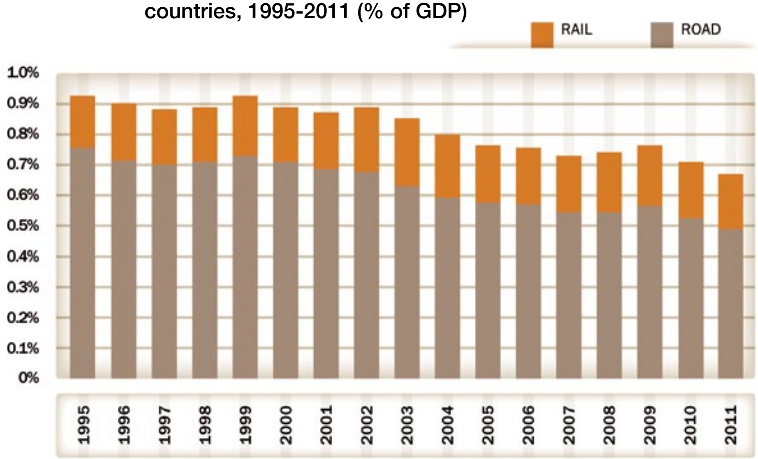
Fig. 99: **Carbon Footprint of freight rail transport in select countries**




Source: Tuchschmid (2011)

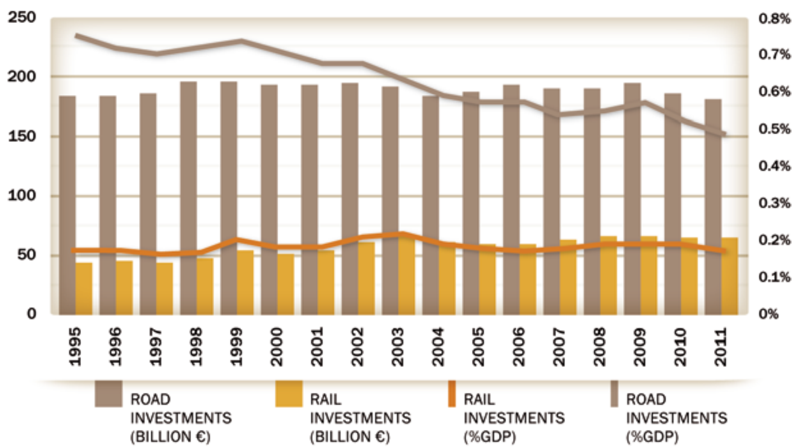
# Infrastructure Investments

Fig. 100: **Total road and rail infrastructure investments for select ITF countries, 1995-2011 (% of GDP)**




Source: Elaboration by IEA and Susdef based on OECD (2014)

Fig. 101: **Total road and rail infrastructure investments for select ITF countries, 1995-2011 (billion constant Euros - left, % of GDP - right)**




Source: Elaboration by IEA and Susdef based on OECD (2014)

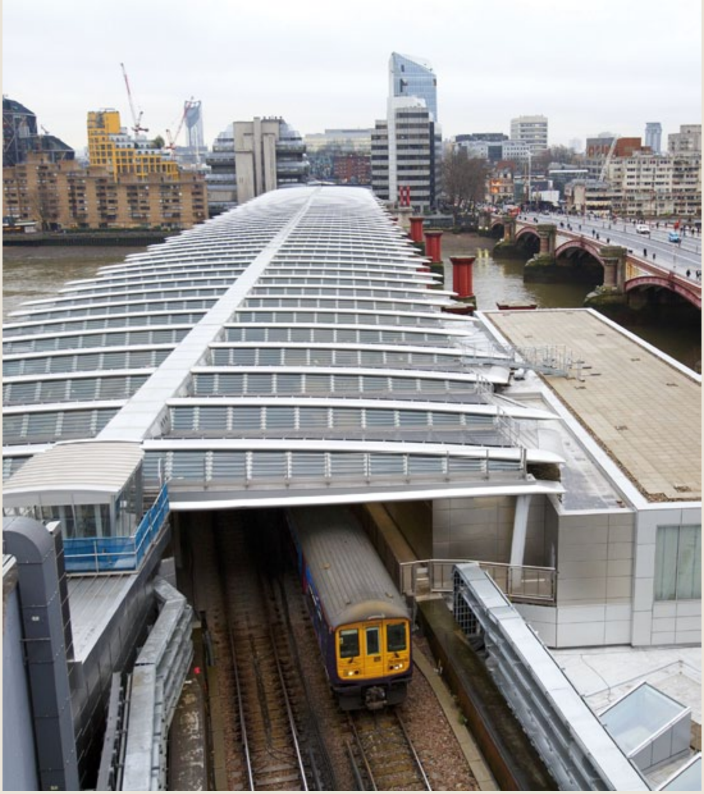
---

Note: For data consistency, these graphs take into account all ITF countries except: Azerbaijan, Belarus, Bulgaria, Georgia, Iceland, Liechtenstein, Malta, Montenegro and New Zealand.

# Investments in energy efficient infrastructure: the Blackfriars Solar Bridge

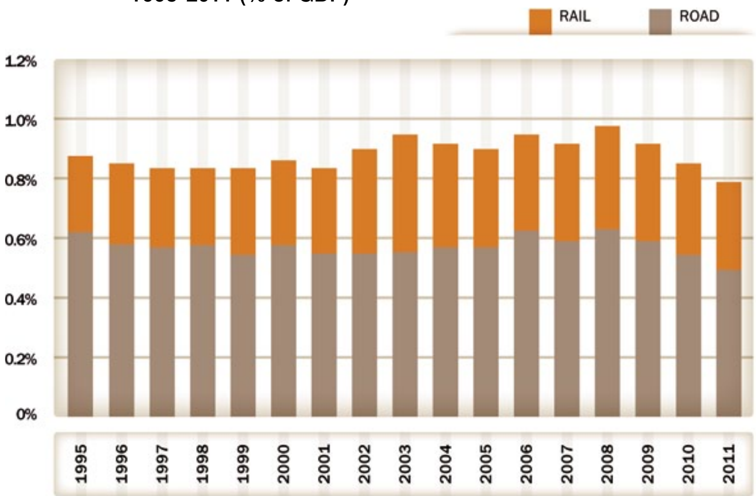
In January 2014, Network Rail inaugurated the new Blackfriars rail bridge, rebuilt as part of an upgrade to the Blackfriars railway station. It is the largest solar bridge in the world, featuring a 6 000 m² area covered with 4 400 photovoltaic panels for a nominal power of 1.1 MW. The annual electricity generation is 0.9 GWh, covering 50% of the railway station needs. The $CO_2$ savings are estimated at 513 tonnes per year.

The bridge is a part of a 6.5 billion GBP (8 billion EUR, 11 billion USD) investment to increase capacity on the Thameslink route.



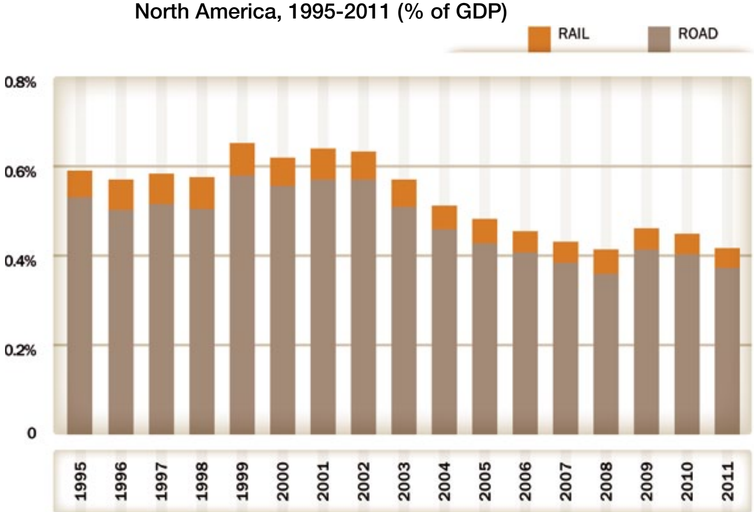
Blackfriars Solar Bridge (photo © Network Rail)

Fig. 102: **Capital investments on road and rail infrastructure in EU27, 1995-2011 (% of GDP)**



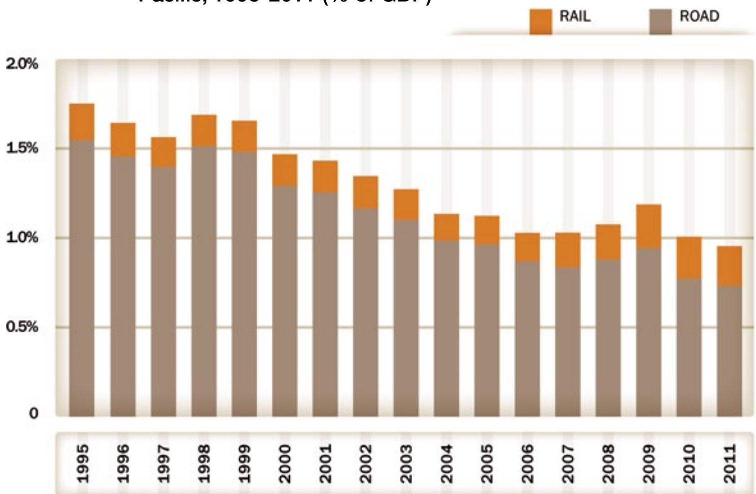

Source: Elaboration by IEA based on OECD (2014)

Fig. 103: **Capital investments on road and rail infrastructure in OECD North America, 1995-2011 (% of GDP)**




Source: Elaboration by IEA based on OECD (2014)

Fig. 104: **Capital investments on road and rail infrastructure in OECD Pacific, 1995-2011 (% of GDP)**




Source: Elaboration by IEA based on OECD (2014)

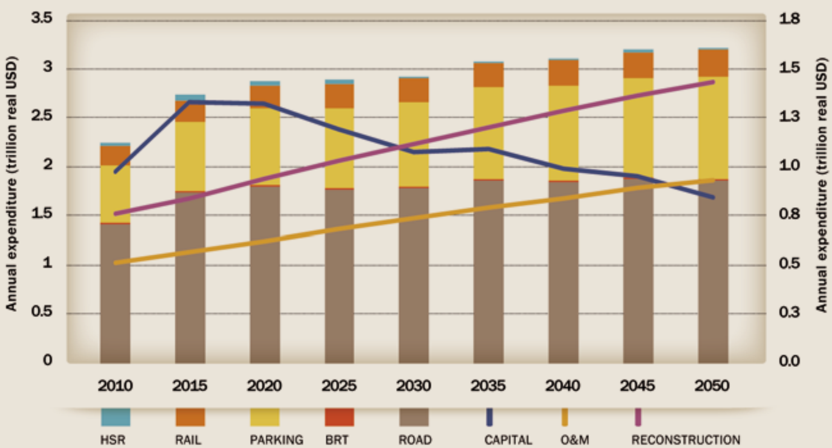
## Projected annual expenditures

The IEA publication *Global Land Transport Infrastructure Requirements* (IEA, 2013) shows that as the world continues to build new transport infrastructure to support growing travel activity in the coming decades, global annual capital investments for road, rail and parking infrastructure are expected to reach as high as USD 1.4 trillion in a business-as-usual scenario. Those annual capital expenditures will drop back slightly to around USD 700 billion a year by 2050 as infrastructure levels catch up to travel increases. Road additions account for nearly 75% of those expected capital expenditures to 2050.

While capital spending on transport infrastructure is projected to decrease by 2050, annual reconstruction, operations and maintenance (O&M) expenditures are expected to continue increasing. In particular, road reconstruction costs are projected to rise to as much as USD 700 billion per year as the world's road infrastructure continues to grow and age – meaning the world will spend as much on fixing and rebuilding road infrastructure over the next 40 years as it does building new roadway.

Rail infrastructure investments are projected to cost roughly USD 1.5 trillion in capital construction and USD 2.2 trillion in reconstruction and O&M to 2050. Regionally, this represents roughly 0.03% and 0.45% of GDP, which is consistent with rail investments and maintenance expenditures today.

Fig.105: **Projected annual expenditures for infrastructure, 2010-2050**



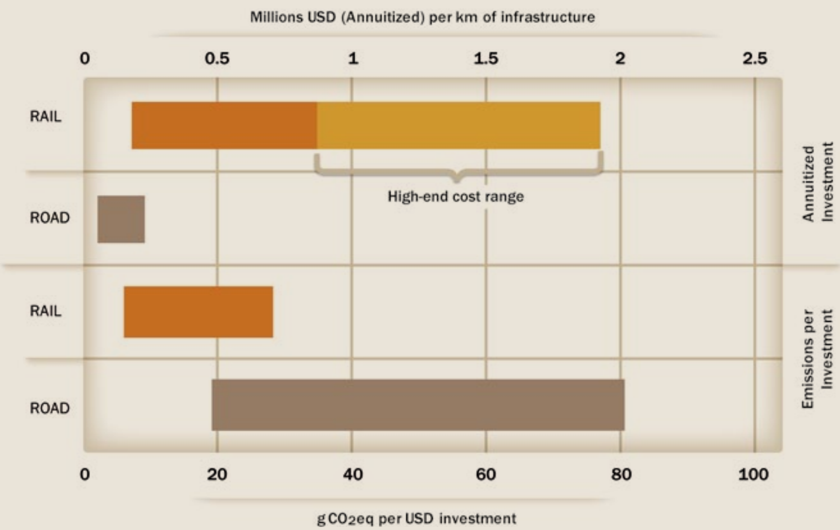

Source: IEA (2013c)

# Estimate of emissions per investment

IEA estimates put the emissions of rail at a range of 6 to 28 $gCO_2$ per every USD invested in infrastructure, compared to a range of 19 to 81 $gCO_2$ per USD invested in road infrastructure. The estimates consider the emissions generated by vehicle operation over the built infrastructure (i.e. emissions from railway traction and road vehicles exhaust), and the investments take into account the annuitized capital, annual operation and maintenance costs and partial reconstruction across 30 years of operations. The detailed methodology is available in the "Methodological Notes" annex of this handbook.

The IEA calculations show that while rail is typically more expensive to build and maintain than road (annuitized investments range between 180 and 870 thousand USD per track-km with a peak of nearly 2 million USD for top-of-the-line high speed railway infrastructure, compared to 50-230 thousand dollars in annuitized investment per paved lane-km of road), those investments are more efficient in terms of emissions per dollar spent: on average, road activities generate annually 3 to 14 times more $CO_2$ per USD spent on infrastructure than for rail investments.

Fig.106: **Estimate of annuitized investments (top) and emissions per investment (bottom) for road and rail**




Source: IEA elaboration based on Mobility Model, IEA (2013c) and UIC (2013a)

# Methodology Notes

**Share of $CO_2$ emissions from fuel combustion by sector (fig.1, 12, 26, 37, 48, 59, 69)**

The IEA *$CO_2$ from fuel combustion* database does not attribute any $CO_2$ emissions from the use of electricity in the transport sector. The $CO_2$ emissions from electricity generation are attributed to the power sector. The power sector, even though not being a final user of energy, is subjected to its own objective in terms of $CO_2$ emission reduction, such as the EU ETS in the EU.

Railway $CO_2$ emissions in the various "Share of $CO_2$ emissions from fuel combustion by sector" figures presented in this publication are an exception to the previous rule, as those figures take into account emissions for the whole railway sector, including electric traction. Accordingly, in those figures, the emissions for railway electric traction have not been counted in the power sector. In all cases except for the EU figures (which come from UIC, 2012b) the emissions from railway electric traction have been estimated from the use of electric power in the railway sector, from which $CO_2$ emissions have been calculated by using the national production electricity mix (IEA, 2012b), fuel emission factors (IPCC, 2006) and power plant efficiency values (IEA, 2008).

In all cases, international aviation and navigation bunkers have been included in the calculations.

**Railway specific energy consumption (fig. 10, 24, 35, 46, 57, 67, 78)**

Railway specific energy consumption is based on combinations of different data from UIC. Some railway companies provide UIC with their tractive stock total consumption divided by electric/diesel and passenger/freight. These total consumptions combined with pkm and tkm (which are distributed between electric, diesel and coal following repartition of train-km given by UIC) allows the calculation of energy intensity. As total energy consumption is not provided by all companies, specific energy consumption for several countries is an estimation based on intensity in other countries. A second step is the comparison of total energy use calculated in this way with the IEA *World Energy Balances* database (IEA, 2012b), which allows a calibration of the estimated energy intensity.

**Railway specific energy consumption and specific $CO_2$ emissions**

In some cases, figures showing specific energy consumption and specific $CO_2$ emissions can appear different from the figures in the Railway Handbook 2013. IEA and UIC continue to work together to improve energy and emissions statistics with respect to data reported by UIC members, including specific energy and emissions data for rail tractive stock.

**Railway energy sources mix (fig. 21, 22, 23; tables 4 and 5)**

For EU27, the railway energy sources mix has been calculated. The railway energy sources mix indicates in what proportion the energy sources are being used for rail traction. As seen in fig. 21, part of the trains run on diesel (which are oil products) and the rest run on electricity, which is produced from different sources according to the electricity mix used (fig. 22 and table 4). By applying the electricity mix to the portion of electric energy used, it is possible to obtain the energy sources mix shown in fig. 23 and table 5.

**Emissions per investment (fig. 106)**

Emissions per U.S. Dollar (USD) spent on rail and road infrastructure were calculated using average network operating emissions (rolling stock, in grams $CO_2$ equivalent) per annuitized dollar spent on infrastructure (including capital construction, annual operations and maintenance [O&M] and expected repair or reconstruction to the capital infrastructure). Capital construction, reconstruction and O&M costs were estimated from typical low and high project costs described in the IEA's Global Land Transport Infrastructure Requirements report (IEA, 2013c), where capital recovery factors were applied assuming a fixed interest rate of 5% and typical infrastructure lifetimes of 10 and 30 years for road and rail, respectively. It was also assumed that typical capital repair and/or reconstruction would occur at least once during the infrastructure lifetime (or once every 5 years for road and once every 15 years for rail). High-end rail costs were included to account for atypical rail projects and high-speed rail, which can be as much as 4 to 5 times more expensive than conventional rail projects. Once the annuitized costs using a capital recovery factor were determined, average annual operating emissions (from road vehicle and rail tractive stock along one paved lane-km or one track-km) were applied to determine the average range of emissions per dollar spent across road and rail infrastructure. A low-to-high range was provided to show the variation in typical annuitized costs and the resulting range in typical emissions per investment.

# Glossary

**Electrified track**
Track provided with an overhead catenary or a conductor rail to permit electric traction.

**Electrified line**
Line with one or more electrified running tracks.

**Energy consumption by rail transport**
Final energy consumed by tractive vehicles for traction, train services and facilities (heating, air conditioning, lighting etc.).

**Gross tonne-kilometre hauled**
Unit of measurement representing the movement over a distance of one kilometre of one tonne of hauled vehicles (and railcars) and contents.

**HDV**
Heavy Duty Vehicle (gross vehicle weight > 3.5 tonnes)

**Joule (J)**
Unit of measurement of energy consumption.
Kilojoule: 1 kJ = 1 000 J
Megajoule: 1 MJ = $1 \times 10^{6}$ J
Gigajoule: 1 GJ = $1 \times 10^{9}$ J
Terajoule: 1 TJ = $1 \times 10^{12}$ J
Petajoule: 1 PJ = $1 \times 10^{15}$ J

**Passenger-kilometre (pkm)**
Unit of measurement representing the transport of one passenger over a distance of one kilometre.

**P2W**
Powered 2 wheelers

**PLDV**
Passenger light duty vehicle

**Tonne-kilometre (tkm)**
Unit of measurement of goods transport which represents the transport of one tonne of goods over a distance of one kilometre.

**Tonne of oil equivalent (toe)**
Unit of measurement of energy consumption: 1 TOE = 41.868 GJ

**Train-kilometre (train-km)**
Unit of measurement representing the movement of a train over one kilometre.

**Transport Unit (tu)**
The sum of passenger kilometre and tonne kilometre

**TTW**
Tank to wheel

**WTT**
Well to tank

**WTW**
Well to wheel

**OECD**
Organisation for Economic Co-operation and Development.

Member countries are: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.

*OECD North America*: Canada, Mexico and USA

*OECD Europe*: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

*OECD Pacific*: Australia, Japan, Korea and New Zealand

**ITF**
International Transport Forum.

Member countries are: Albania, Armenia, Australia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Canada, China, Chile, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, India, Ireland, Italy, Japan, South Korea, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Malta, Mexico, Moldova, Montenegro, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. Morocco is an observer country.

# References

CNBS 2013, *China Statistical Yearbook 2013.* China Statistics Press, National Bureau of Statistics of China, Beijing.

EC 2013, *EU transport in figures – Statistical pocketbook 2013.*

Publications Office of the European Union, Luxembourg. http://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2013_en.htm
Accessed April 9, 2014.

FAO 2013, *Land Use Database.* On-line data service. Internet: http://faostat.fao.org/site/377/default.aspx#ancor. Food and Agriculture Organisation of the United Nations. Accessed, March 4, 2013.

IEA 2008, *Energy Efficiency Indicators for Public Electricity Production from Fossil Fuels.* International Energy Agency (IEA). Paris, 2008.

IEA 2013a, *$CO_2$ Emissions from Fuel Combustion.* On-line data service. Internet: http://data.iea.org/. Accessed March 3, 2014.

IEA 2013b, *World Energy Balances.* On-line data service. Internet: http://data.iea.org/. Accessed March 3, 2014.

IEA 2013c, *Global Land Transport Infrastructure Requirements. Estimating road and railway infrastructure capacity and costs to 2050.* IEA/OECD, Paris.

IEA 2014, *Energy Technology Perspectives 2014 - Harnessing Electricity's Potential.* IEA/OECD, Paris.

IPCC 2006, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds), *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme.* IGES, Japan, 2006.

IRF 2013, *World Road Statistics 2013.* International Road Federation (IRF). Geneva, 2013.

JMLIT 2014. *Summary of Transportation Statistics.* Japan Ministry of Land, Infrastructure and Tourism. Internet: http://www.mlit.go.jp/k-toukei/transportation_statistics.html. Accessed June 26, 2014.

JSB 2013, *Japan Statistical Yearbook 2013*. Japan Statistics Bureau, Tokyo.

NTS 2014, National Transportation Statistics. Internet: http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/index.html. Accessed April 3, 2014.

OECD 2014, *OECD.Stat Extracts.* On-line data service. Internet: http://stats.oecd.org/. Accessed March, 26 2014.

Rosstat 2014, *Russia in figures.* Russian Federal Statistics Service. Internet: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/en/figures/transport/. Accessed March 31, 2014.

Tuchschmid 2011, *Carbon Footprint and environmental impact of Railway Infrastructure.* Matthias Tuchschmid, IFEU and Öko-Institut. Commissioned by UIC. Heidelberg – Zurich – Berlin 2011.

UIC 2013a, *International Railway Statistics 2013*, Statistics Centre of the International Union of Railways, Paris.

UIC 2013b, *UIC Environmental Performance Database 2013*. International Union of Railways, Paris.

UNCTAD 2013, *Review of Maritime Transport 2013*. UNCTAD/RMT/2013. United Nations Conference on Trade and Development. Geneva, 2013.

International Energy Agency

INTERNATIONAL UNION OF RAILWAYS

International Energy Agency
9, rue de la Fédération
75739 Paris Cedex 15 FRANCE
www.iea.org

INTERNATIONAL UNION OF RAILWAYS
16, rue Jean Rey
F-75015 Paris FRANCE
www.uic.org

with the technical support of

SUSTAINABLE DEVELOPMENT FOUNDATION
Fondazione per lo Sviluppo Sostenibile

The publication can be downloaded at:
http://www.uic.org