RAILWAY HANDBOOK 2013

ENERGY CONSUMPTION AND CO_2 EMISSIONS

FOCUS ON ENERGY MIX

International Energy Agency

INTERNATIONAL UNION OF RAILWAYS

Railway Handbook 2013

Energy Consumption and CO_2 Emissions

- Focus on Energy Mix -

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 28 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
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

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www.iea.org

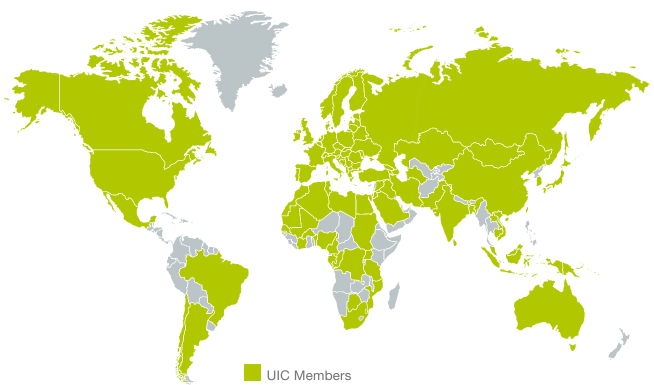
INTERNATIONAL UNION OF RAILWAYS

UIC: the international professional association representing the railway sector

UIC, the international railway association which celebrates its 90th anniversary in 2012, counts 200 members across 5 continents (railway companies, infrastructure managers, rail-related transport operators, etc.). UIC's members represent 1 million kilometres of lines, 2,800 billion passenger-km, 9,500 billion tonne-km, and a workforce of 6.7 million people.

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

The International Energy Agency and the International Union of Railways are pleased to launch the second edition of the IEA/UIC data handbook on “Energy Consumption and CO_2 Emissions of World Railway Sector”.

The first edition was successful in providing valuable information on rail energy use and emissions to actors in the energy field and broader transport sector.

Expanding on the regional energy and emissions data presented in last year’s handbook, this second edition goes deeper into rail energy and emissions statistics and, for the first time, presents aggregate data on worldwide rail activity and energy use.

Since the last edition, rail and energy data has improved considerably as UIC and the IEA have worked closely together.

Though the reliability and quality of rail data can still be improved, we hope this annual publication will help railway operators to implement a more systematic data collection process. Assessing the efficiency of railway operations is a strategic move that will allow railways to evolve over time while keeping their environmental advantage for the coming decades.

Railways are at the core of electro-mobility, which will be a focus of the IEA’s Energy Technology Perspectives publication in 2014.

This edition of the “Energy Consumption and CO_2 Emissions of World Railway Sector” looks closely at railway electricity mixes in Europe as well as options to provide renewable electricity to railway operators.

Moving towards sustainable mobility requires both integrated and efficient transport systems as well as secure and clean energy. Modal shifts to rail can be a major driver for decarbonisation of the transport sector, and the set of data presented in this new edition illustrates this potential.

The IEA and UIC continue to work hand-in-hand to encourage policy makers and railway operators to move toward a sustainable and efficient energy future.

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 Statistics Department, which has collected and managed energy balances and CO_2 emissions data from fuel combustion.

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

A special mention goes to the cooperation of UIC and IEA staff, and in particular to Elodie Arlaud (IEA), Nicholas Craven, Andrea Braschi and Snejana Markovic-Chenais (UIC).

A special thanks to the Sustainable Development Foundation for its technical support, especially to Daniele Arena, Raimondo Orsini, Andrea Barbabella and Valeria Gentili.

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Railway Handbook 2013

Energy Consumption and CO_2 Emissions

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Introduction

After the excellent reception of the Railway Handbook 2012 on Energy Consumption and CO_2 Emissions published last year, the International Energy Agency and the International Union of Railways have decided to strengthen their collaboration and publish a new Handbook every year.

In this edition, several significant improvements have been made, even if the level of detail for energy and CO_2 data of non-European operators has not yet reached the standard of the European Database. Together with updates of the most significant facts and figures from last year's Handbook, new insights have been added for several countries and regions, including the USA, Japan and the countries known as BRICS (Brazil, Russia, India, China and South Africa).

An entire new "World" section has also been introduced, with global trends and statistics on railway transport activity, energy consumption and CO_2 emissions. At the EU level, a high degree of data detail has permitted the introduction of a special focus on Energy Mix, showing the sources of energy used by railways in Europe.

This publication combines UIC and IEA data: UIC Statistics (UIC, 2012a) and the UIC Energy and CO_2 Database (UIC, 2012b) are pooled with IEA World Energy Balances (IEA, 2012b) and CO_2 Emissions from Fuel Combustion (IEA, 2012a) to get a consolidated vision of the railway sector. Further additions come from IEA infrastructure analysis (IEA, 2013) and the IEA Mobility Model, which allows projections on energy and emissions for the global transport sector.

The data collected in this year's Handbook shows how shifting to rail would benefit sustainable mobility: worldwide, railways generate only 3% of transport CO_2 emissions, while sustaining more than 9% of total transport activity. Rail energy efficiency and emissions are also constantly improving: worldwide rail energy consumption and CO_2 emissions per passenger-kilometre shrank by more than 30% between 2000 and 2010, according to the data released in this handbook.

This is partly due to the continued electrification of railways as more than one-third of energy consumed by railways in the world is now electricity. The special focus on Energy Mix in Europe allows the reader to look in more depth as to how much this increasing share of energy comes from sustainable sources.

The good news is that the EU railway sector has already surpassed the target set by EU directives, which requires 10% of renewable energy to be used in transport by 2020. Railways in 2010 already used nearly 20% of renewables in their energy mix. The Handbook shows how different countries are dealing with renewables in their electricity use, together with some case studies of electricity supply from national railway operators.

The IEA and the UIC are undertaking a significant effort to widen the scope of their environmental data collection and to gather data from railways all over the world. The ultimate goal is to provide policy makers with continuously improved indicators on which to build choices towards sustainable mobility – thanks to editions of the Handbook that will be more accurate and comprehensive each year.

Part I: The Railway Sector Main data

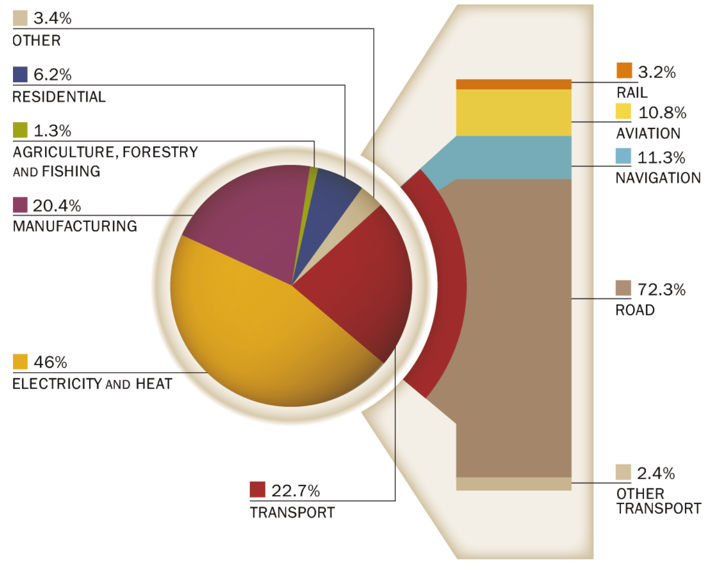
World

Key facts[1]

- India and China move more railway passenger-kilometres than the rest of the world combined (61% of total). For freight, 52% of railway tonne-kilometres are moved in North America and Russia.
- Nearly 50% of the world's railway lines are in North America and the European Union. China and India together have 12.5% of the world's railway lines.
- A quarter of the world's railway lines are electrified; nearly none of them in North America. In India 30% of the network is electrified and in China 50%.
- From 2000 to 2010, paved roads grew in length by 32% while railway lines decreased by 3% globally.
- High-speed lines are constantly growing, but they only represent around 1% of total railway lines. China currently has nearly half of the world's high-speed lines in operation.
- More than one-third of energy use in railways comes from electricity.
- From 1975 to 2010, energy consumption per passenger-km decreased by 63% (35% between 2000 and 2010); energy consumption per freight tonne-km decreased by 52% (18% between 2000 and 2010).
- Energy consumption and CO_2 emissions per passenger-km are consistently lower in India and China than in Europe or USA, mainly due to higher passenger load factors.
- The transport sector is responsible for 23% of the total energy-related CO_2 emissions, of which 3% is due to rail activity. Therefore railways generate less than 1% of total energy-related CO_2 emissions.
- CO_2 emissions per passenger-km went down by 32% in the period 2000-2010; CO_2 emissions per freight tonne-km shrunk by 18% in the same period.

[1] If not otherwise specified, data is related to the year 2010

Fig. 1: Share of CO_2 emissions from fuel combustion by sector, 2010



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

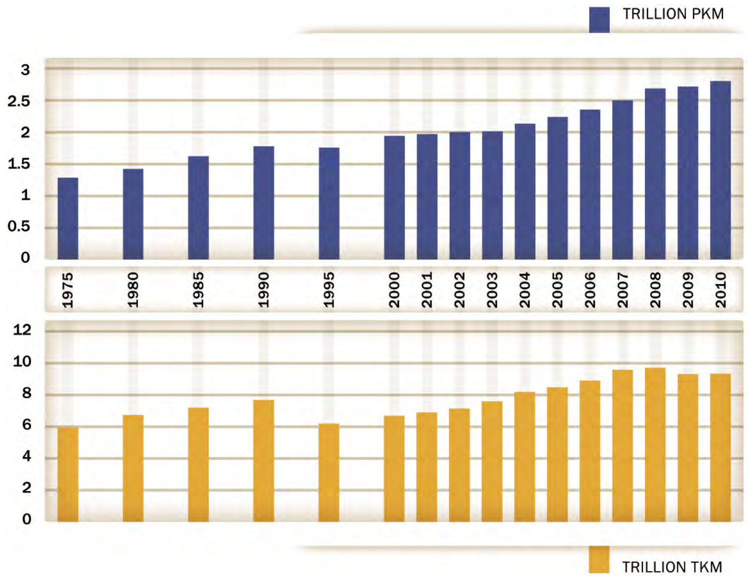
Source: Elaboration by Susdef based on IEA (2012a), IEA (2012b), IPCC (2006) and IEA (2008)

Table 1: World transport modal share, 2010

	Passenger PKM	Freight TKM	Total TU
ROAD	83.1%	10.0%	33.7%
NAVIGATION	0.3%	79.3%	53.8%
RAIL	6.5%	10.4%	9.2%
AVIATION	10.1%	0.3%	3.3%

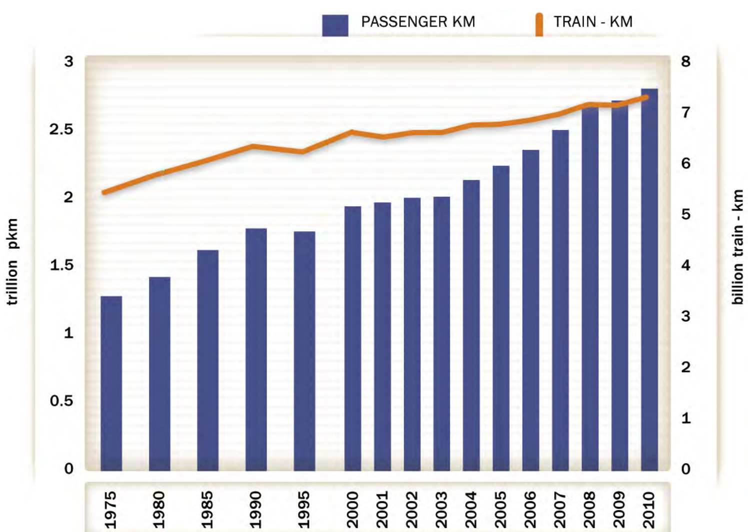
Source: IEA Mobility Model

Fig. 2: **Passenger and freight railway activity, 1975-2010**



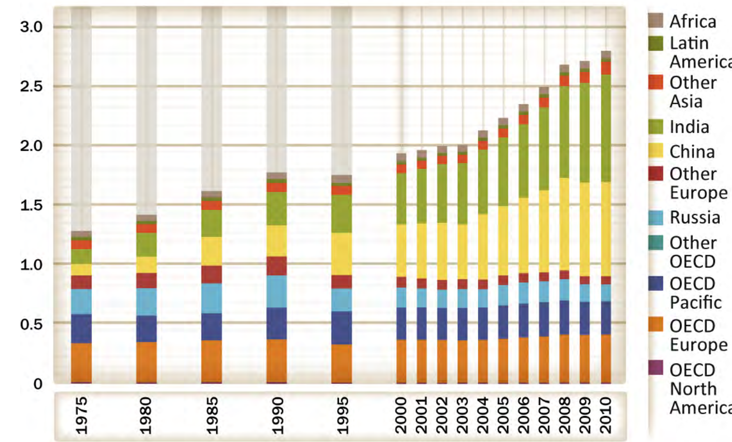
Source: Elaboration by IEA based on UIC (2012a)

Fig. 3: **Railway passenger transport activity, 1975-2010 (pkm and train-km)**



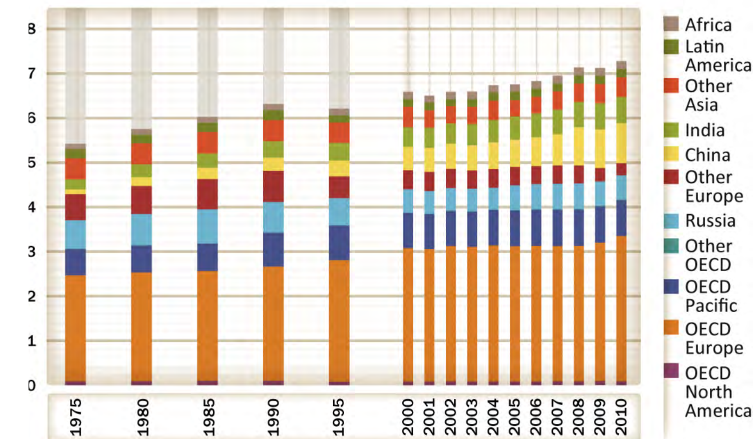
Source: Elaboration by IEA based on UIC (2012a)

Fig. 4: **Railway passenger transport activity by geographic area, 1975-2010 (trillion pkm)**



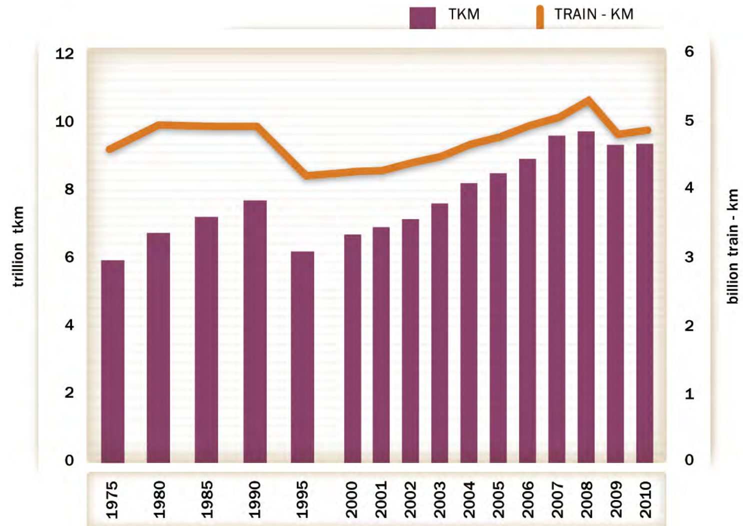
Source: Elaboration by IEA based on UIC (2012a)

Fig. 5: **Railway passenger transport activity by geographic area, 1975-2010 (billion train-km)**



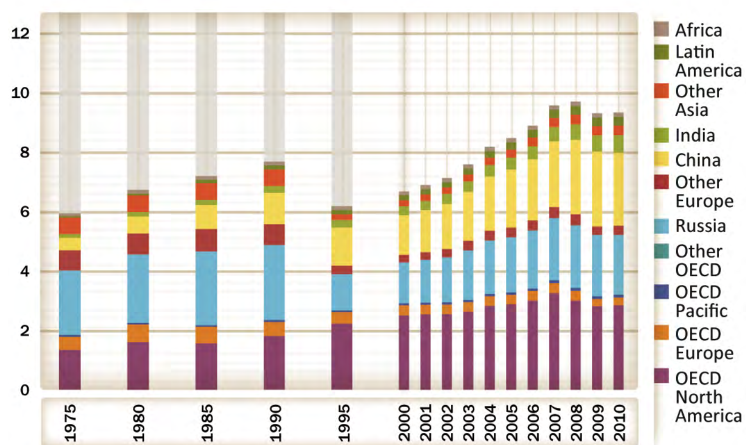
Source: Elaboration by IEA based on UIC (2012a)

Fig. 6: **Railway freight transport activity, 1975-2010 (tkm and train-km)**



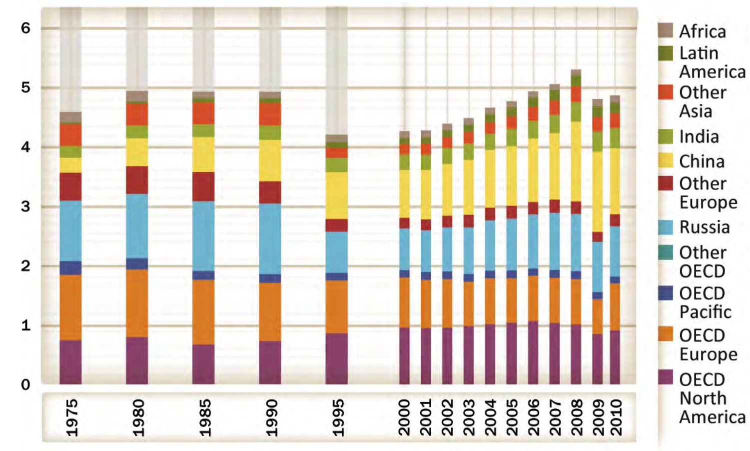
Source: Elaboration by IEA based on UIC (2012a)

Fig. 7: **Railway freight transport activity by geographic area, 1975-2010 (trillion tkm)**



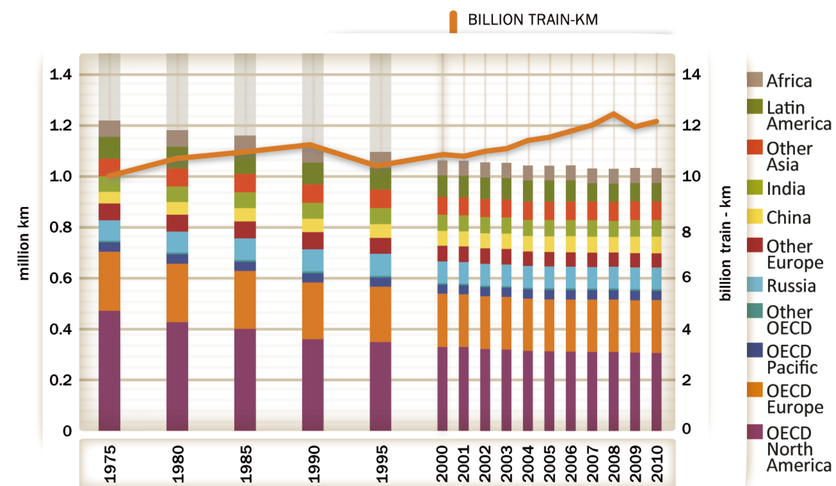
Source: Elaboration by IEA based on UIC (2012a)

Fig. 8: **Railway freight transport activity by geographic area, 1975-2010 (billion train-km)**



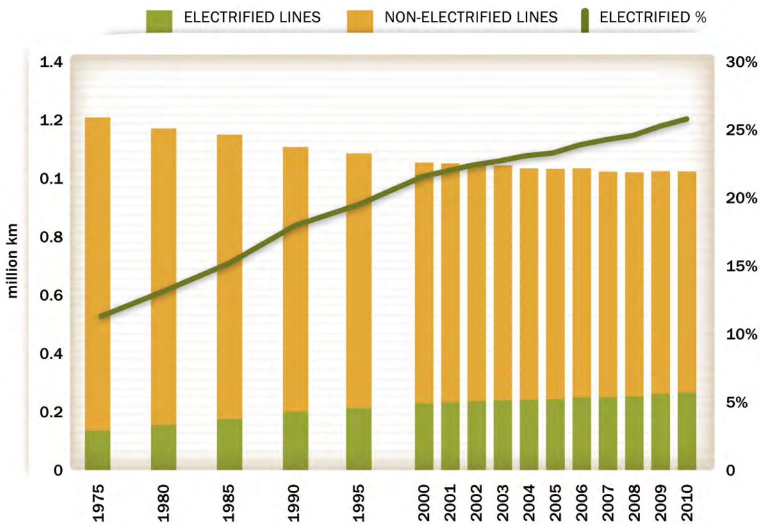
Source: Elaboration by IEA based on UIC (2012a)

Fig. 9: **Length of railway lines in operation by geographic area (milllion km) & total passenger and freight train-km (billion), 1975-2010**



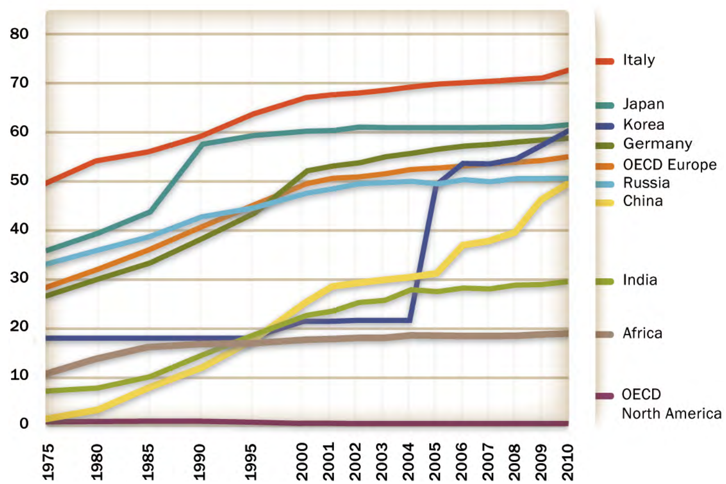
Source: Elaboration by IEA based on UIC (2012a)

Fig. 10: **Length and share of electrified versus non-electrified railway lines, 1975-2010**



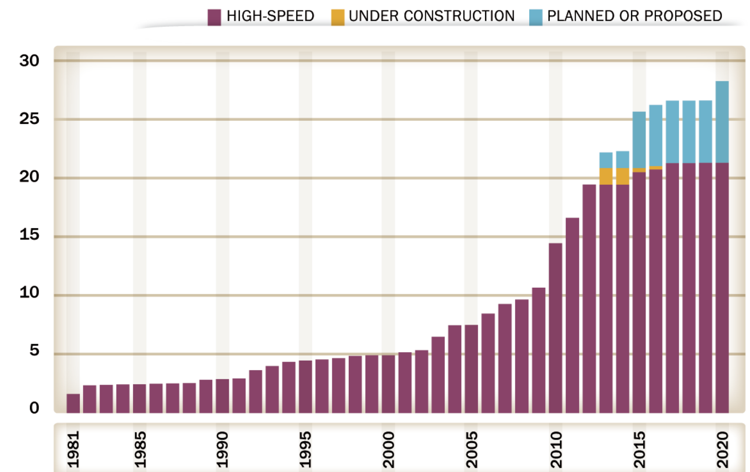
Source: Elaboration by IEA based on UIC (2012a)

Fig. 11: **Share of electrified railway lines in selected countries and geographic areas, 1975-2010 (%)**



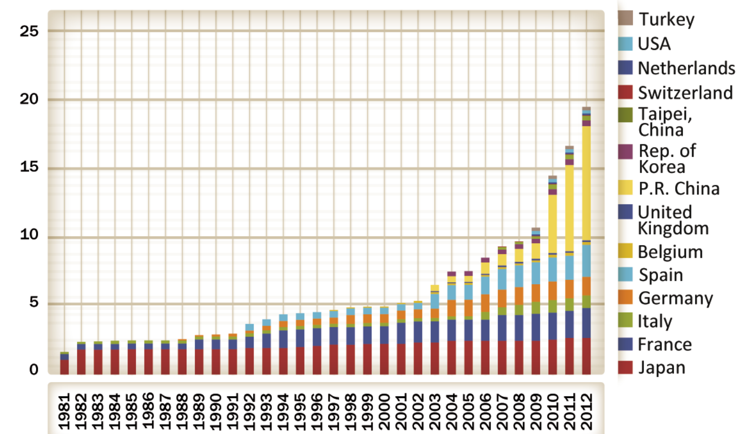
Source: Elaboration by IEA based on UIC (2012a)

Fig. 12: **High-speed lines in operation and forecasted, 1981-2020 (thousand km)**



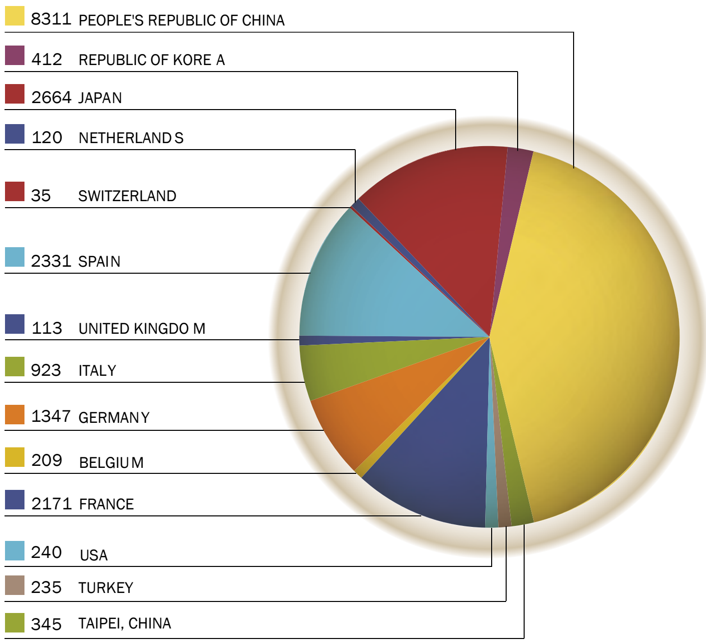
Source: Elaboration by IEA based on (UIC, 2012a)

Fig. 13: **High-speed lines in operation by country, 1981-2012 (thousand km)**



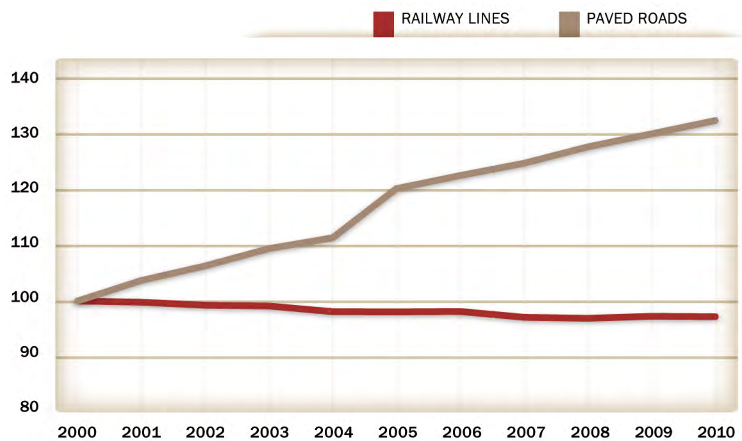
Source: Elaboration by IEA based on (UIC, 2012a)

Fig. 14: **High-speed lines in operation by country (km) and share of world total (%), 2012**



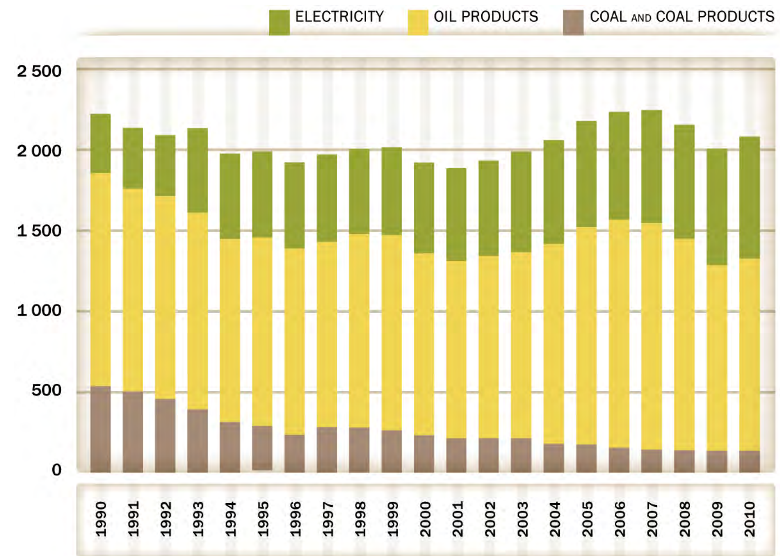
Source: Elaboration by IEA based on (UIC, 2012a)

Fig. 15: **Evolution of paved roads and railway lines, 2000-2010 (km)**



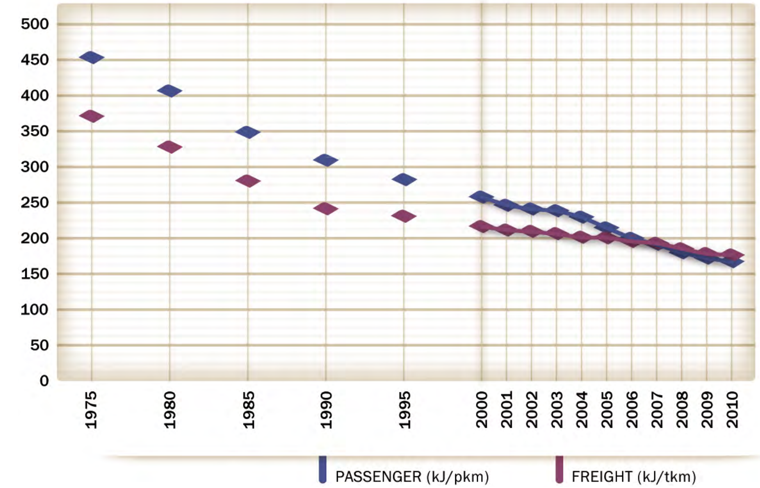
Year 2000=100
Source: Elaboration by Susdef from IEA (2013) and UIC (2012a)

Fig. 16: **Railway energy consumption by fuel, 1990-2010 (PJ)**



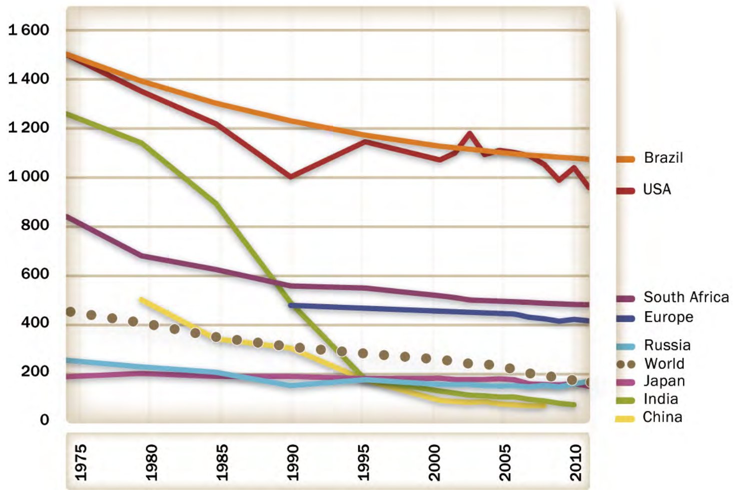
Source: IEA (2012b)

Fig. 17: **Railway specific energy consumption, 1975-2010**



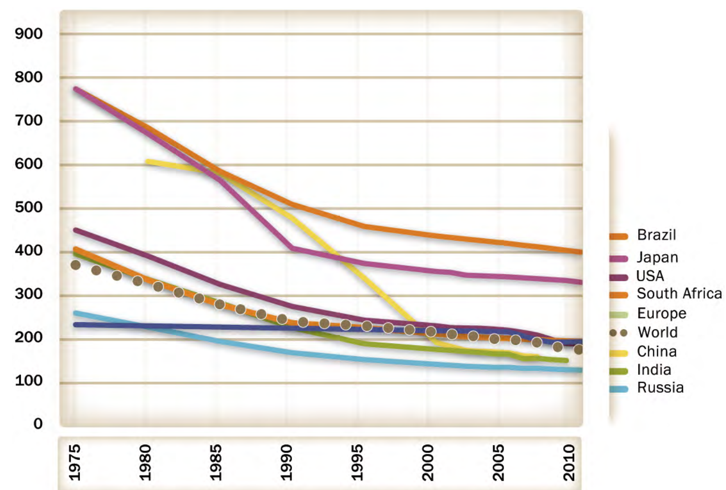
Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Fig. 18: **Railway passenger specific energy consumption in selected countries, 1975-2010 (kJ/pkm)**



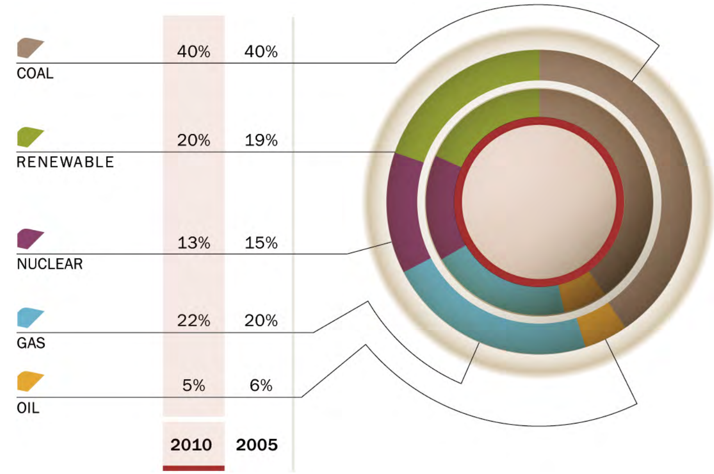
Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Fig. 19: **Railway freight specific energy consumption in selected countries, 1975-2010 (kJ/tkm)**



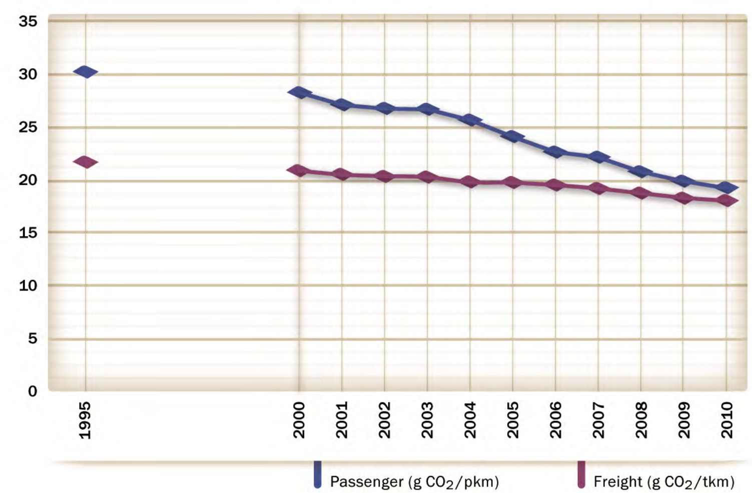
Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Fig. 20: **World electricity mix evolution, 2010 outside – 2005 inside**



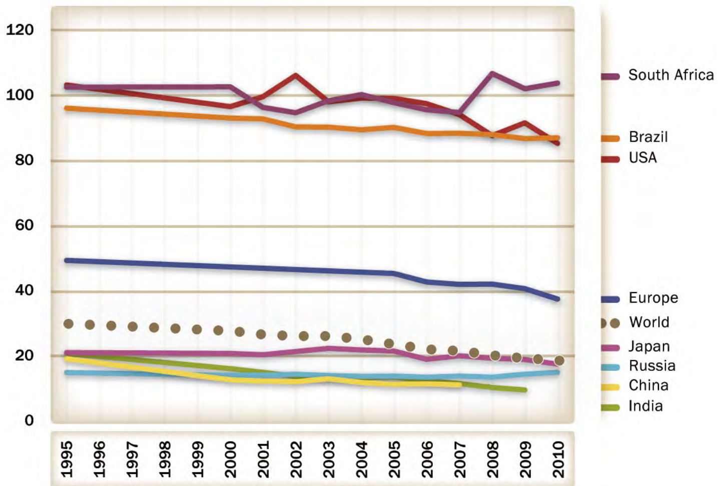
Source: IEA (2012b)

Fig. 21: **Railway specific CO_2 emissions, 1995-2010**



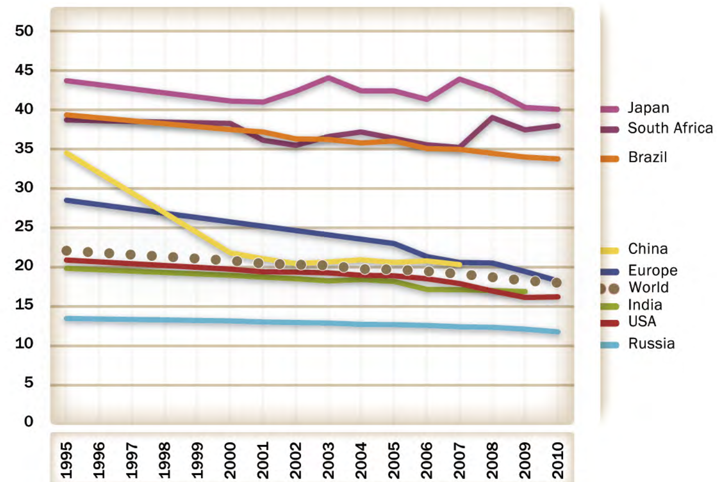
Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Fig. 22: Railway passenger specific CO_2 emissions in selected countries, 1995-2010 (gCO_2/pkm)



Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Fig. 23: Railway freight specific CO_2 emissions in selected countries, 1995-2010 (gCO_2/tkm)



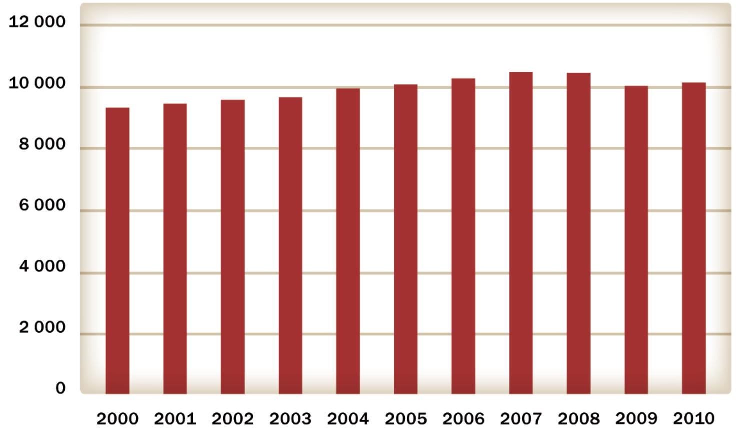
Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Europe (EU27)

Key facts

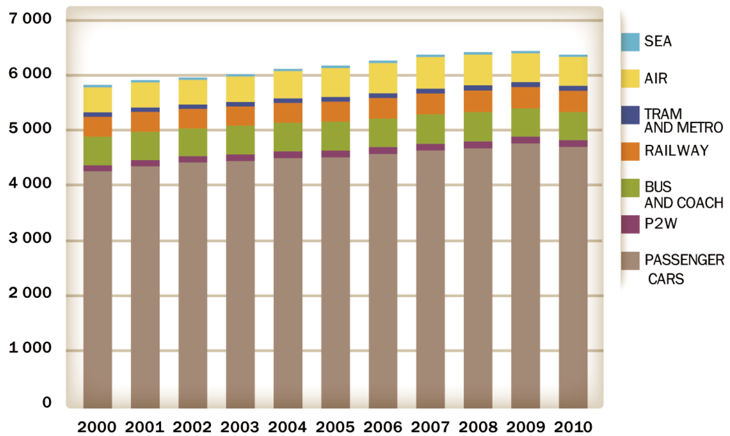
- Freight transport (all modes) recovered in 2010 after the economic crisis of 2009, while passenger activity (all modes) decreased mainly due to the decrease of private car use.
- High-speed passenger rail activity represents more than 26% of total railway activity (growing from 16% in 2000).
- More than 50% of railway lines are electrified.
- From 2000 to 2010, railway lines decreased in length by 2%. In the same timeframe, paved roads increased by 3%.
- More than half of the energy consumed by railways is electricity-related.
- CO_2 emissions from railways are 1.8% of transport emissions (same as 2009) while railways represent 7.4% of transport activity (increased from 7.1% in 2009). The transport sector as a whole has decreased its share of CO_2 emissions from 31.2% of total emissions in 2009 to 30.3% of total emissions in 2010.
- An Italian case study shows that nearly 70% of transport CO_2 emissions are generated for journeys shorter than 50 km.
- European railways have committed to reduce their specific CO_2 emissions by 50% by 2030, compared to baseline year 1990. In 2010, passenger specific emissions were already reduced by 27% and freight specific emissions by 41% compared to 1990.

Fig. 24: **Passenger and freight transport activity, 2000-2010 (billion transport units)**



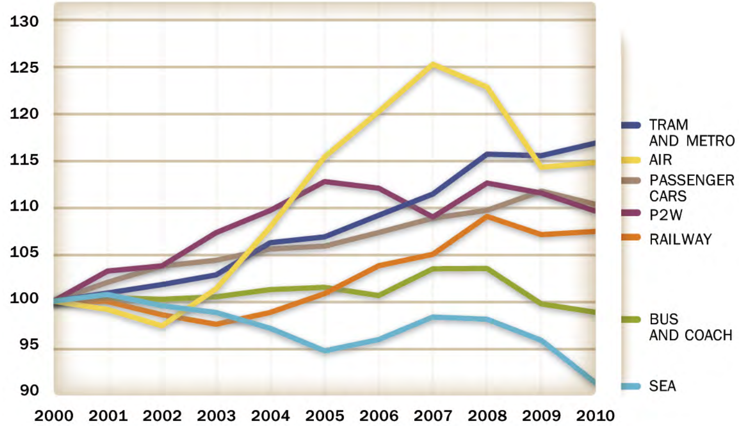
Source: Elaboration by Susdef based on EC (2012) and UIC (2012a)

Fig. 25**: Passenger transport activity by mode, 2000-2010 (billion pkm)**



Source: EC (2012) and UIC (2012a)

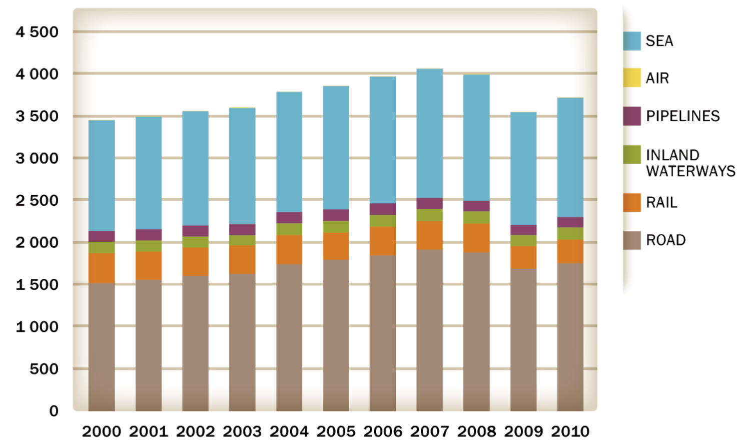
Fig. 26**: Modal evolution of passenger traffic activity, 2000-2010 (pkm)**



Year 2000=100

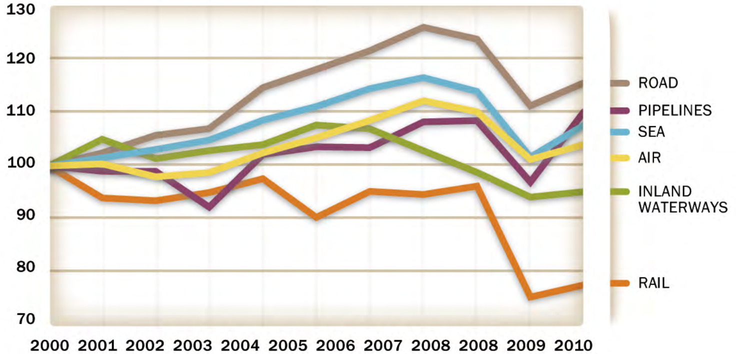
Source: EC (2012) and UIC (2012a)

Fig. 27**: Freight transport activity by mode, 2000-2010 (billion tkm)**



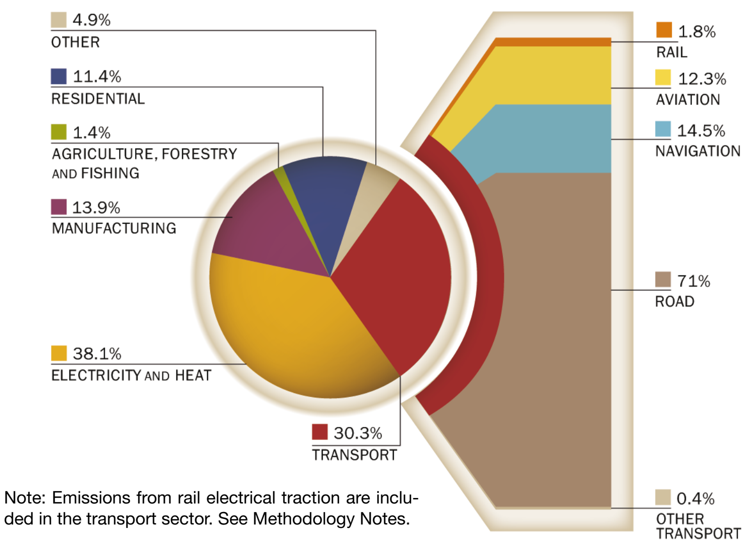
Source: EC (2012) and UIC (2012a)

Fig. 28: **Modal evolution of freight traffic activity, 2000-2010 (tkm)**



Year 2000=100 Source: EC (2012) and UIC (2012a)

Fig. 29: **Share of CO_2 Emissions from fuel combustion by sector, 2010**



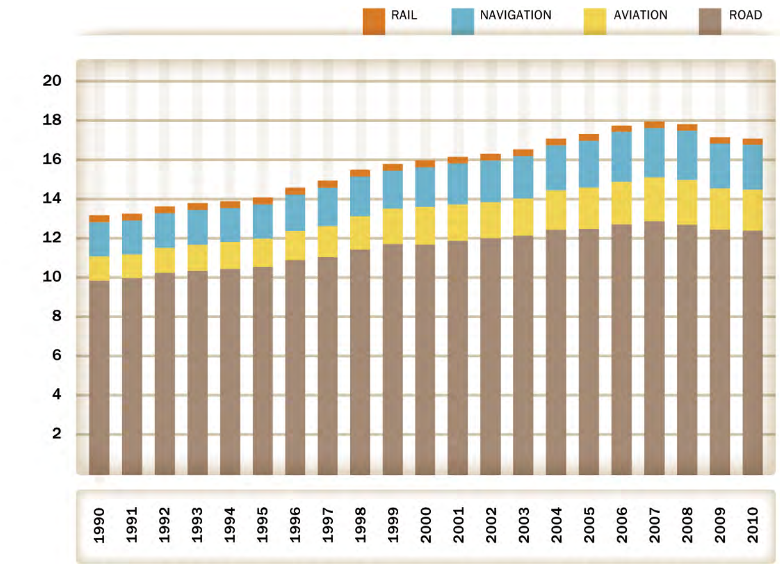
Note: Emissions from rail electrical traction are included in the transport sector. See Methodology Notes.

Source: Elaboration by Susdef based on IEA (2012a) and UIC (2012b)

Table 2: **EU27 transport modal share, 2010**

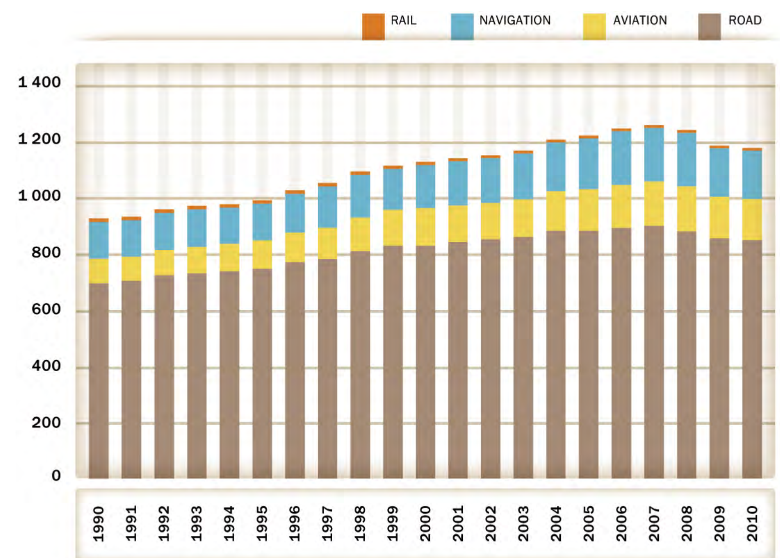
		Passenger PKM	Freight TKM	Total TU
ROAD		83.8%	47.2%	71.1%
NAVIGATION		0.6%	42.0%	15.0%
RAIL		7.4%	7.5%	7.4%
AVIATION		8.2%	0.1%	5.3%
OTHER		0.0%	3.2%	1.2%

Fig. 30: **Transport sector energy consumption by mode, 1990-2010 (EJ)**



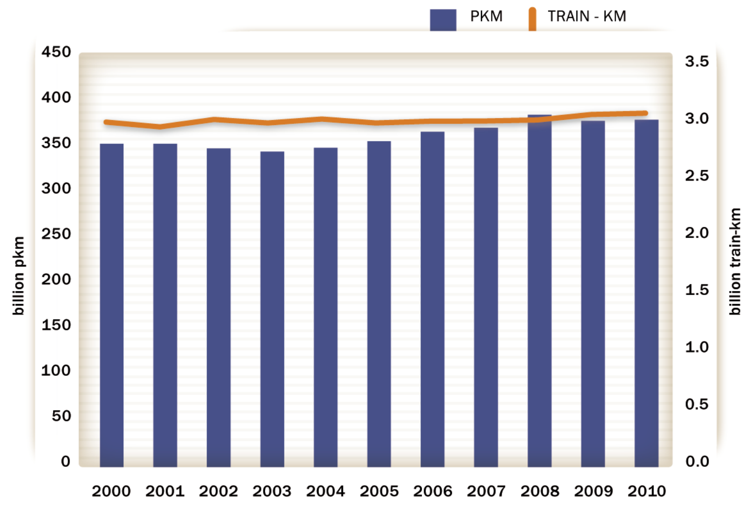
Source: IEA (2012b)

Fig. 31: **Transport sector CO_2 emissions by mode 1990-2010 (million tCO_2)**



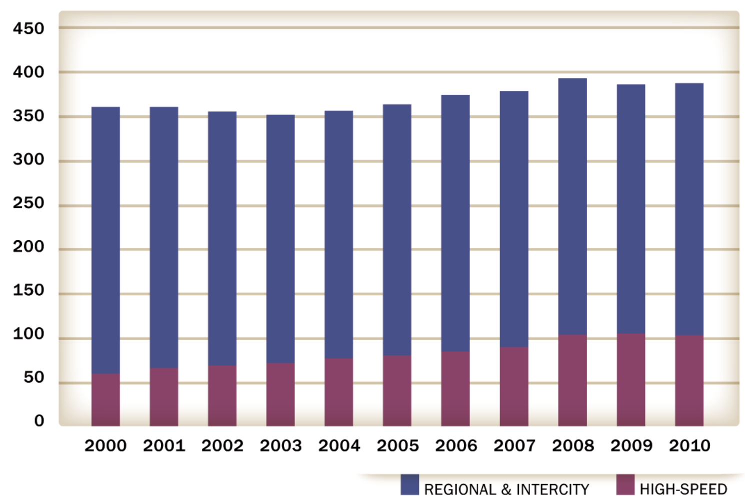
Source: IEA (2012a)

Fig. 32: **Railway passenger transport activity, 2000-2010 (pkm and train-km)**



Source: UIC (2012a)

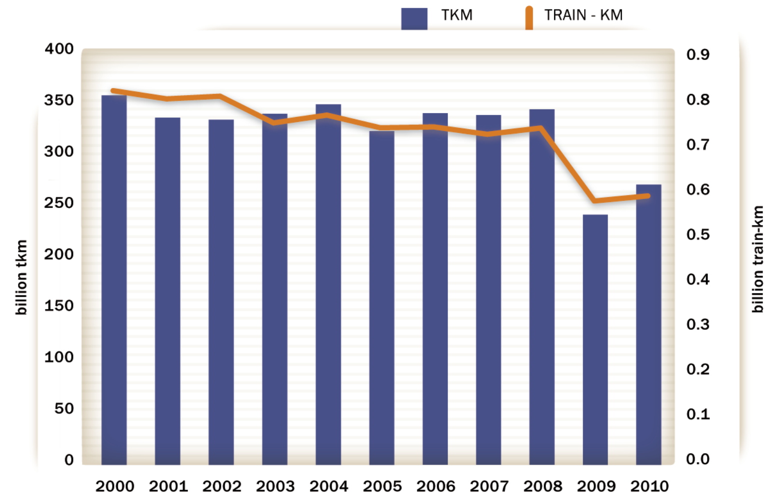
Fig. 33: **Railway passenger transport activity by service type, 2000-2010 (billion pkm)**



Note: Urban rail (tram and metro) is not included.

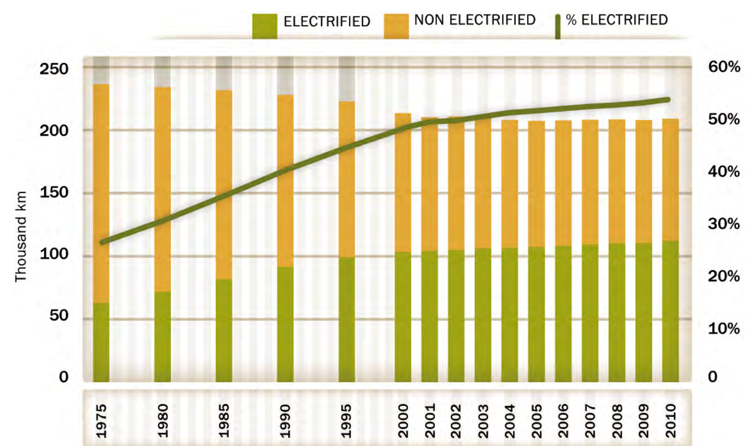
Source: Elaboration by Susdef based on UIC (2012a)

Fig. 34: **Railway freight transport activity, 2000-2010 (tkm and train-km)**



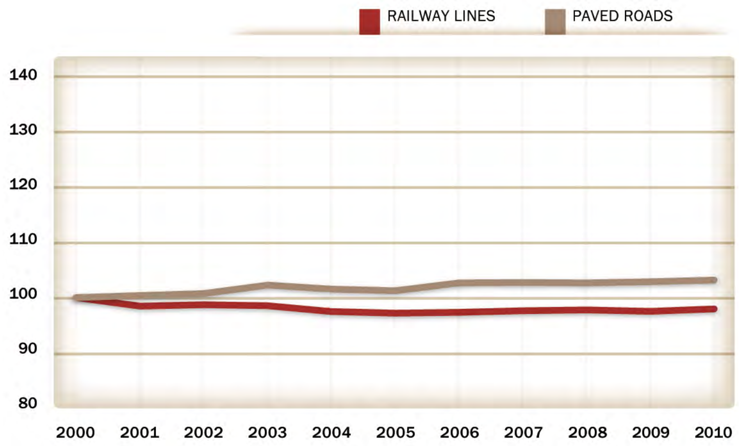
Source: UIC (2012a)

Fig. 35: **Length and share of electrified versus non-electrified railway lines, 1975-2010**



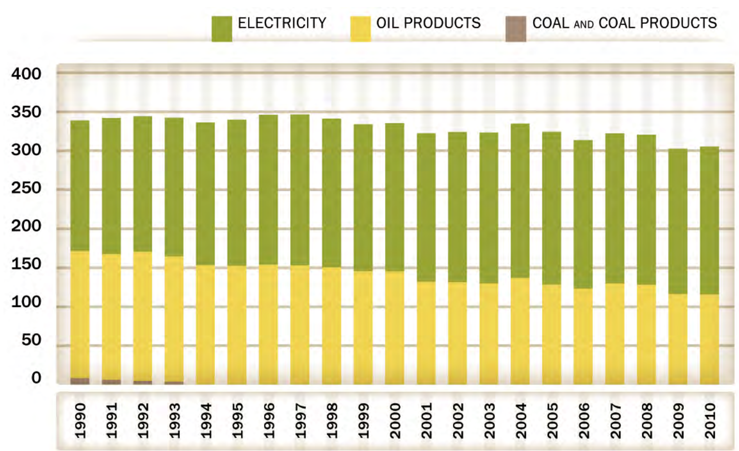
Source: Elaboration by IEA based on UIC (2012a)

Fig. 36: **Evolution of paved roads and railway lines, 2000-2010 (km)**



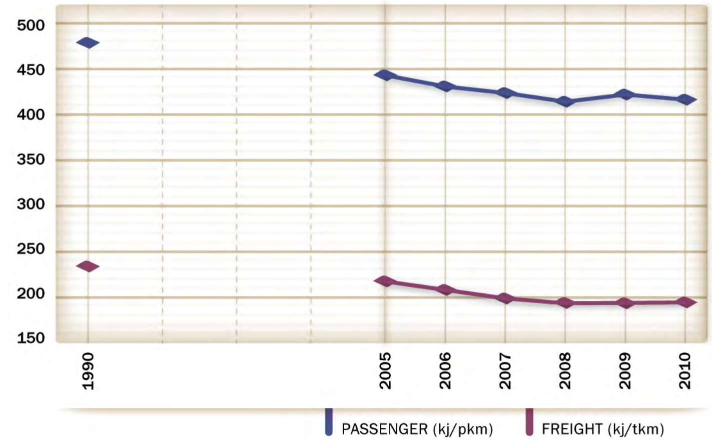
Year 2000=100
Source: Elaboration by Susdef from IEA (2013) and UIC (2012a)

Fig. 37: **Railway energy consumption by fuel, 1990-2010 (PJ)**



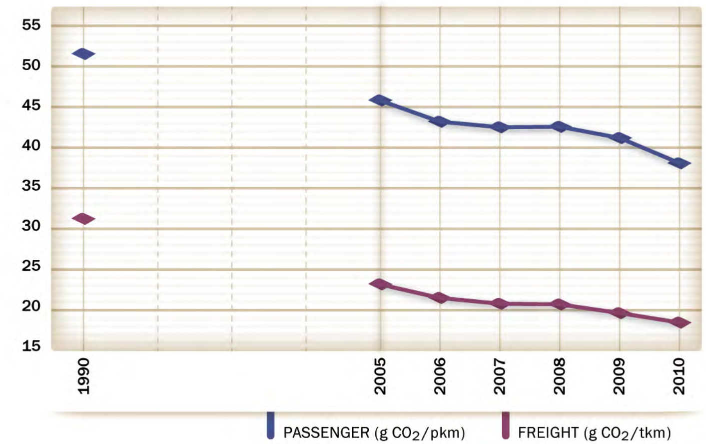
Source: IEA (2012b)

Fig. 38: **Railway specific energy consumption, 1990-2010**



Source: UIC (2012b)

Fig. 39: **Railway specific CO_2 emissions, 1990-2010**



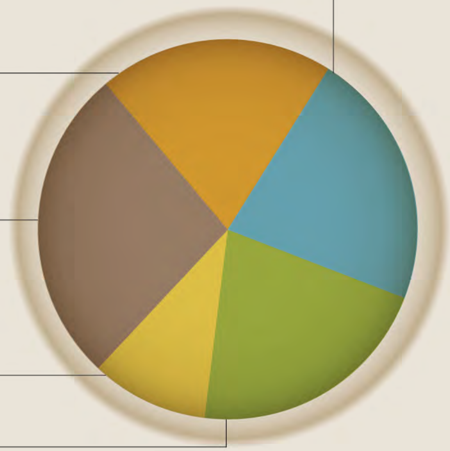
Source: UIC (2012b)

Case Study:
Passenger CO_2 Emissions by Distance in Italy

An Italian study conducted by the Sustainable Development Foundation on behalf of the Italian Ministry for Environment shows that nearly 70% of passenger transport emissions are generated to cover distances shorter than 50 km.

This is an argument to develop strategies to avoid emissions, improve vehicles efficiency and shift transport to more efficient modes, especially for short distances. In particular, development of urban rail transport for commuters can contribute to modal shift from private cars, leading to a potential reduction of 15-20% of emissions produced by private vehicles in urban areas.

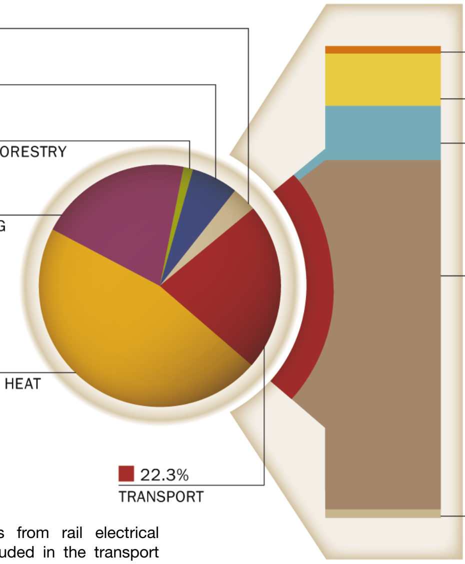
Fig. 40: **Share of passenger transport CO_2 emissions by distance of trip, Italy 2010**



Source: Susdef (2013)

USA

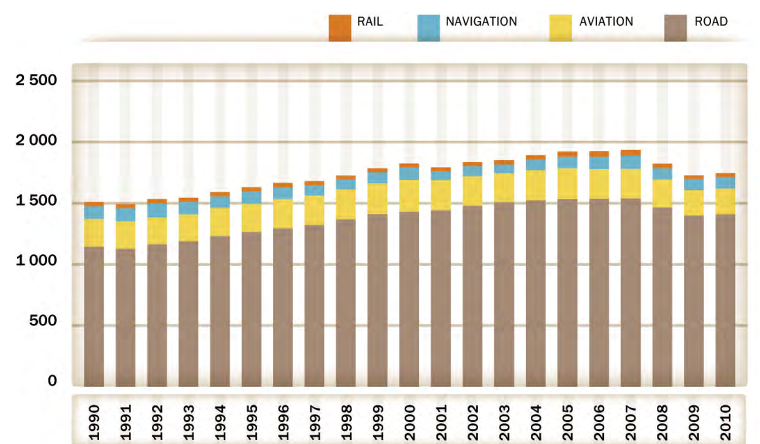
Fig. 41: **Share of CO_2 emissions from fuel combustion by sector, 2010**



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

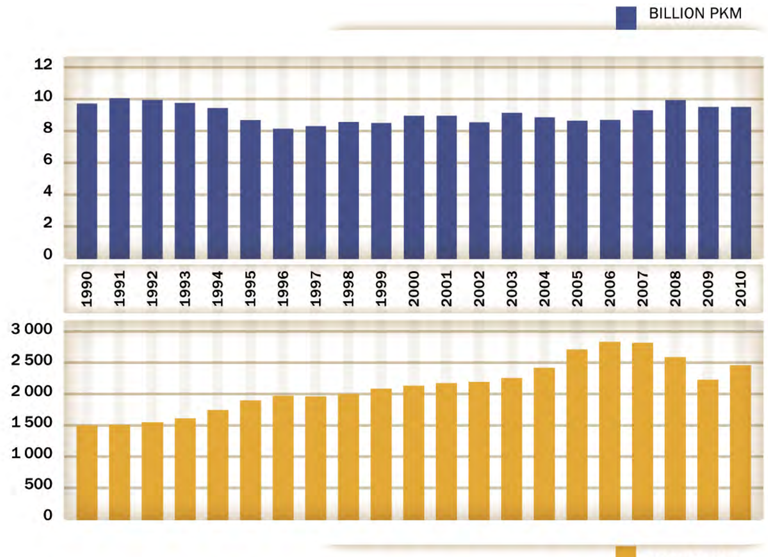
Source: Elaboration by Susdef based on IEA (2012a), IEA (2012b), IPCC (2006) and IEA (2008).

Fig. 42: **Transport CO_2 emissions by mode, 1990-2010 (million tCO_2)**



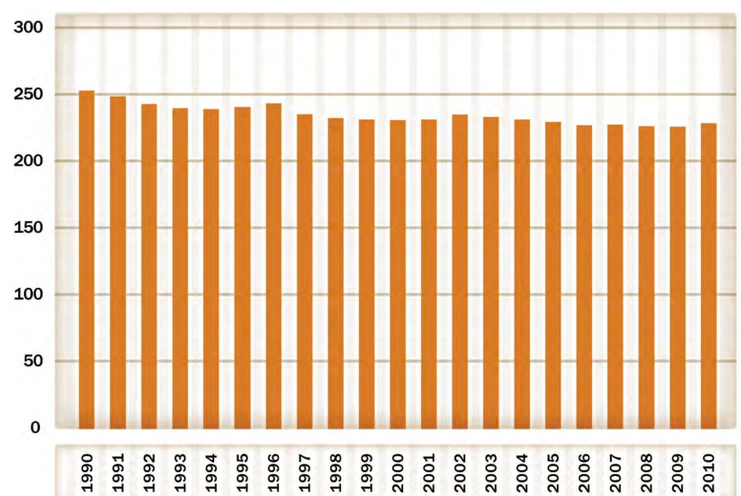
Source: IEA (2012a)

Fig. 43: **Passenger and freight railway activity, 1990-2010**



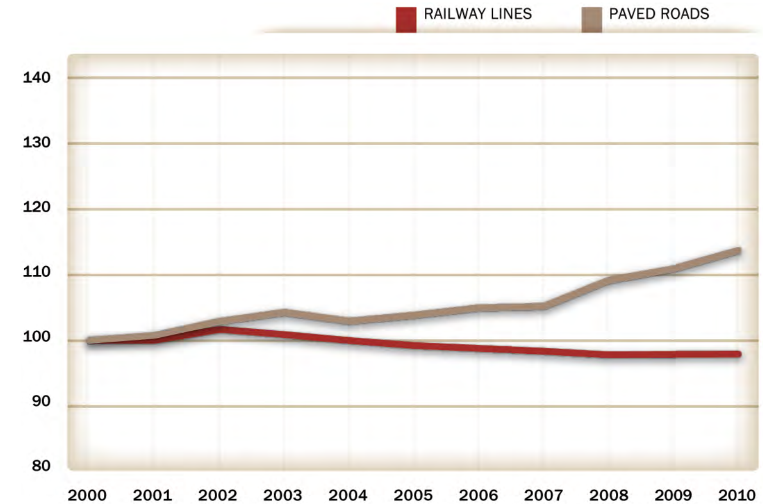
Source: UIC (2012a)

Fig. 44: **Length of railway lines, 1990-2010 (thousand km)**



Source: UIC (2012a)

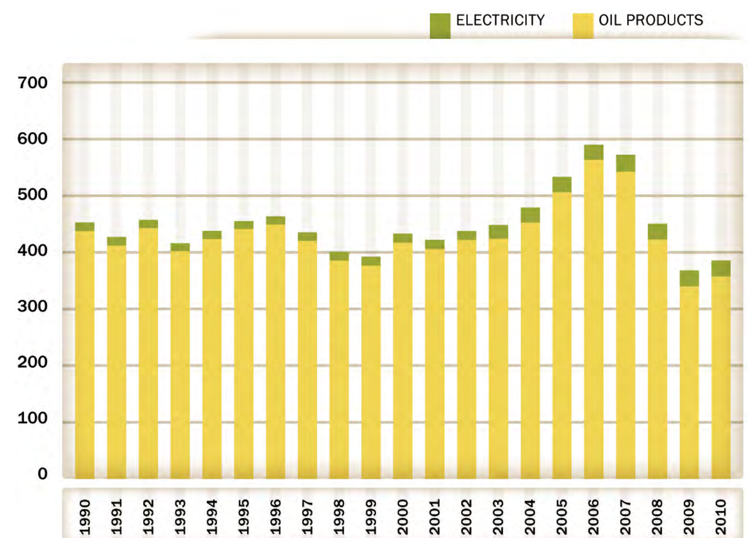
Fig. 45: **Evolution of paved roads and railway lines, 2000-2010 (km)**



Year 2000=100

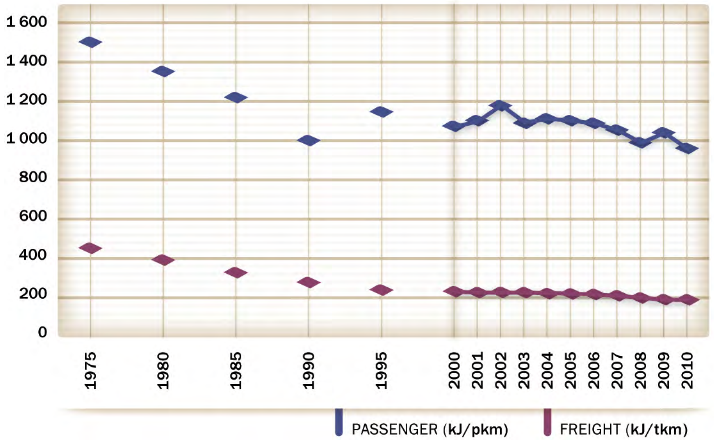
Source: Elaboration by Susdef from IEA (2013) and UIC (2012a)

Fig. 46: **Railway energy consumption by fuel, 1990-2010 (PJ)**



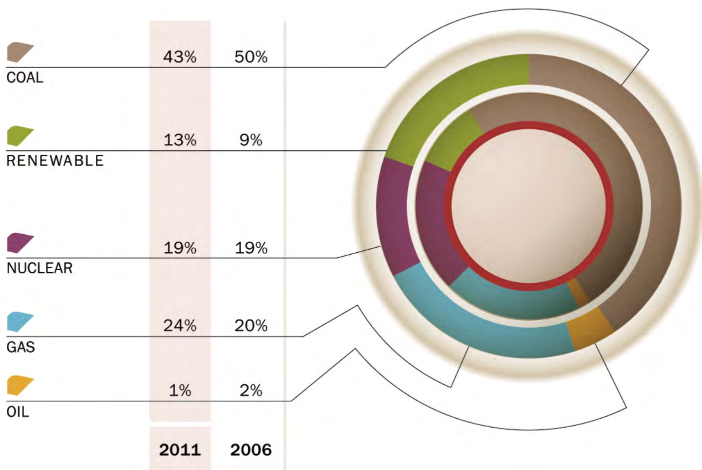
Source: IEA (2012b)

Fig. 47: **Railway specific energy consumption, 1975-2010**



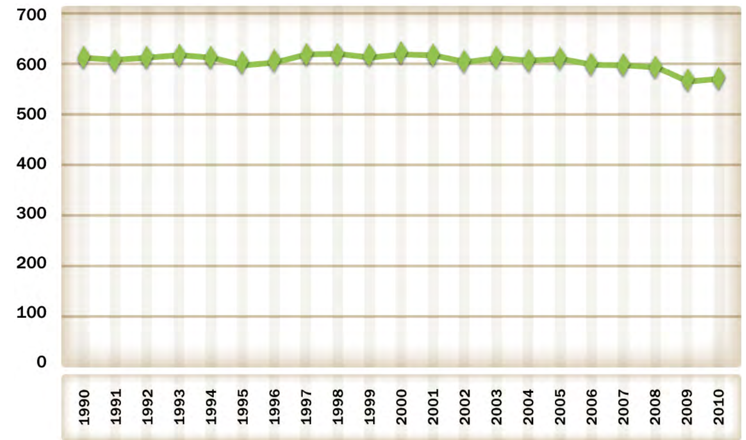
Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Fig. 48: **National electricity production mix evolution, 2011 outside – 2006 inside**



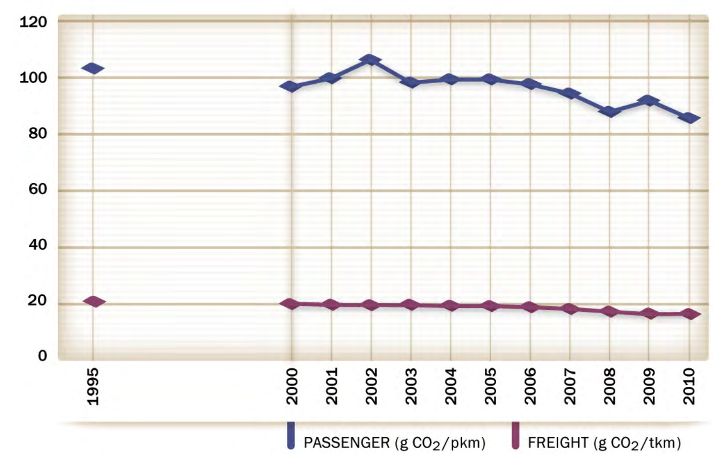
Source: IEA (2012b)

Fig. 49: **National CO_2 emission factor from electricity production mix, 1990-2010 (gCO_2/kWh)**



Source: Elaboration by Susdef based on IEA (2012b), IPCC (2006) and IEA (2008).

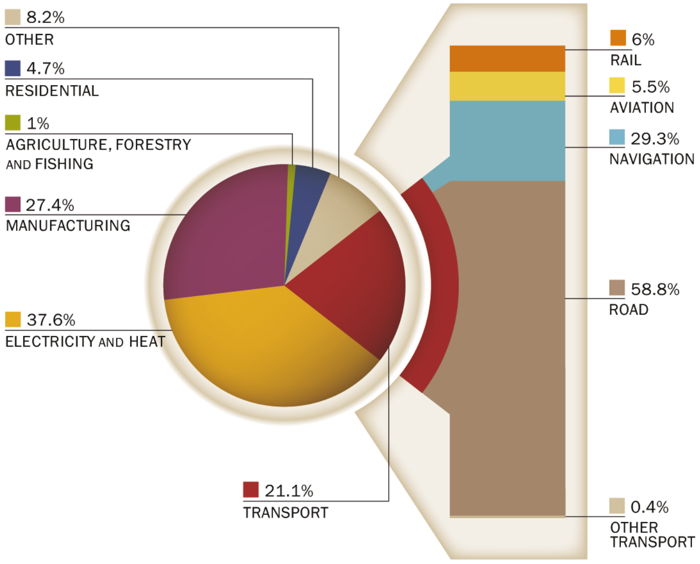
Fig. 50: **Railway specific CO_2 emissions, 1995-2010**



Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Japan

Fig. 51: **Share of CO_2 emissions from fuel combustion by sector, 2010**



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

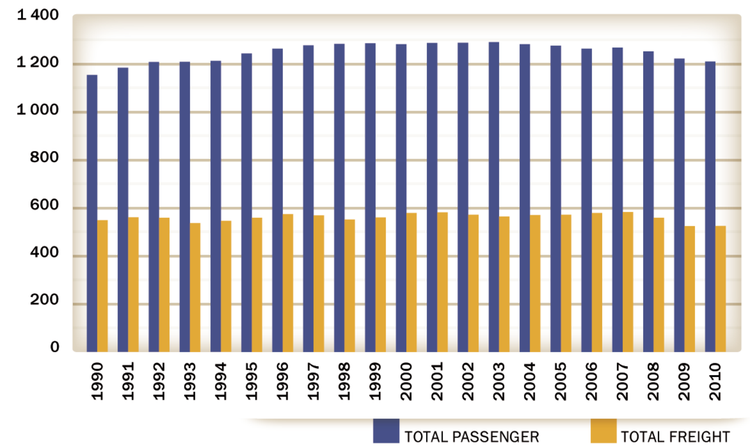
Source: Elaboration by Susdef based on IEA (2012a), IEA (2012b), IPCC (2006) and IEA (2008).

Table 3: **Japan transport modal share, 2010**

	Passenger PKM	Freight TKM	Total TU
ROAD	73.1%	61.5%	69.6%
NAVIGATION	0.3%	34.4%	4.5%
RAIL	20.3%	3.9%	10.6%
AVIATION	6.3%	0.2%	15.3%

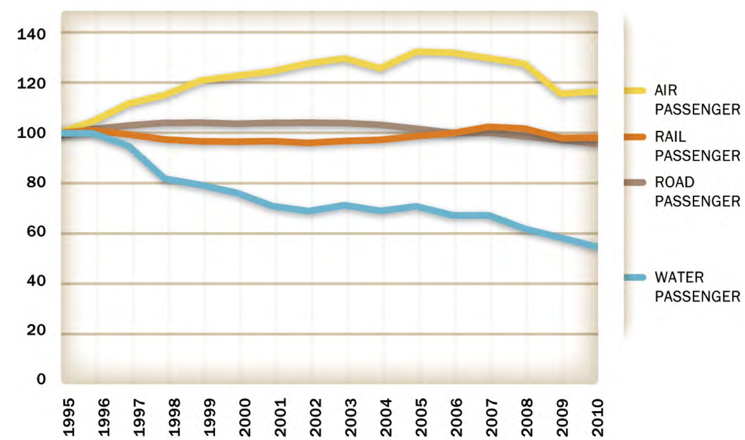
Source: OECD (2013), UIC (2012a), JSB (2012) and JMLIT (2012)

Fig. 52: **Passenger and freight transport activity, 1990-2010 (billion pkm and tkm)**



Source: OECD (2013), UIC (2012a), JSB (2012) and JMLIT (2012)

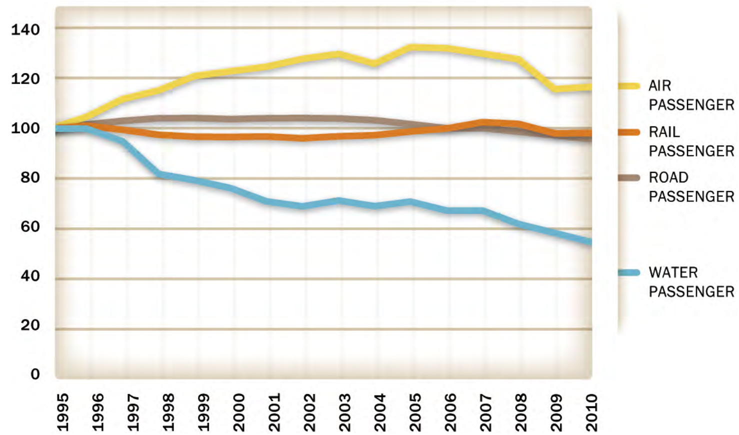
Fig. 53: **Modal evolution of passenger traffic activity, 1995-2010 (pkm)**



Year 1995=100

Source: OECD (2013), UIC (2012a), JSB (2012) and JMLIT (2012)

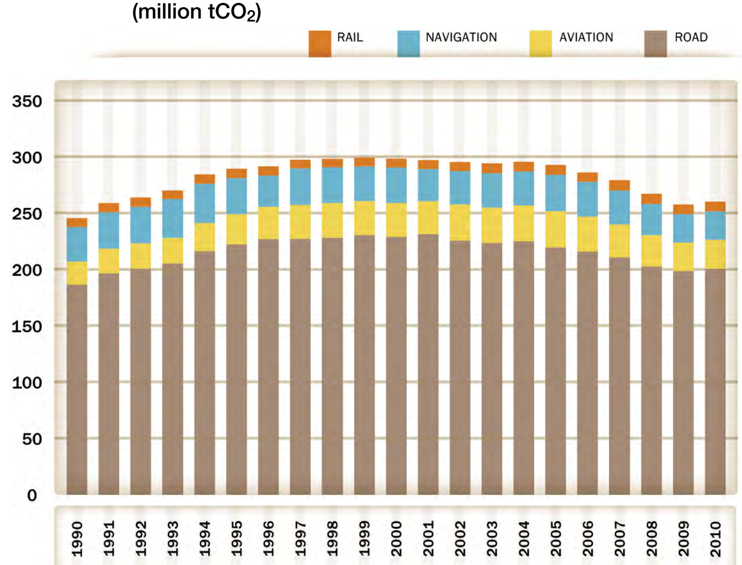
Fig. 54: **Modal evolution of freight traffic activity, 1995-2010 (tkm)**



Year 1995=100

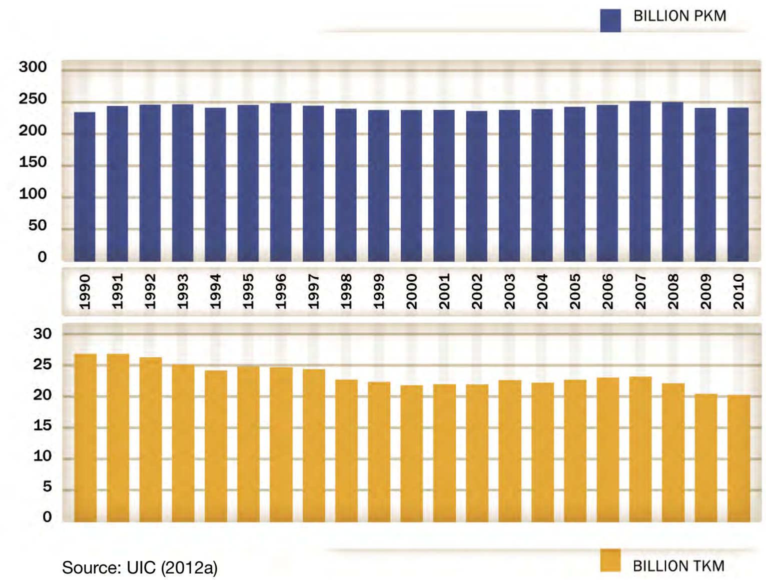
Source: OECD (2013), UIC (2012a), JSB (2012) and JMLIT (2012)

Fig. 55: **Transport sector CO_2 emissions by mode, 1990-2010 (million tCO_2)**



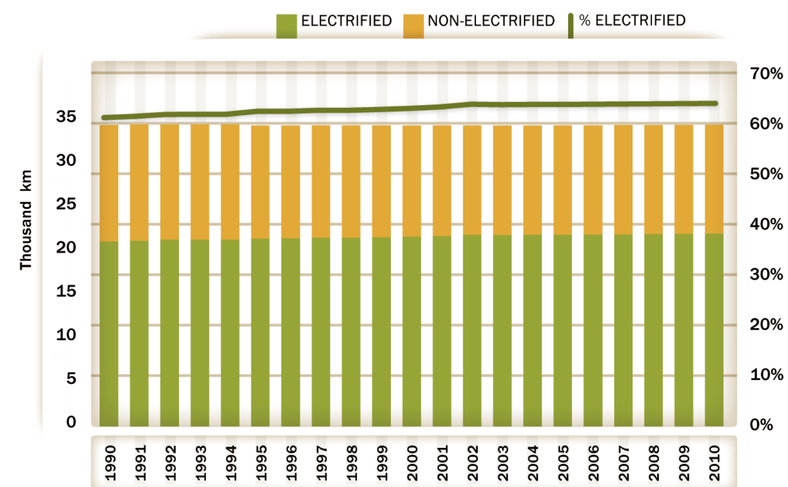
Source: IEA (2012a)

Fig. 56: **Passenger and freight railway activity, 1990-2010**



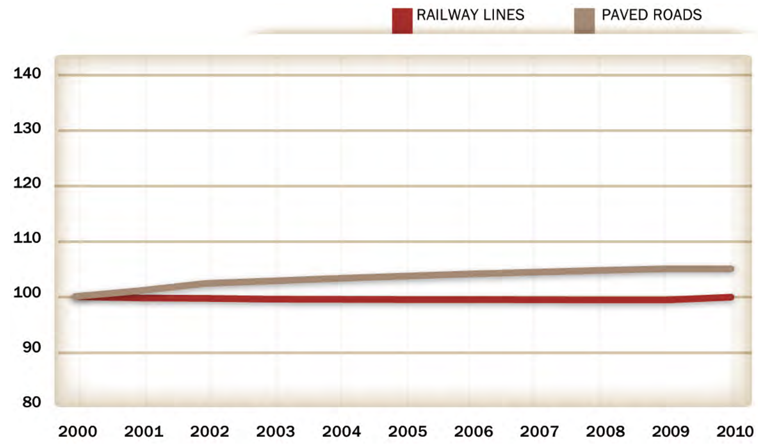
Source: UIC (2012a)

Fig. 57: **Length and share of electrified versus non-electrified railway lines, 1990-2010**



Source: UIC (2012a)

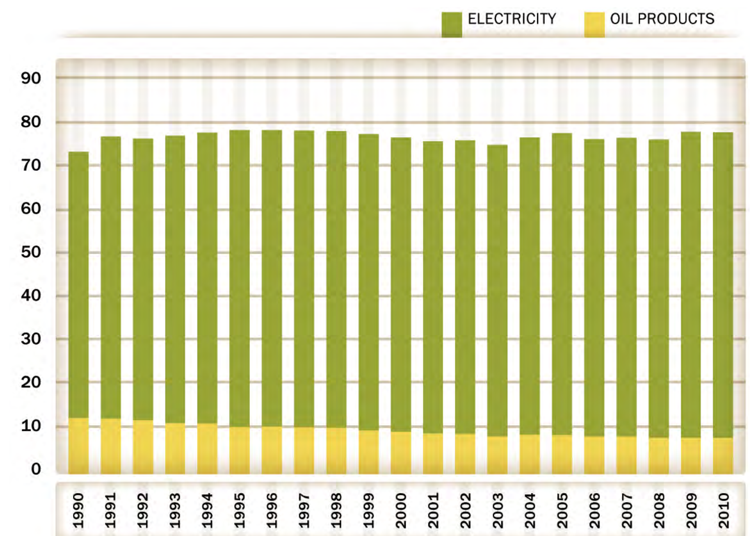
Fig. 58: **Evolution of paved roads and railway lines, 2000-2010 (km)**



Year 2000=100

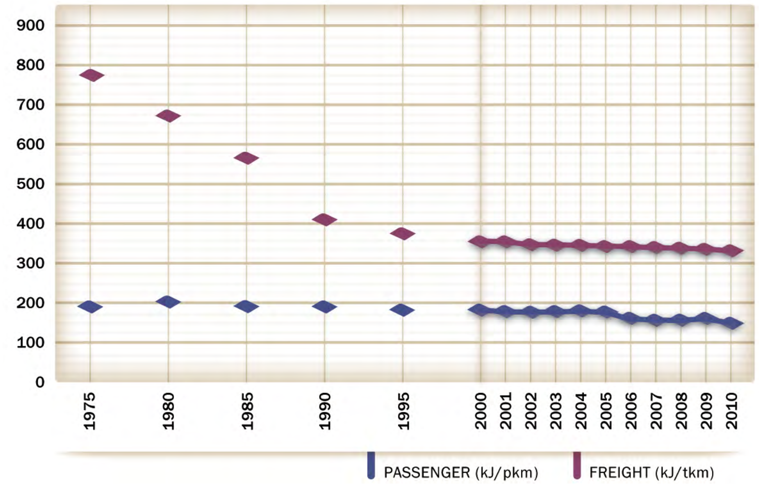
Source: Elaboration by Susdef from IEA (2013) and UIC (2012a)

Fig. 59: **Railway energy consumption by fuel, 1990-2010 (PJ)**



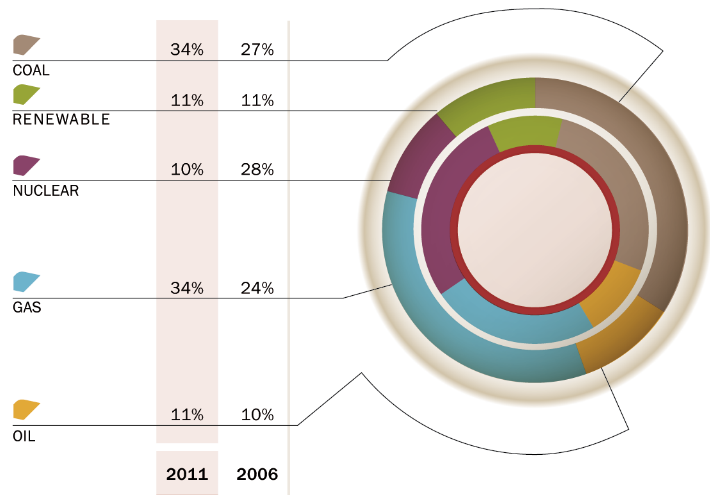
Source: IEA (2012b)

Fig. 60: **Railway specific energy consumption, 1975-2010**



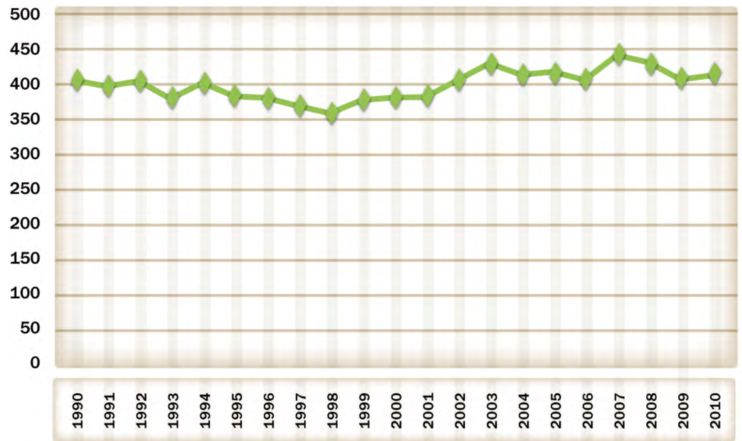
Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Fig. 61: **National electricity production mix evolution, 2011 outside – 2006 inside**



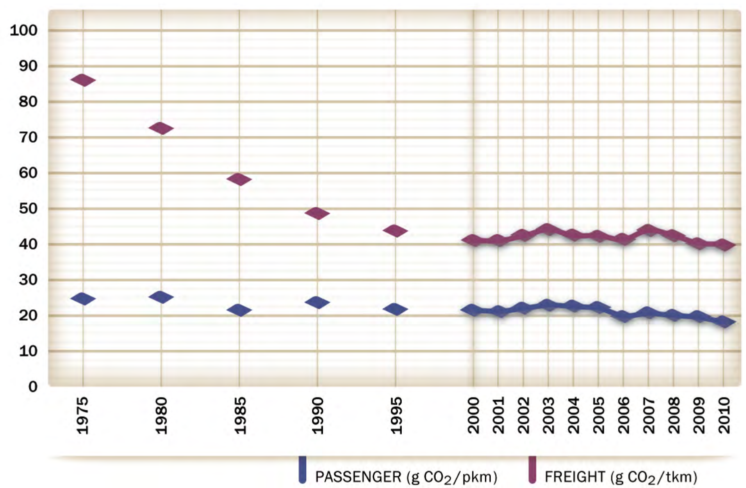
Source: IEA (2012b)

Fig. 62: **National CO_2 emission factor from electricity production mix, 1990-2010 (gCO_2/kWh)**



Source: Elaboration by Susdef based on IEA (2012b), IPCC (2006) and IEA (2008).

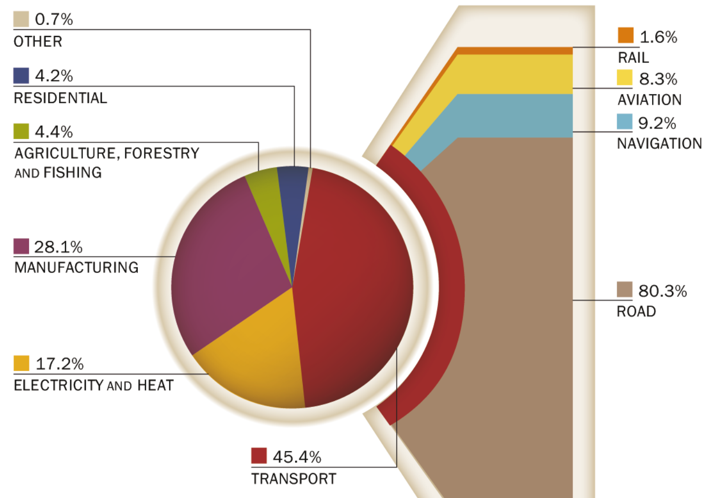
Fig. 63: **Railway specific CO_2 emissions, 1995-2010**



Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Brazil

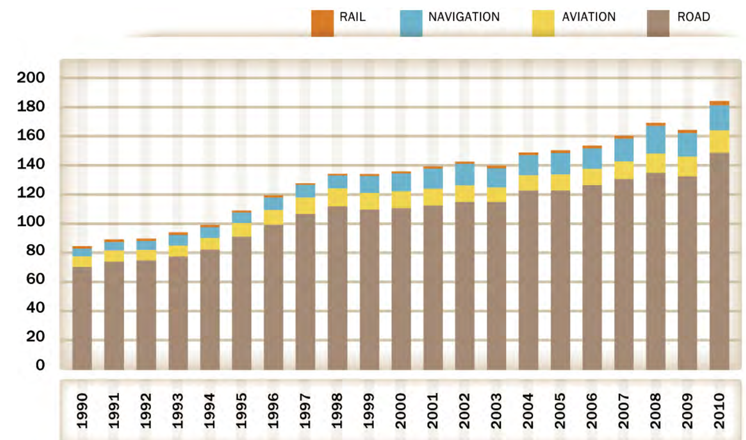
Fig. 64: **Share of CO_2 emissions from fuel combustion by sector, 2010**



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

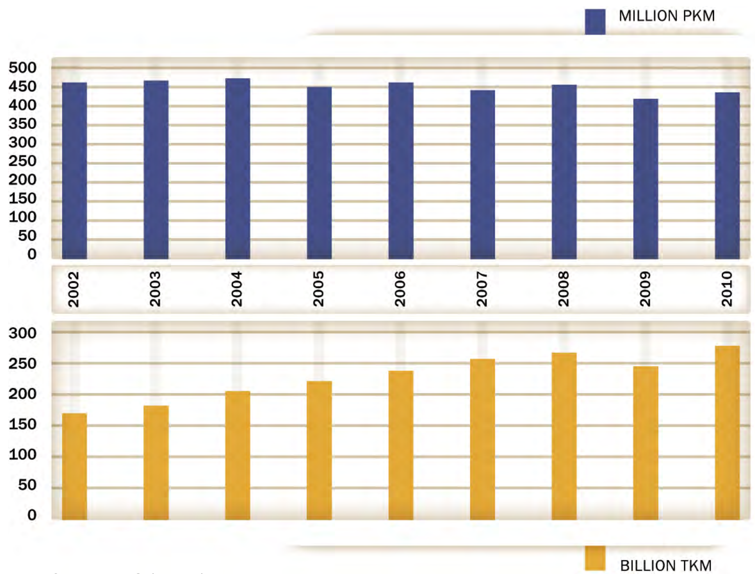
Source: Elaboration by Susdef based on IEA (2012a), IEA (2012b), IPCC (2006) and IEA (2008).

Fig. 65: **Transport sector CO_2 emissions by mode, 1990-2010 (million tCO_2)**



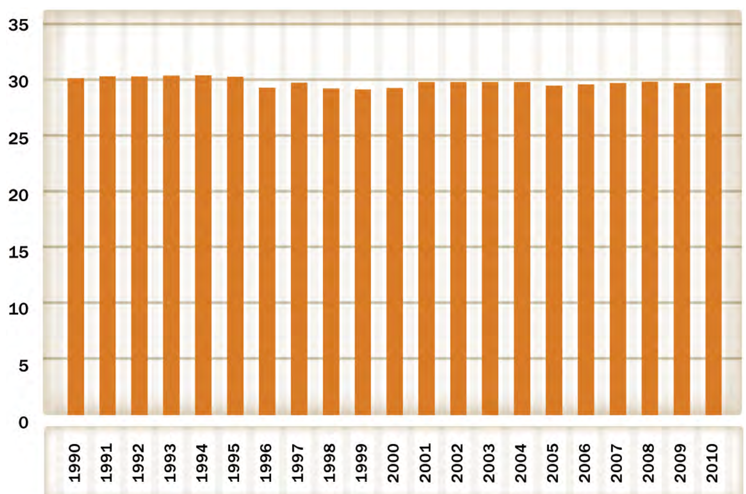
Source: IEA (2012a)

Fig. 66: **Passenger and freight railway activity, 2002-2010**



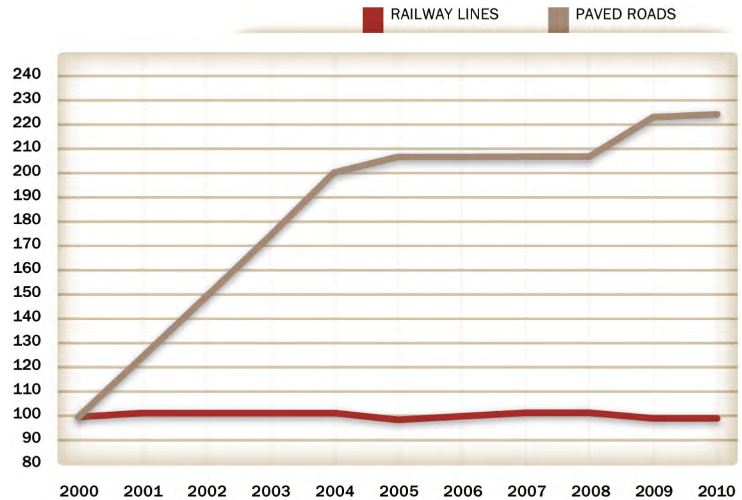
Source: UIC (2012a)

Fig. 67: **Length of railway lines, 1990-2010 (thousand km)**



Source: UIC (2012a)

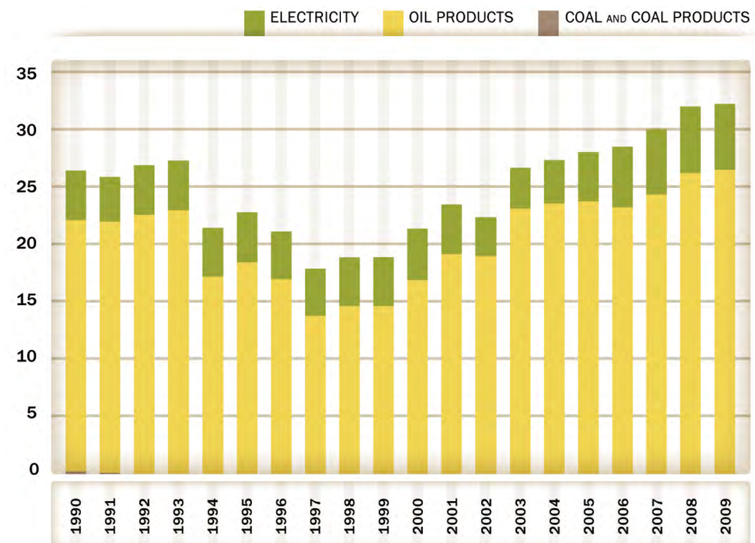
Fig. 68: **Evolution of paved roads and railway lines, 2000-2010 (km)**



Year 2000=100

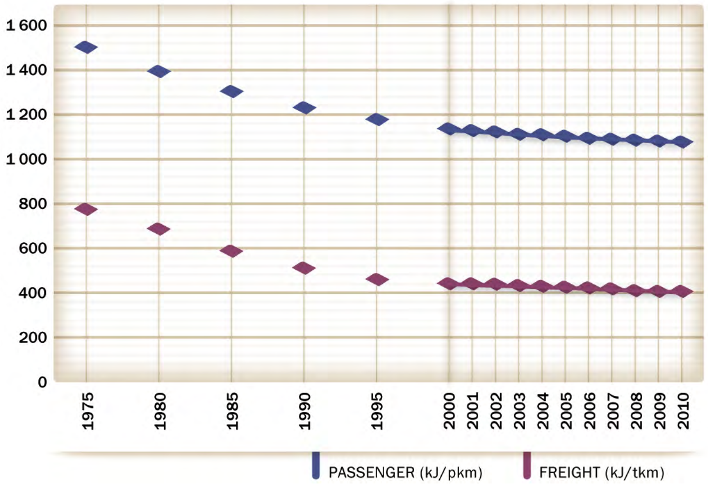
Source: Elaboration by Susdef from IEA (2013) and UIC (2012a)

Fig. 69: **Railway energy consumption by fuel, 1990-2009 (PJ)**



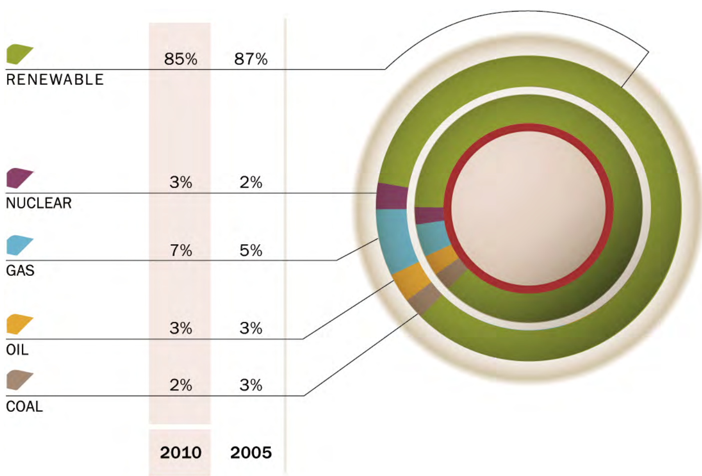
Source: IEA (2012b)

Fig. 70: **Railway specific energy consumption, 1975-2010**



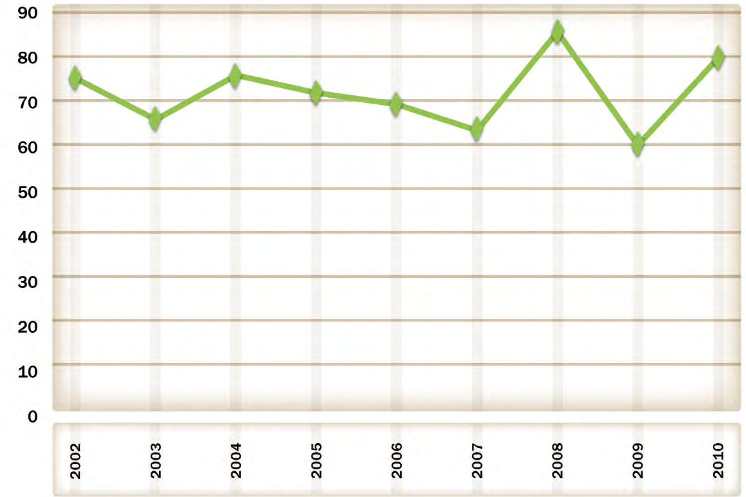
Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Fig. 71: **National electricity production mix evolution, 2010 outside – 2005 inside**



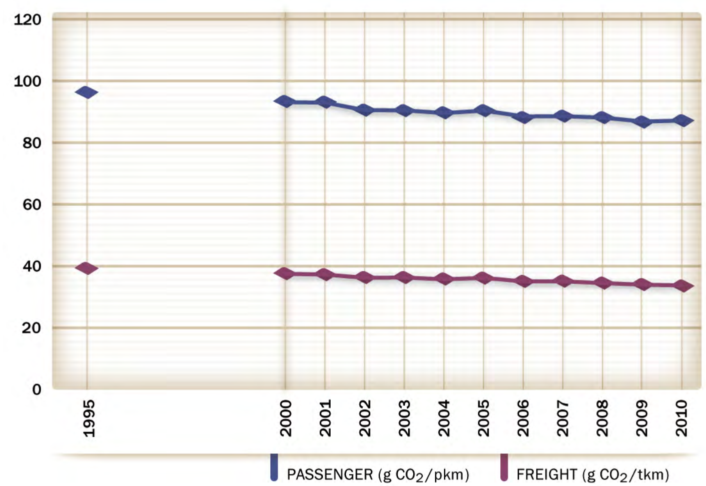
Source: IEA (2012b)

Fig. 72: **National CO_2 emission factor from electricity production mix, 2002-2010 (gCO_2/kWh)**



Source: Elaboration by Susdef based on IEA (2012b), IPCC (2006) and IEA (2008)

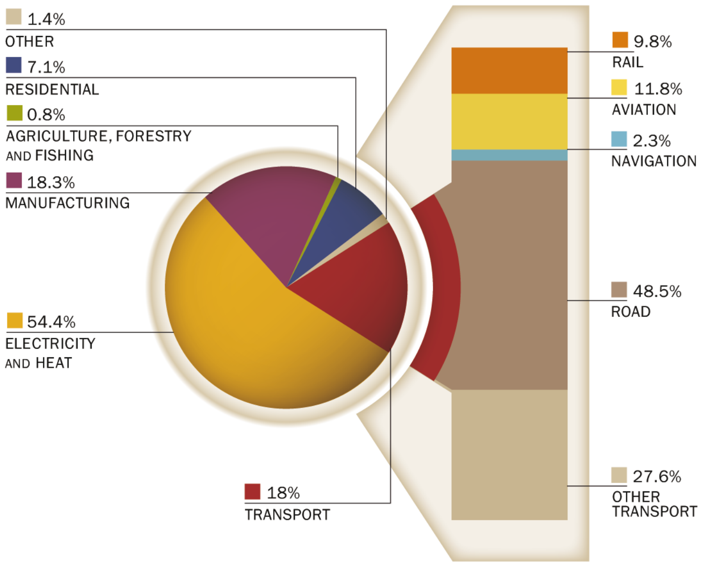
Fig. 73: **Railway specific CO_2 emissions, 1995-2010**



Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Russian Federation

Fig. 74: **Share of CO_2 emissions from fuel combustion by sector, 2010**



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

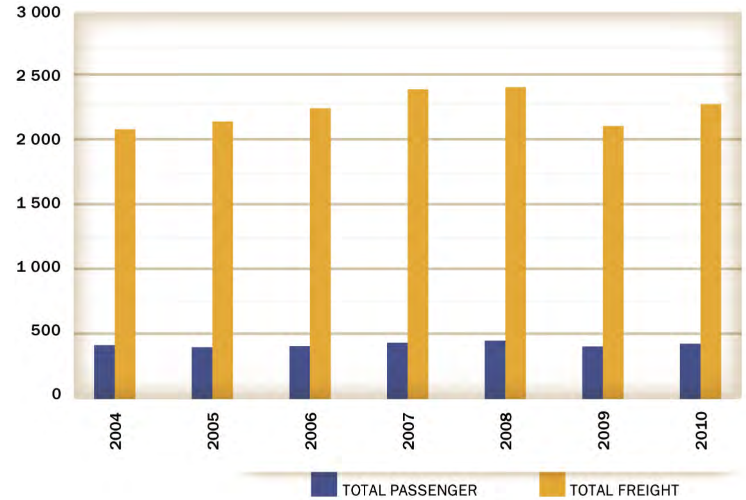
Source: Elaboration by Susdef based on IEA (2012a), IEA (2012b), IPCC (2006) and IEA (2008).

Table 4: **Russia transport modal share, 2010**

	Passenger PKM	Freight TKM	Total TU
ROAD	32.9%	8.8%	12.6%
NAVIGATION	0.2%	2.4%	2.0%
RAIL	32.5%	88.6%	79.8%
AVIATION	34.4%	0.2%	5.6%

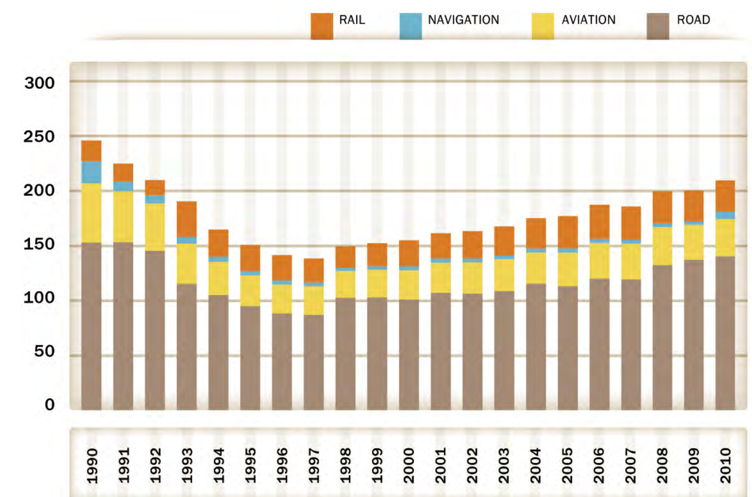
Source: IEA (2011b)

Fig. 75: **Passenger and freight transport activity, 2004-2010 (billion pkm and tkm)**



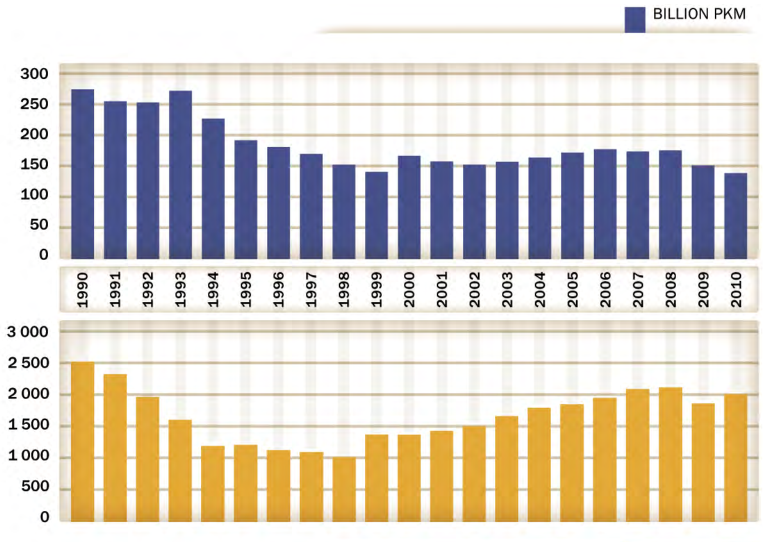
Source: OECD (2013), UIC (2012a) and Rosstat (2013)

Fig. 76: **Transport sector CO_2 emissions by mode, 1990-2010 (million tCO_2)**



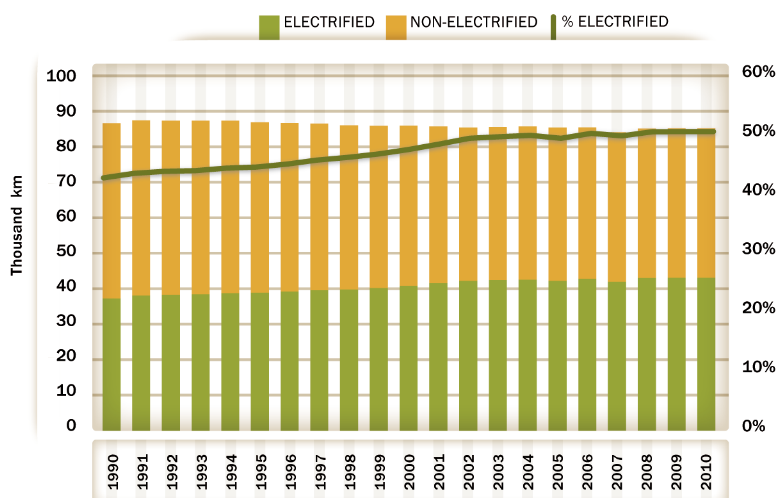
Source: IEA (2012a)

Fig. 77: **Passenger and freight railway activity, 1975-2010**



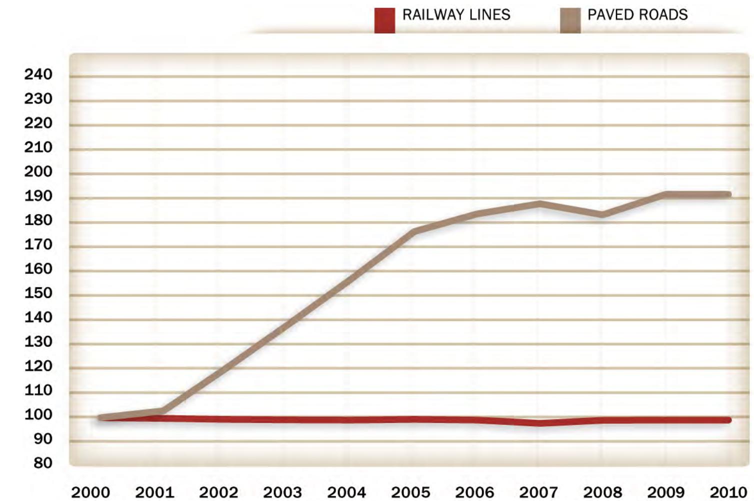
Source: UIC (2012a)

Fig. 78: **Length and share of electrified versus non-electrified railway lines, 1990-2010**



Source: UIC (2012a)

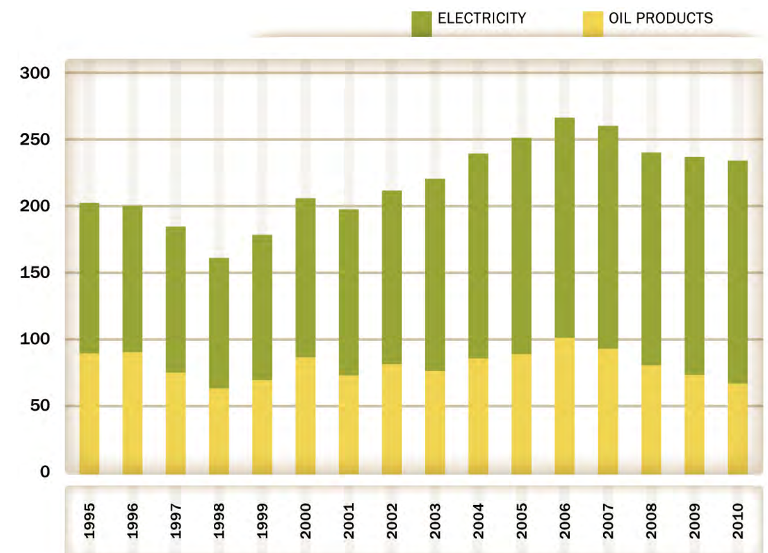
Fig. 79: **Evolution of paved roads and railway lines, 2000-2010 (km)**



Year 2000=100

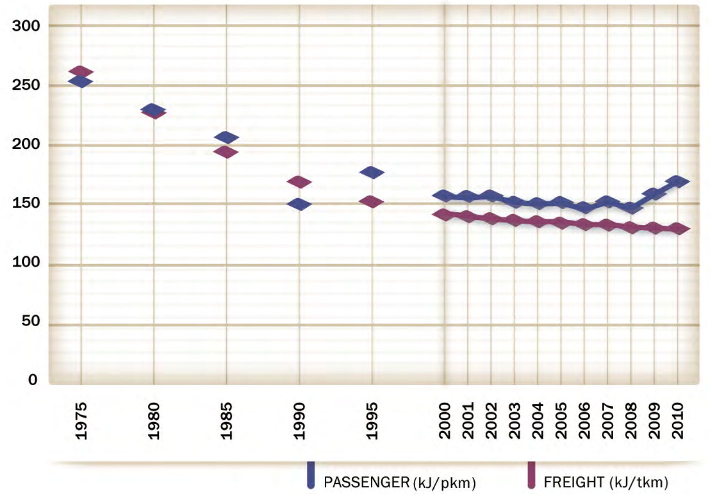
Source: Elaboration by Susdef from IEA (2013) and UIC (2012a)

Fig. 80: **Railway energy consumption by fuel, 1990-2010 (PJ)**



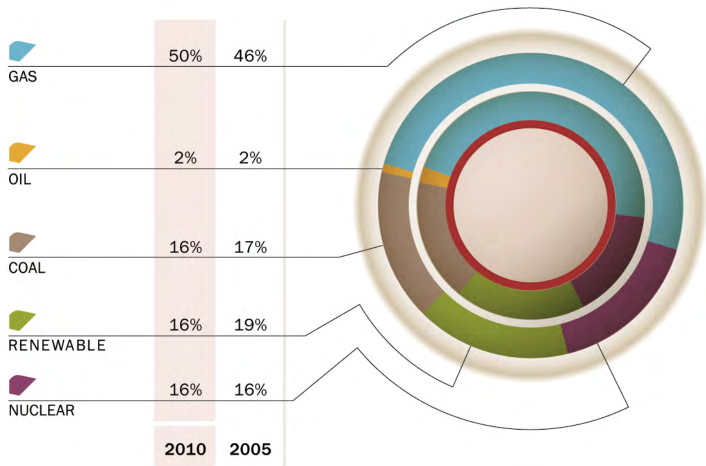
Source: IEA (2012b)

Fig. 81: **Railway specific energy consumption, 1975-2010**



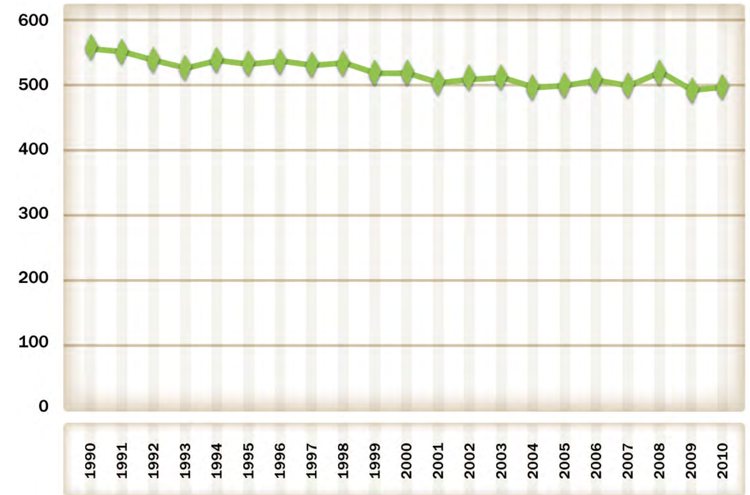
Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Fig. 82: **National electricity production mix evolution, 2010 outside – 2005 inside**



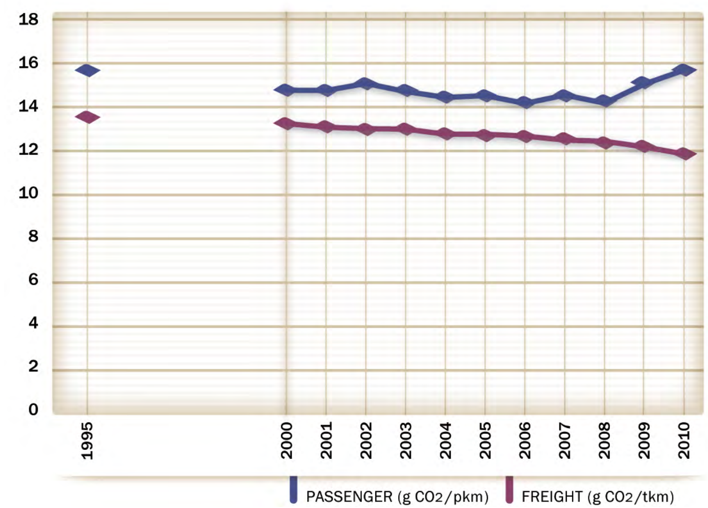
Source: IEA (2012b)

Fig. 83: **National CO_2 emission factor from electricity production mix, 1990-2010 (gCO_2/kWh)**



Source: Elaboration by Susdef based on IEA (2012b), IPCC (2006) and IEA (2008).

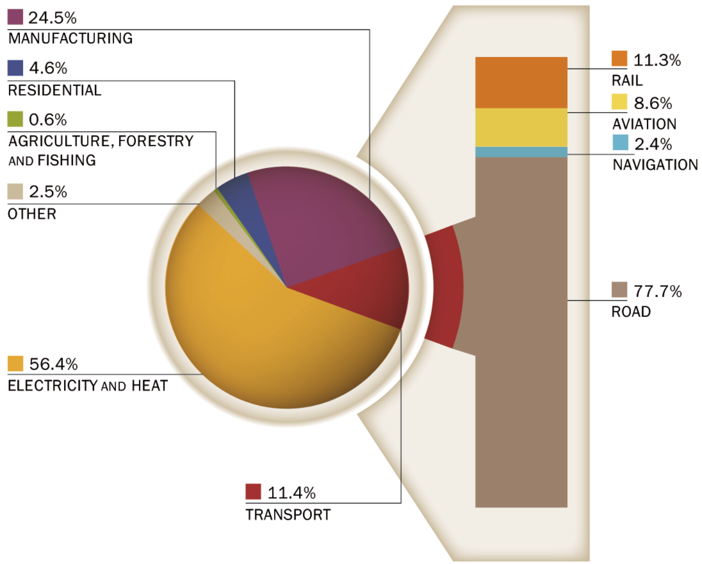
Fig. 84: **Railway specific CO_2 emissions, 1995-2010**



Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

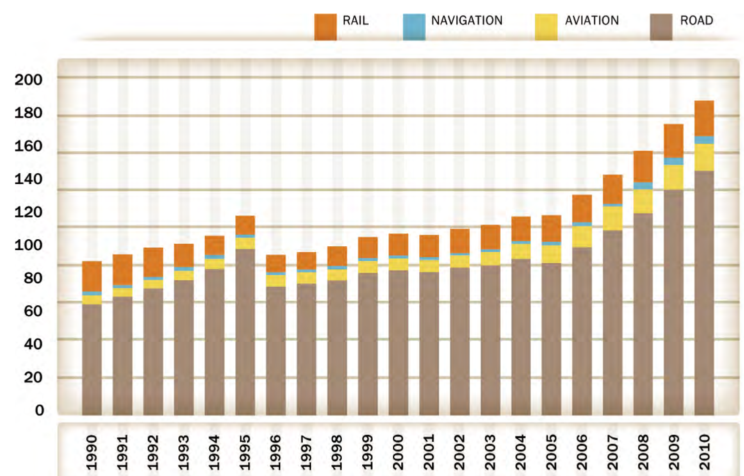
India

Fig. 85: **Share of CO_2 emissions from fuel combustion by sector, 2010**



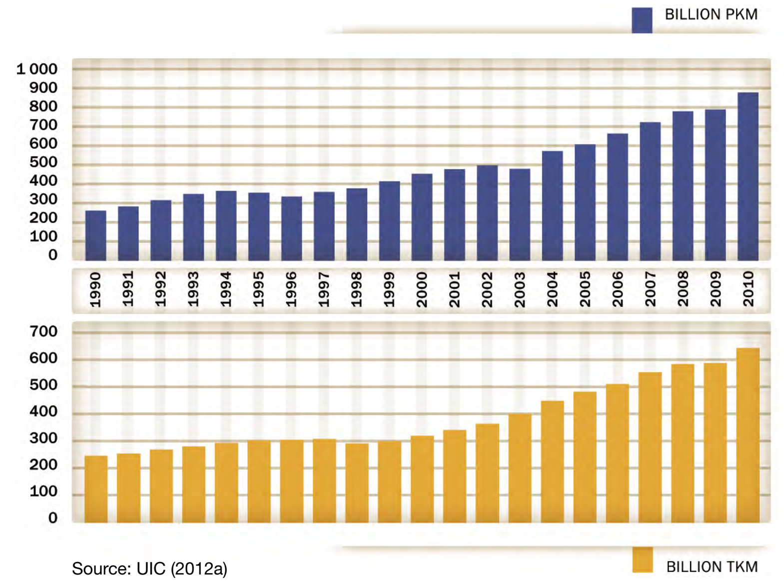
Note: Emissions from rail electrical traction are included in the transport sector. See Methodology Notes.
Source: Elaboration by Susdef based on IEA (2012a), IEA (2012b), IPCC (2006) and IEA (2008).

Fig. 86: **Transport sector CO_2 emissions by mode, 1990-2010 (million tCO_2)**



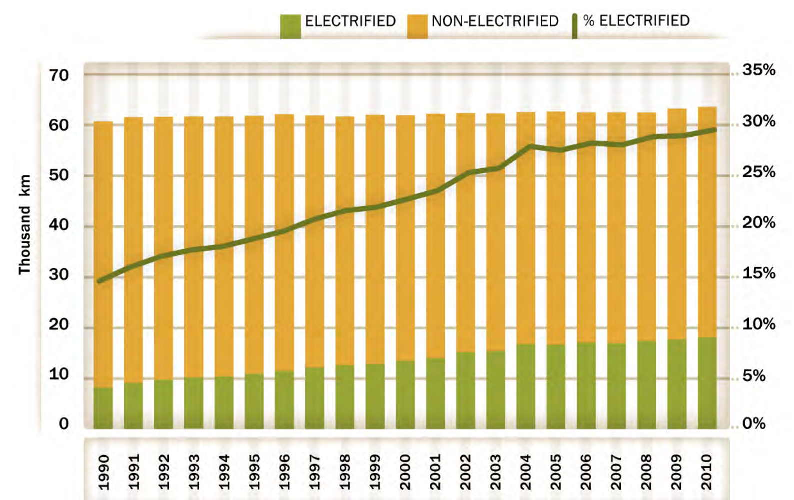
Source: IEA (2012a)

Fig. 87: **Passenger and freight railway activity, 1990-2010**



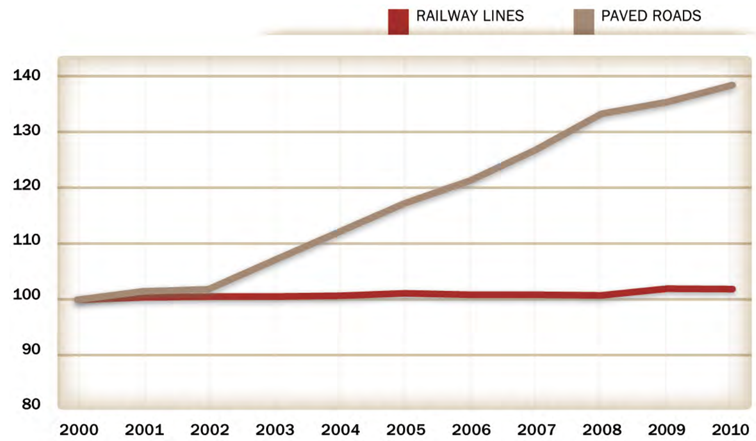
Source: UIC (2012a)

Fig. 88: **Length and share of electrified versus non-electrified railway lines, 1990-2010**



Source: UIC (2012a)

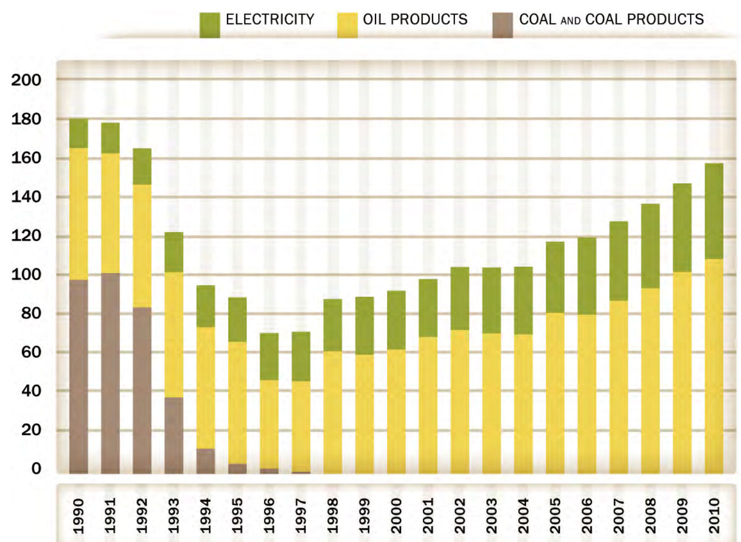
Fig. 89: **Evolution of paved roads and railway lines, 2000-2010 (km)**



Year 2000=100

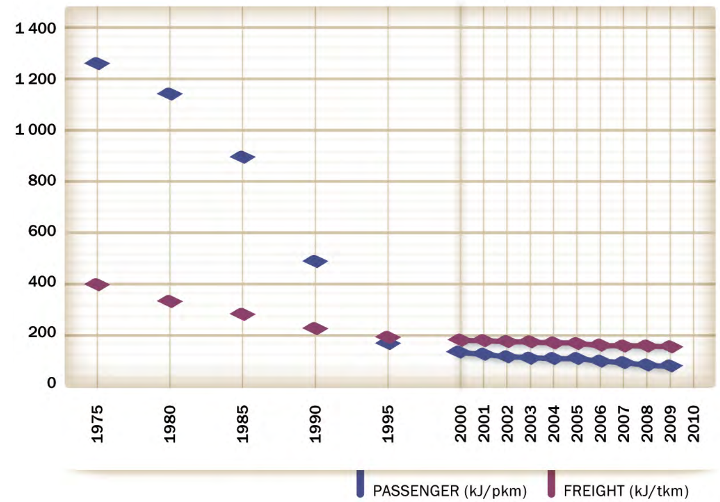
Source: Elaboration by Susdef from IEA (2013) and UIC (2012a)

Fig. 90: **Railway energy consumption by fuel, 1990-2010 (PJ)**



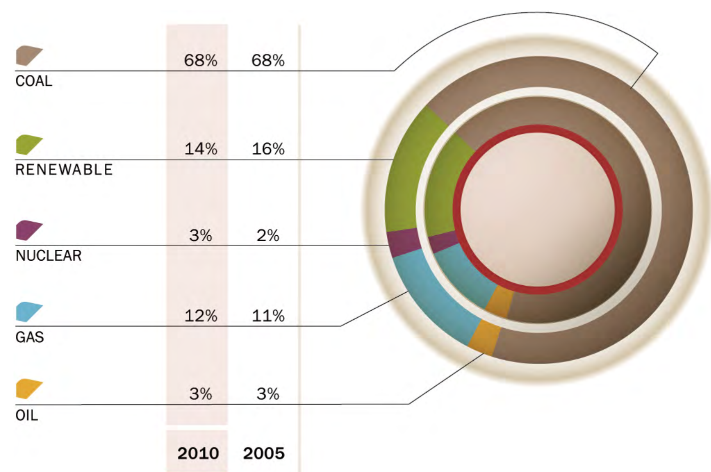
Source: IEA (2012b)

Fig. 91: **Railway specific energy consumption, 1975-2010**



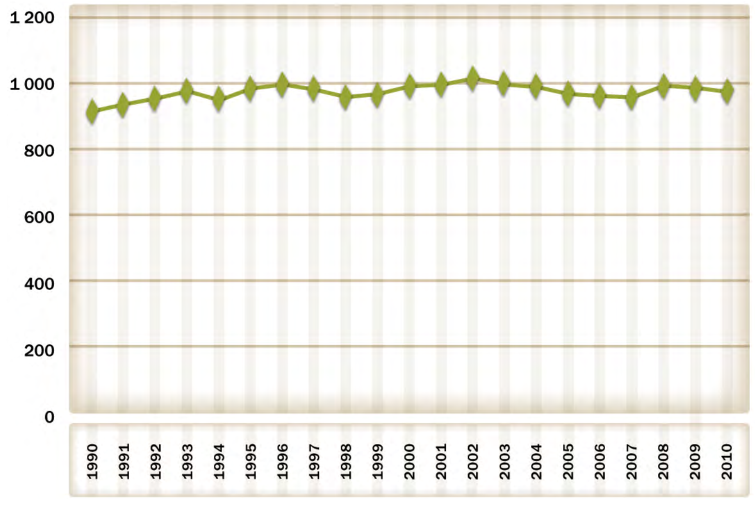
Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Fig. 92: **National electricity production mix evolution, 2010 outside – 2005 inside**



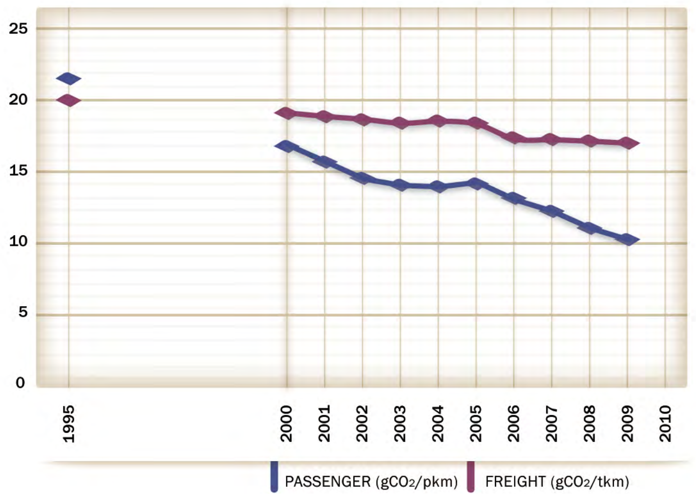
Source: IEA (2012b)

Fig. 93: **National CO_2 emission factor from electricity production mix, 1990-2010 (gCO_2/kWh)**



Source: Elaboration by Susdef based on IEA (2012b), IPCC (2006) and IEA (2008).

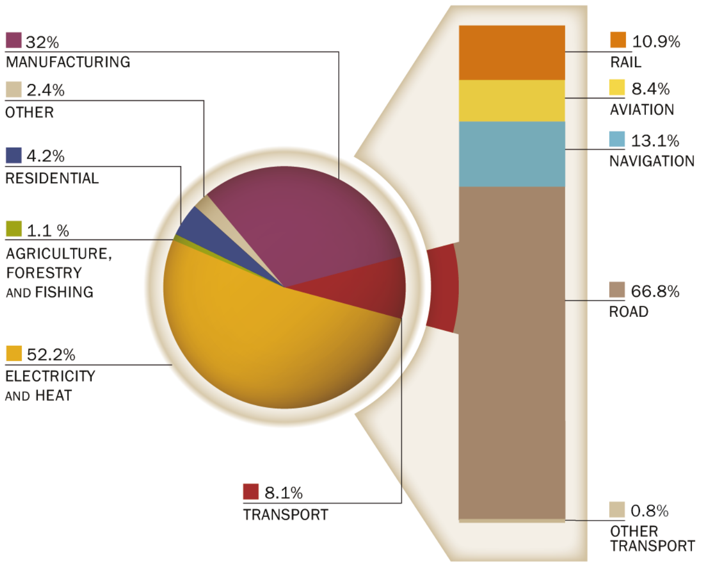
Fig. 94: **Railway specific CO_2 emissions, 1995-2010**



Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

People's Republic of China

Fig. 95: **Share of CO_2 emissions from fuel combustion by sector, 2010**



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

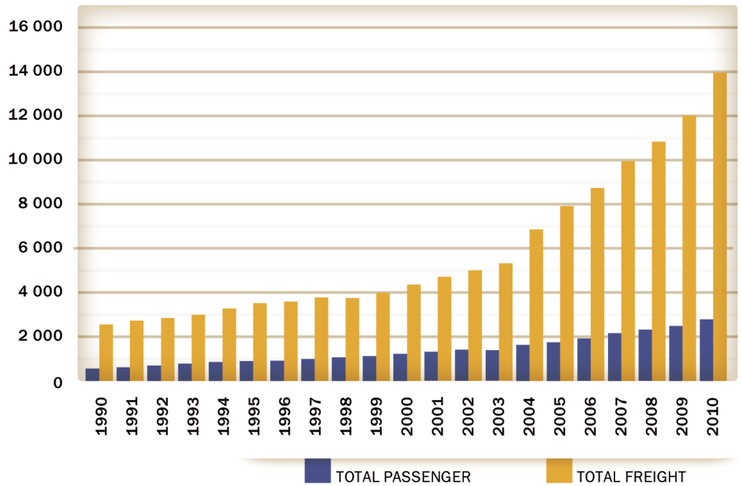
Source: Elaboration by Susdef based on IEA (2012a), IEA (2012b), IPCC (2006) and IEA (2008).

Table 5: **China transport modal share, 2010**

	Passenger PKM	Freight TKM	Total TU
ROAD	53.8%	31.1%	34.9%
NAVIGATION	0.3%	49.0%	40.9%
RAIL	31.4%	19.8%	21.7%
AVIATION	14.5%	0.1%	2.5%

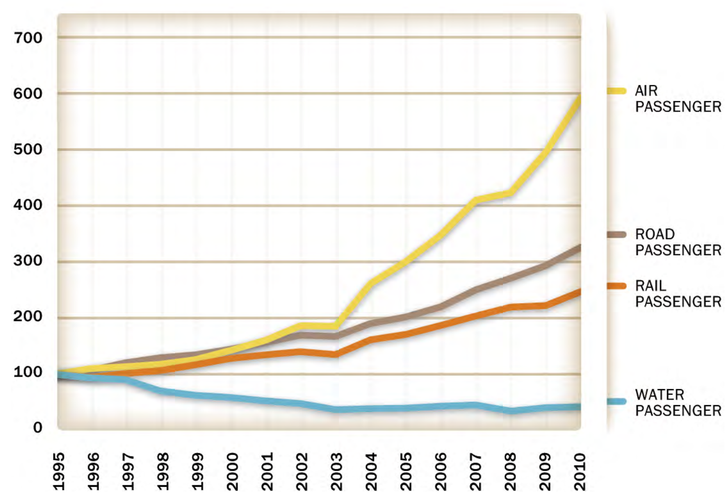
Source: UIC (2012a) and CNBS (2012)

Fig. 96: **Passenger and freight transport activity, 1990-2010 (billion pkm and billion tkm)**



Source: UIC (2012a) and CNBS (2012)

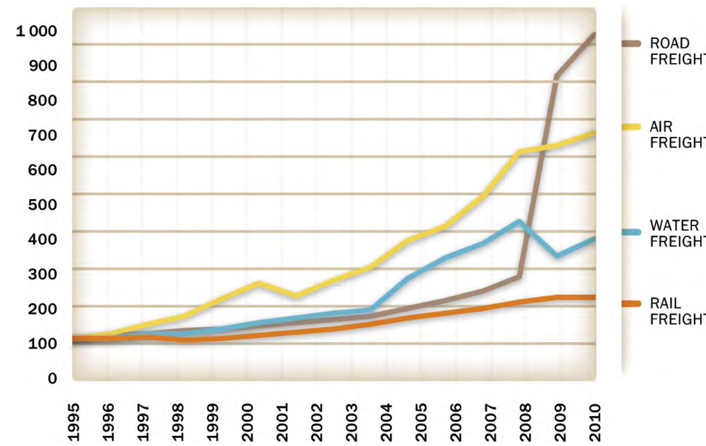
Fig. 97: **Modal evolution of passenger traffic activity, 1995-2010 (pkm)**



Year 1995=100

Source: UIC (2012a) and CNBS (2012)

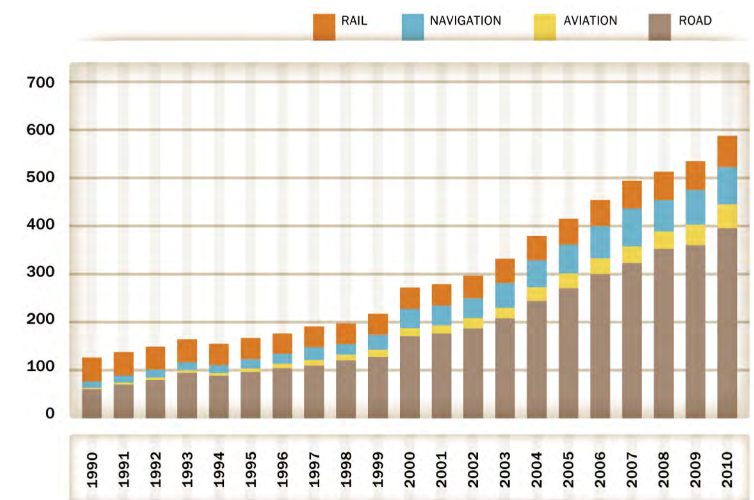
Fig. 98: **Modal evolution of freight traffic activity, 1995-2010 (tkm)**



Year 1995=100

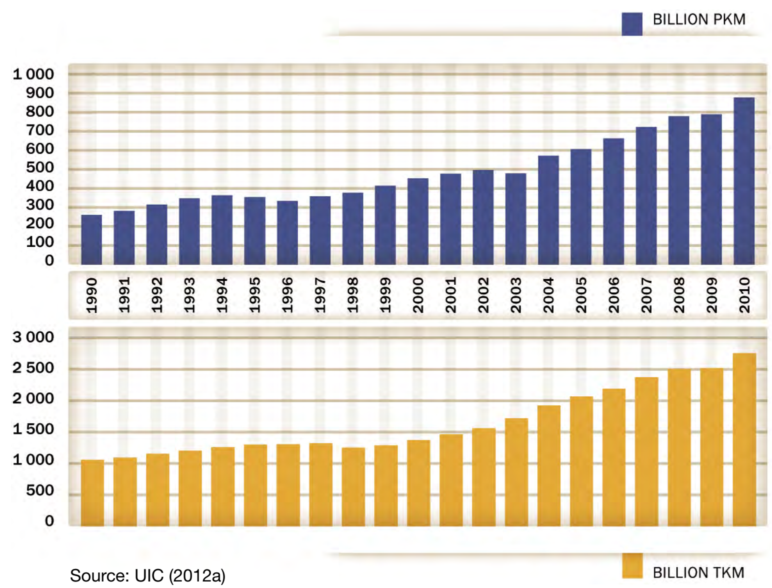
Source: UIC (2012a) and CNBS (2012)

Fig. 99: **Transport sector CO_2 emissions by mode, 1990-2010 (million tonnes)**



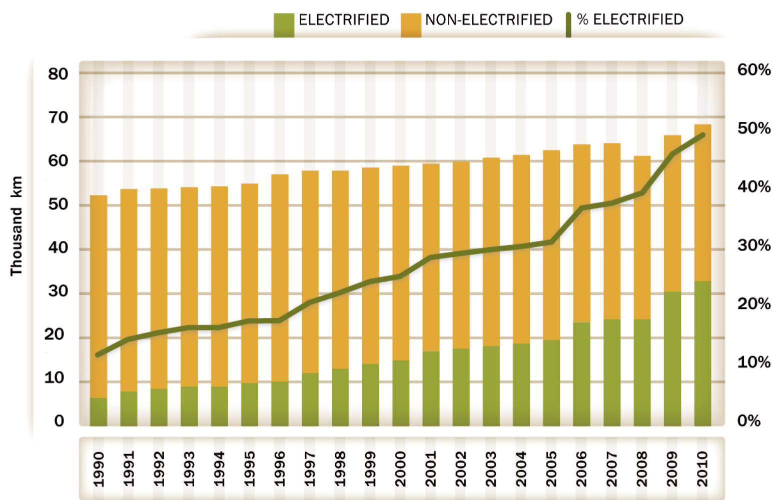
Source: IEA (2012a)

Fig. 100: **Passenger and freight railway activity, 1990-2010**



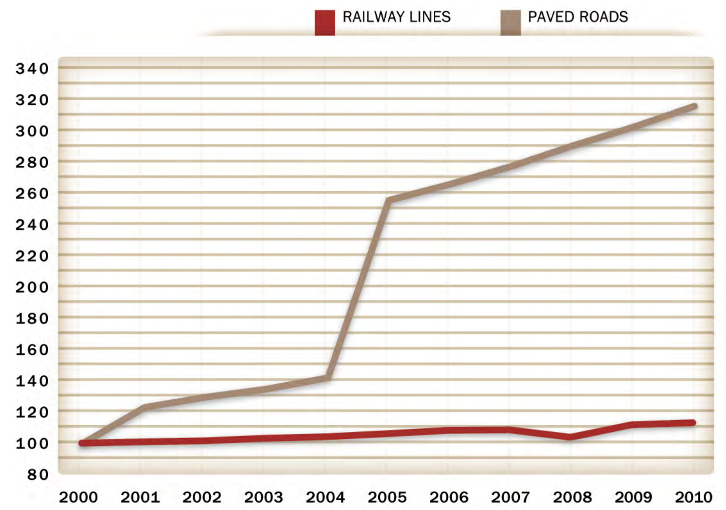
Source: UIC (2012a)

Fig. 101: **Length and share of electrified versus non-electrified railway lines, 1990-2010**



Source: UIC (2012a)

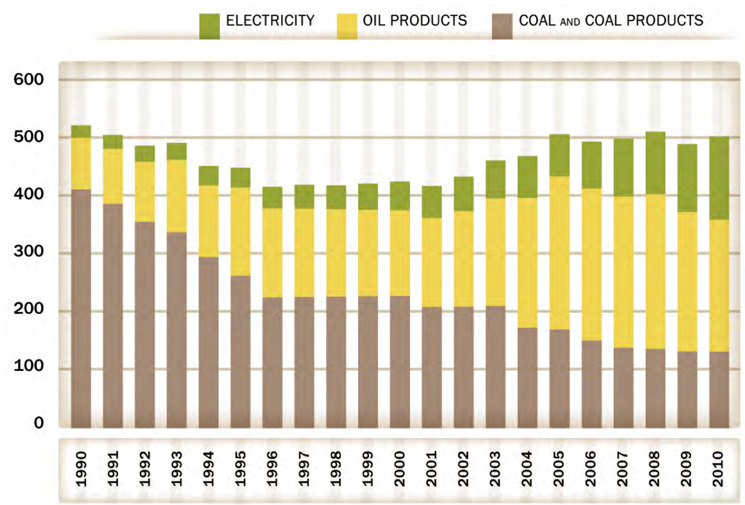
Fig. 102: **Evolution of paved roads and railway lines, 2000-2010 (km)**



Year 2000=100

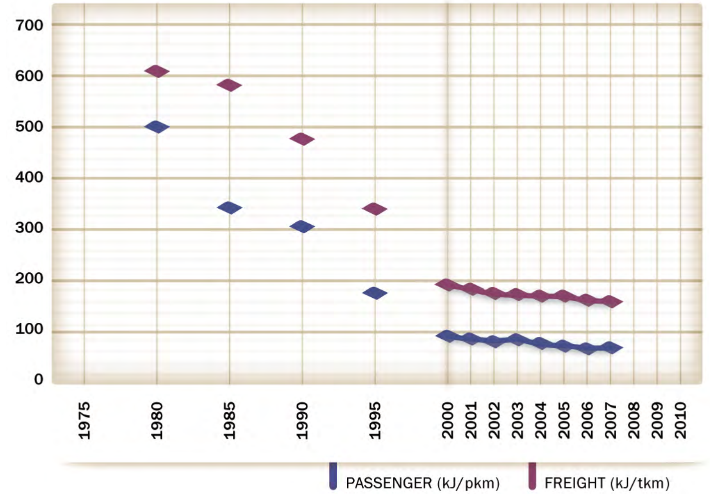
Source: Elaboration by Susdef from IEA (2013) and UIC (2012a)

Fig. 103: **Railway energy consumption by fuel, 1990-2010 (PJ)**



Source: IEA (2012b)

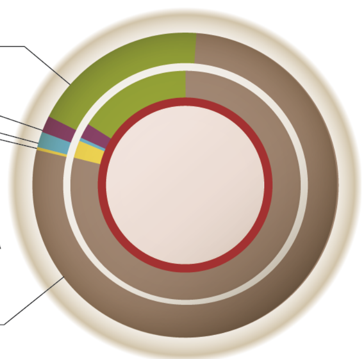
Fig. 104: **Railway specific energy consumption, 1975-2010**



Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

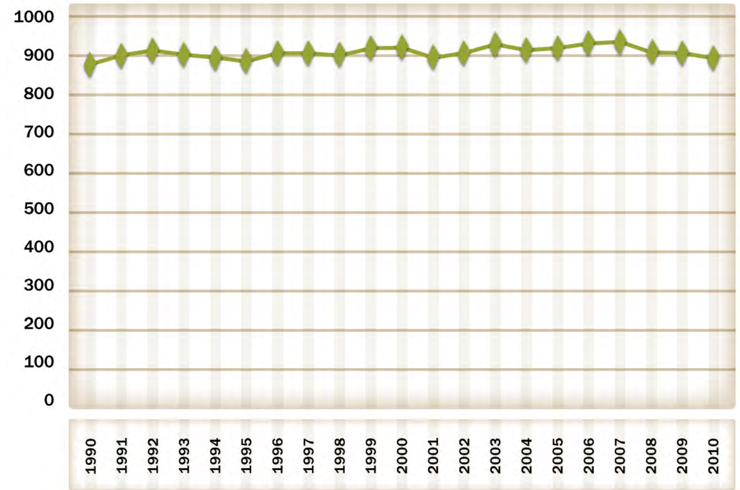
Fig. 105: **National electricity production mix evolution, 2010 outside – 2005 inside**

	2010	2005
RENEWABLE	18%	16%
NUCLEAR	2%	2%
GAS	2%	0%
OIL PRODUCTS	0%	3%
COAL PRODUCTS	78%	79%



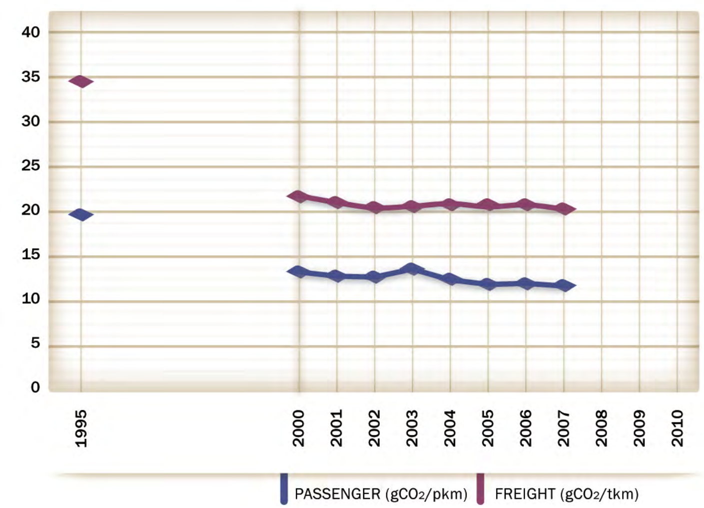
Source: IEA (2012b)

Fig. 106: **National CO_2 emission factor from electricity production mix, 1990-2010 (gCO_2/kWh)**



Source: Elaboration by Susdef based on IEA (2012b), IPCC (2006) and IEA (2008).

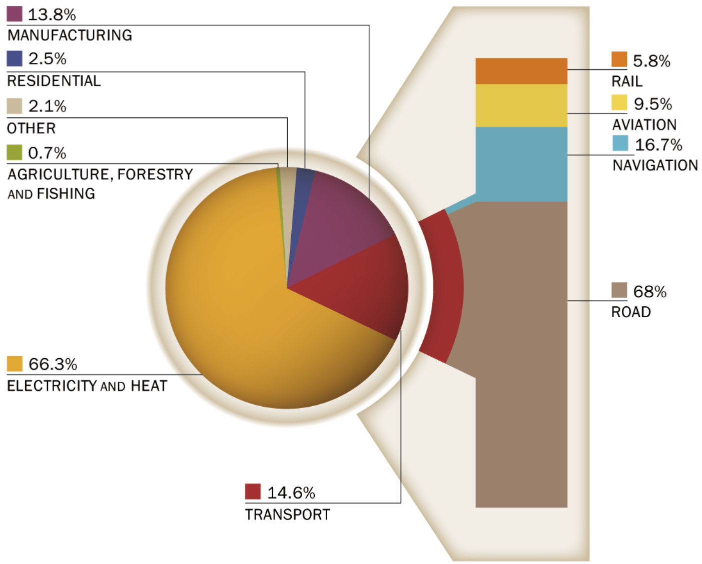
Fig. 107: **Railway specific CO_2 emissions, 1995-2010**



Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

South Africa

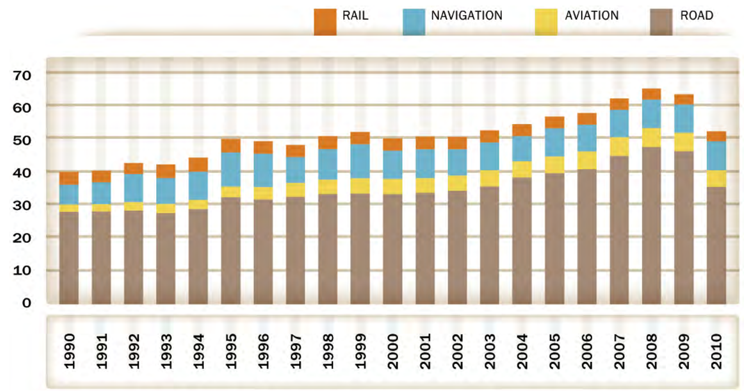
Fig. 108: **Share of CO_2 emissions from fuel combustion by sector, 2010**



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

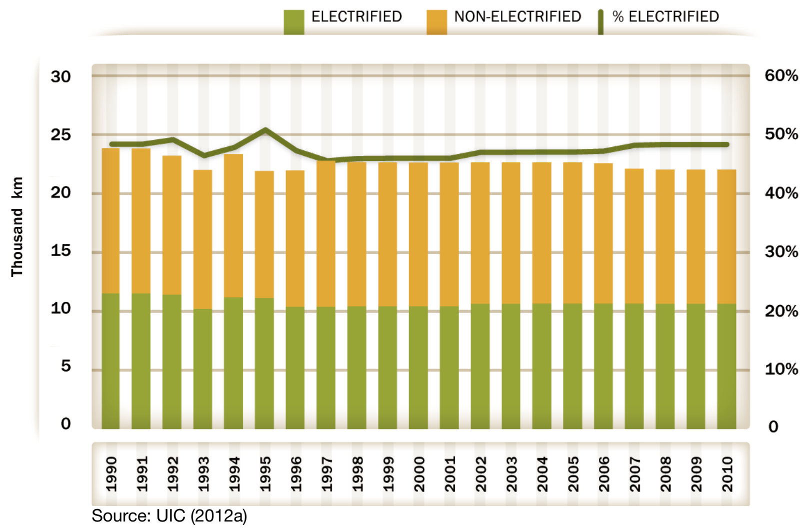
Source: Elaboration by Susdef based on IEA (2012a), IEA (2012b), IPCC (2006) and IEA (2008).

Fig. 109: **Transport sector CO_2 emissions by mode, 1990-2010 (million tCO_2)**



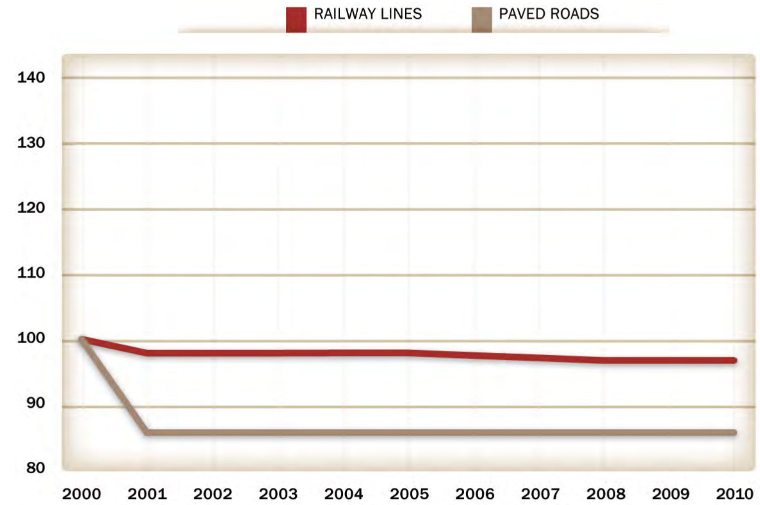
Source: IEA (2012a)

Fig. 110: **Length and share of electrified versus non-electrified railway lines, 1990-2010**



Source: UIC (2012a)

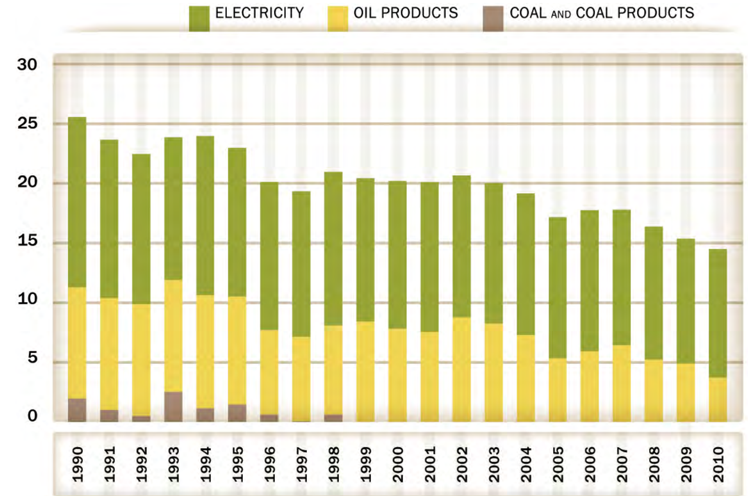
Fig. 111: **Evolution of paved roads and railway lines, 2000-2010 (km)**



Year 2000=100

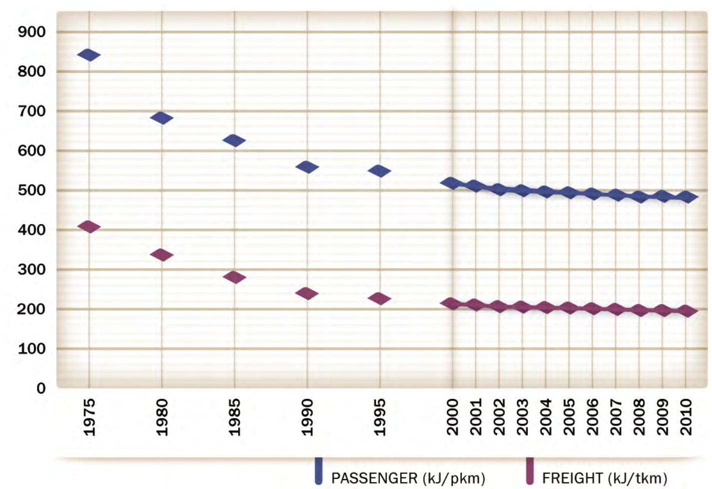
Source: Elaboration by Susdef from IEA (2013) and UIC (2012a)

Fig. 112: **Railway energy consumption by fuel, 1990-2009 (PJ)**



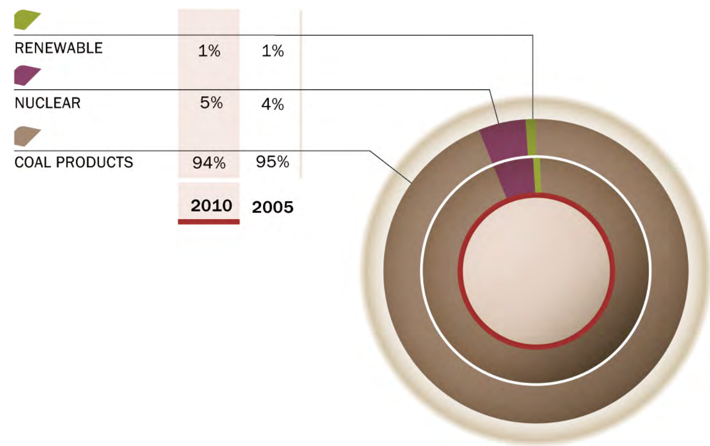
Source: IEA (2012b)

Fig. 113: **Railway specific energy consumption, 1975-2010**



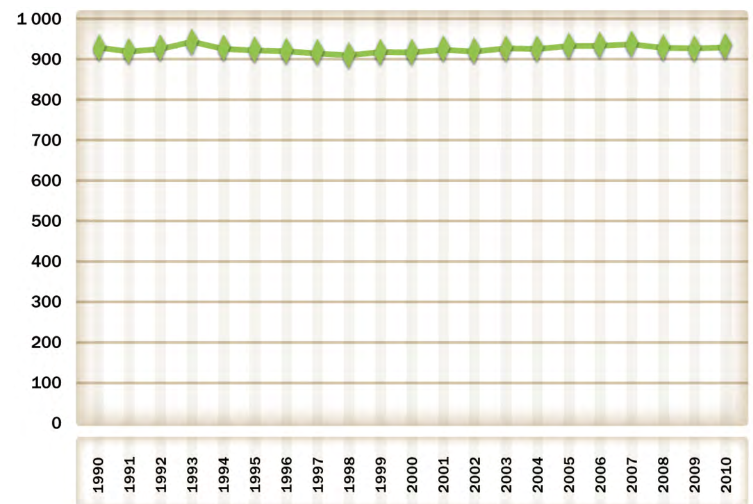
Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Fig. 114: **National electricity production mix evolution, 2010 outside – 2005 inside**



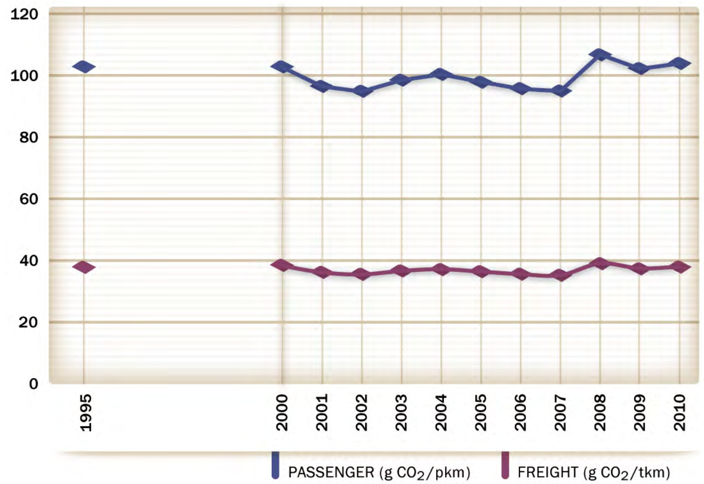
Source: IEA (2012b)

Fig. 115: **National CO_2 emission factor from electricity production mix, 1990-2010 (gCO_2/kWh)**



Source: Elaboration by Susdef based on IEA (2012b), IPCC (2006) and IEA (2008).

Fig. 116: **Railway specific CO_2 emissions, 1995-2010**

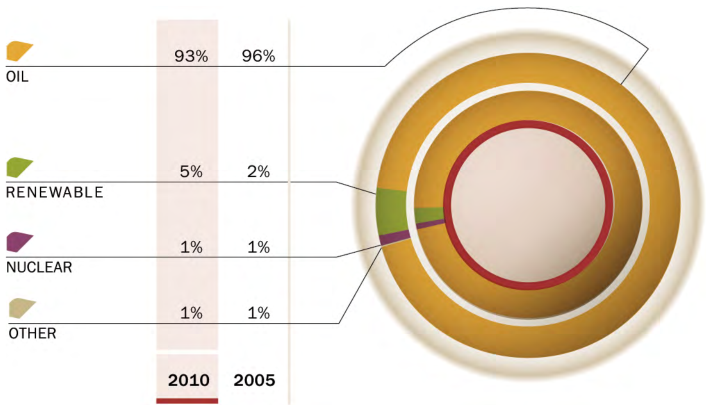


Source: Elaboration by IEA and Susdef based on IEA Mobility Model and UIC (2012a)

Part II: Focus on Energy Mix

Energy Mix in Transport and Railways

Fig. 117: **EU27 transport energy mix evolution, 2010 outside – 2005 inside**

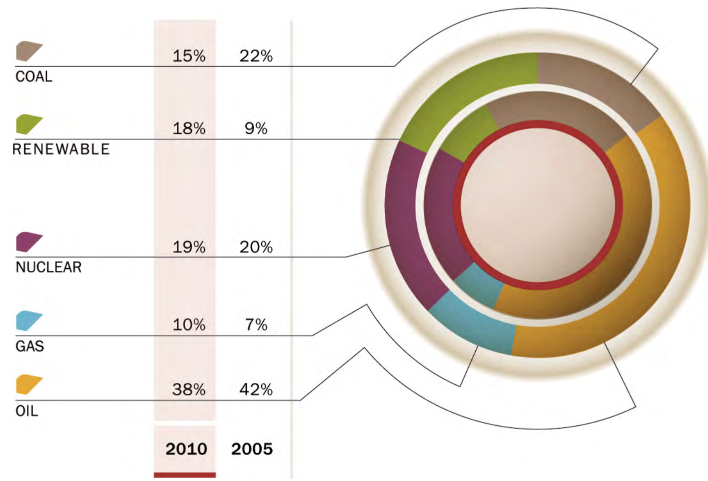


Note: in this graph, renewable energy sources include both renewable fuels directly used by transport (e.g. biofuels) and renewable sources of electricity that are then used in transport.

Source: Elaboration by Susdef from IEA (2012b)

This is the mix of fuels used by the EU transport sector. It takes into account both the fuels used directly (e.g. oil and diesel) and the composition of the electricity mix for electric traction.

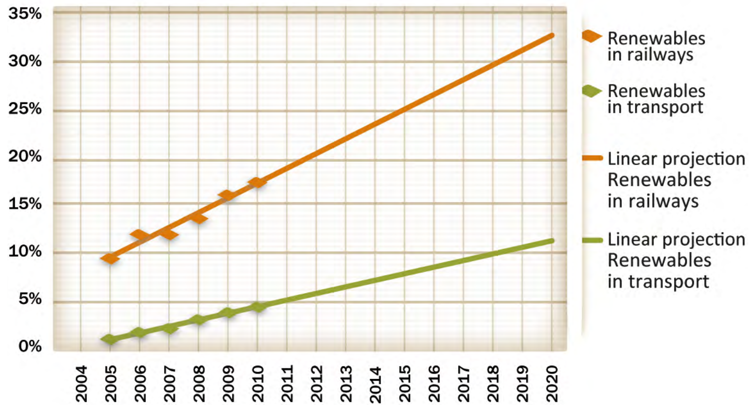
Fig. 118: **EU27 railway energy mix evolution, 2010 outside – 2005 inside**



Source: Elaboration by Susdef of IEA (2012b) and UIC (2012b)

This is the mix of fuels used by the EU railway sector. It takes into account both the fuels used directly (e.g. coal and diesel) and the composition of the electricity mix for electric traction

Fig. 119: **Forecast of the share of renewables in transport and in railways in EU27, 2005-2020**



Source: Elaboration by Susdef based on IEA (2012b) and UIC (2012b)

If the energy sources used by railways continue to follow the trends of past years, EU railways will go to almost 35% of renewables in 2020 (they were already at 18% in 2010). The fuel mix of the whole transport sector is now at 5% of renewables and is set to reach 12% in 2020.

Electricity Mixes in EU27

Fig. 120: **National electricity production mix evolution in EU27, 2010 outside – 2006 middle - 1990 inside**

	2010	2006	1990
COAL	26%	31%	41%
OIL	2%	4%	9%
GAS	23%	20%	7%
NUCLEAR	28%	30%	31%
RENEWABLE	21%	15%	12%

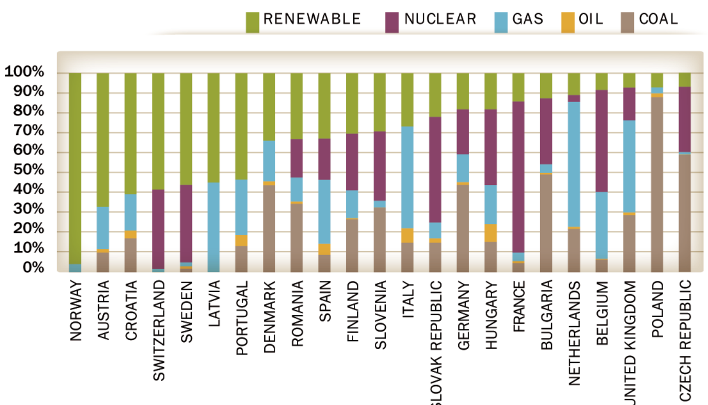
Source: IEA (2012b)

Table 6: **National Production Electricity Mix in selected EU and EFTA states, 2010**

	Coal	Oil	Gas	Nuclear	Renewable
NORWAY	0.1%	0.0%	3.9%	0.0%	96.0%
AUSTRIA	9.9%	1.9%	21.1%	0.0%	67.1%
CROATIA	17.0%	4.0%	18.3%	0.0%	60.7%
SWITZERLAND	0.0%	0.1%	1.6%	39.9%	58.4%
SWEDEN	1.8%	1.2%	1.9%	39.0%	56.1%
LATVIA	0.0%	0.0%	45.1%	0.0%	54.9%
PORTUGAL	13.2%	5.6%	27.8%	0.0%	53.4%
DENMARK	43.8%	1.9%	20.4%	0.0%	33.9%
ROMANIA	34.4%	1.1%	12.1%	19.3%	33.1%
SPAIN	8.8%	5.5%	32.2%	20.7%	32.8%
FINLAND	26.6%	0.6%	14.0%	28.4%	30.4%
SLOVENIA	32.6%	0.0%	3.4%	34.8%	29.2%
ITALY	14.9%	7.3%	51.1%	0.0%	26.7%
SLOVAK REPUBLIC	14.8%	2.2%	8.0%	53.1%	21.9%
GERMANY	44.0%	1.3%	14.0%	22.6%	18.1%
HUNGARY	15.3%	8.9%	19.6%	38.1%	18.1%
FRANCE	4.7%	1.0%	4.2%	75.9%	14.2%
BULGARIA	49.1%	0.9%	4.3%	33.1%	12.6%
NETHERLANDS	21.8%	1.1%	62.8%	3.4%	10.9%
BELGIUM	6.4%	0.4%	33.6%	51.3%	8.3%
UNITED KINGDOM	28.8%	1.3%	46.3%	16.4%	7.2%
POLAND	88.0%	1.8%	3.1%	0.0%	7.1%
CZECH REPUBLIC	58.8%	0.2%	1.3%	32.8%	6.9%

Source: IEA (2012b)

Fig. 121: **National Production Electricity Mix in selected EU and EFTA states, 2010**



Source: IEA (2012b)

Table 7: **National Consumption Electricity Mix in selected EU and EFTA states, 2010**

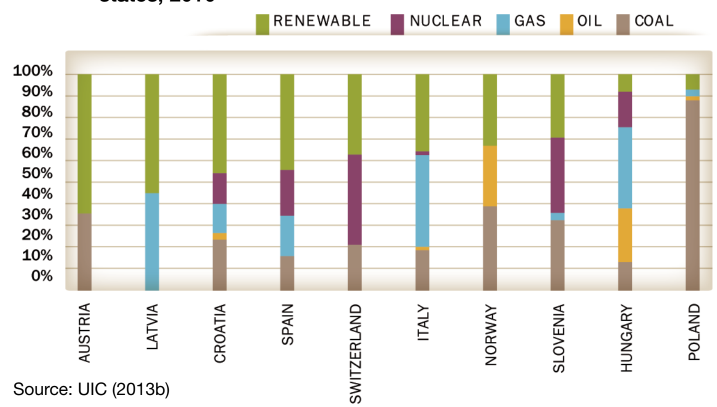
	Coal	Oil	Gas	Nuclear	Renewable
DENMARK	N/A	N/A	N/A	N/A	N/A
FINLAND	N/A	N/A	N/A	N/A	N/A
NORWAY	39.0%	28.0%	0.0%	0.0%	33.0%
SWEDEN	N/A	N/A	N/A	N/A	N/A
AUSTRIA	35.7%	0.0%	0.0%	0.0%	64.3%
SWITZERLAND	21.3%	0.0%	0.0%	41.6%	37.1%
LATVIA	0.0%	0.0%	45.1%	0.0%	54.9%
PORTUGAL	N/A	N/A	N/A	N/A	N/A
CROATIA	23.6%	3.0%	13.5%	14.3%	45.6%
SPAIN	16.0%	0.0%	18.6%	21.2%	44.2%
ITALY	18.7%	1.6%	42.4%	1.7%	35.6%
SLOVENIA	32.6%	0.0%	3.4%	34.8%	29.2%
ROMANIA	N/A	N/A	N/A	N/A	N/A
SLOVAK REPUBLIC	N/A	N/A	N/A	N/A	N/A
GERMANY	N/A	N/A	N/A	N/A	N/A
BULGARIA	N/A	N/A	N/A	N/A	N/A
UNITED KINGDOM	N/A	N/A	N/A	N/A	N/A
BELGIUM	N/A	N/A	N/A	N/A	N/A
FRANCE	N/A	N/A	N/A	N/A	N/A
HUNGARY	13.3%	24.8%	37.5%	16.4%	8.0%
CZECH REPUBLIC	N/A	N/A	N/A	N/A	N/A
POLAND	88.0%	1.8%	3.1%	0.0%	7.1%
NETHERLANDS	N/A	N/A	N/A	N/A	N/A

Note: Colored rows indicate countries for which the data is available.

Source: UIC (2013b)

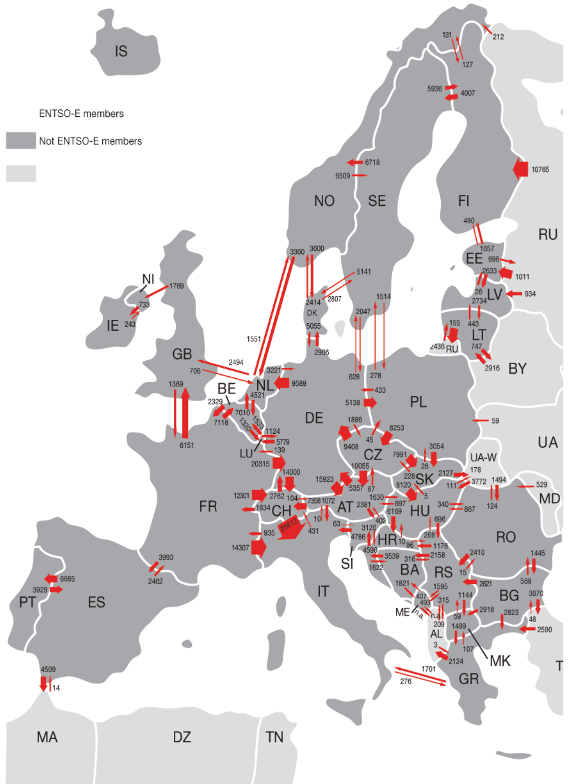
- The national consumption electricity mix indicates the mix of energy sources for the electricity consumed rather than produced in a country, which may be different from the country production electricity mix due to imports and exports of physical electricity and/or the exchange of Guarantees of Origin and Renewable Energy Certificates.

Fig. 122: **National Consumption Electricity Mix in selected EU and EFTA states, 2010**



Source: UIC (2013b)

Fig. 123: **Physical energy flows in Europe, 2011**



Source: ENTSO-E (2011)

Consolidated physical inside and outside flows in GWh:

	Inside	Outside
AT	27 191	1 7885
BA	4 187	5 676
BE	13 189	10 652
BG	1 493	12 000
CH	34 090	30 312
CY	–	–
CZ	10 457	27 501
DE	49 722	55 988
DK	11 647	10 276
EE	1 517	4 986
ES	7 935	13 656
FI	18 489	4 614
FR	9 068	64 185
GB	8 645	3 844
GR	7 181	3 932
HR	14 004	6 318
HU	14 667	8 018
IE	733	243
IS	–	–
IT	47 478	1 715
LT	8 086	1 345
LU	7 099	2 657
LV	4 010	2 760
ME	3 416	900
MK	4 169	1 548
NI	2 012	733
NL	20 665	11 787
NO	11 022	13 600
PL	6 779	12 023
PT	6 685	3 928
RO	2 946	4 846
RS	6 900	6 671
SE	14 229	21 356
SI	7 034	8 308
SK	11 228	10 501

values in GWh

The difference between national production mix and national consumption mix can be explained by the physical import and export energy flows generated by most European countries and by the exchange of Guarantees of Origin (GO) and Renewable Energy Certificates (REC). The map shows physical import and export energy flows in Europe in 2011.

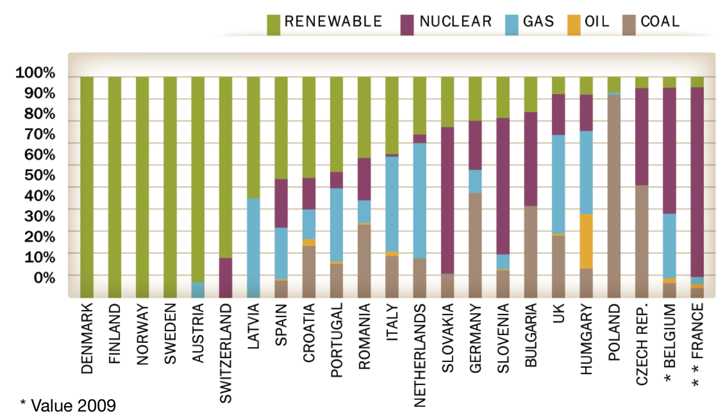
Table 8: **Railway Electricity Mix in selected EU and EFTA states, 2010**

	Coal	Oil	Gas	Nuclear	Renewable
DENMARK	0.0%	0.0%	0.0%	0.0%	100.0%
FINLAND	0.0%	0.0%	0.0%	0.0%	100.0%
NORWAY	0.0%	0.0%	0.0%	0.0%	100.0%
SWEDEN	0.0%	0.0%	0.0%	0.0%	100.0%
AUSTRIA	0.0%	0.0%	7.2%	0.0%	92.8%
SWITZERLAND	0.0%	0.0%	0.0%	18.1%	81.9%
LATVIA	0.0%	0.0%	45.0%	0.0%	55.0%
SPAIN	7.9%	0.7%	23.2%	22.1%	46.1%
CROATIA	23.6%	3.0%	13.5%	14.3%	45.6%
PORTUGAL	15.5%	1.0%	33.1%	7.4%	43.0%
ROMANIA	33.2%	0.7%	10.4%	19.1%	36.6%
ITALY	19.0%	2.0%	43.0%	1.0%	35.0%
NETHERLANDS	18.0%	0.0%	52.0%	4.0%	26.0%
SLOVAKIA	11.0%	0.0%	0.0%	66.3%	22.7%
GERMANY	47.5%	0.0%	10.5%	22.2%	19.8%
SLOVENIA	12.5%	0.6%	6.6%	61.7%	18.6%
BULGARIA	41.7%	0.0%	0.0%	42.4%	15.9%
UNITED KINGDOM	28.0%	1.0%	45.0%	18.0%	8.0%
HUNGARY	13.3%	24.8%	37.5%	16.4%	8.0%
POLAND	92.0%	0.0%	1.0%	0.0%	7.0%
CZECH REPUBLIC	51.0%	0.0%	0.0%	44.0%	5.0%
BELGIUM	6.7%	2.3%	29.1%	57.0%	4.9%
FRANCE	4.5%	1.8%	3.2%	85.8%	4.7%

Source: UIC (2012b)

The railway electricity mix reflects the energy purchased by the railway companies through electricity suppliers. This may be different from national production and national consumption mix (see the case studies for explanations of those differences).

Fig. 124: **Railway Electricity Mix in selected EU and EFTA states, 2010**

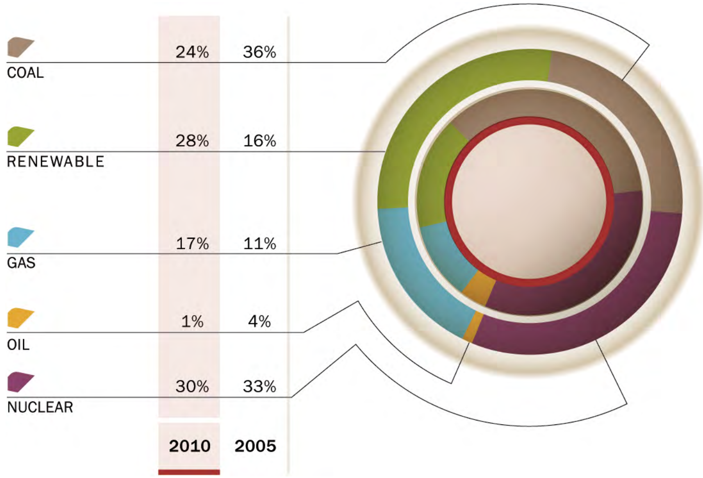


* Value 2009

** Value 2005

Source: UIC (2012b)

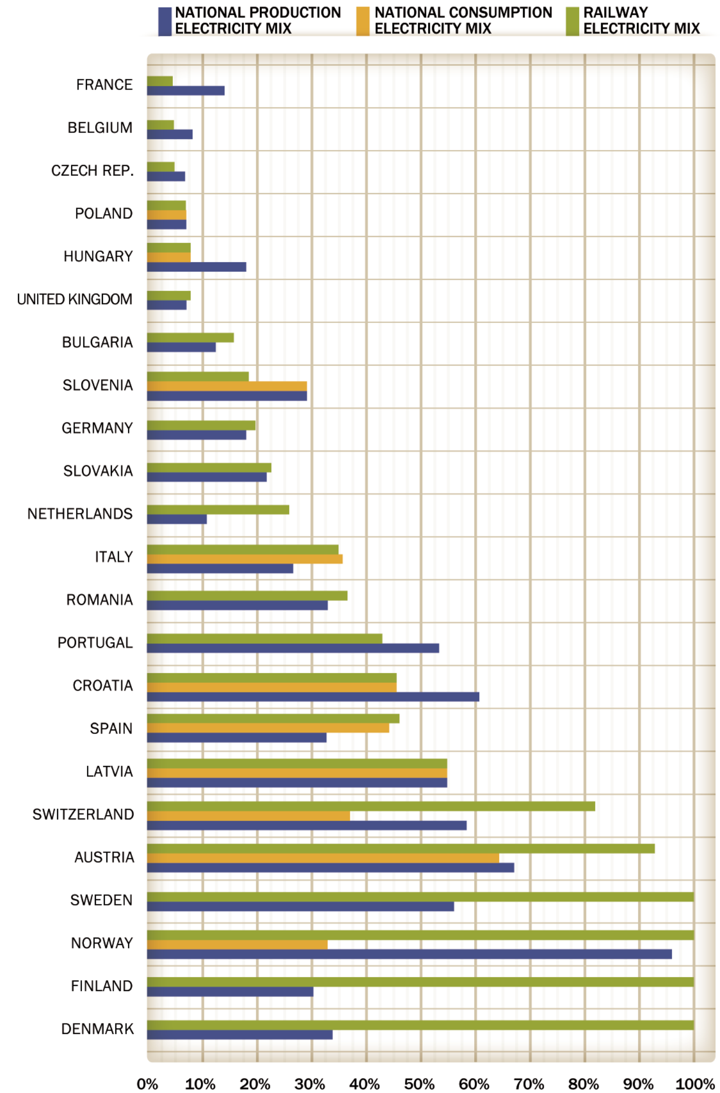
Fig. 125: **Railway electricity mix evolution in EU27, 2010 outside – 2005 inside**



Source: Elaboration by Susdef from UIC (2012b)

Methodological note: This figure is different from the one published in the Railway Handbook 2012 (fig. 27) as data from more railways has been included. Therefore the current figures are more accurate.

Fig. 126: **Share of renewables in national production, national consumption and railway electricity mix for selected European countries, 2010**



Note: National consumption mix is not available for the following countries: France, Czech Republic, Hungary, United Kingdom, Bulgaria, Slovenia, Germany, Slovakia, Netherlands, Spain, Sweden, Finland and Denmark.

Source: IEA (2012b), UIC (2012b) and UIC (2013b)

Comparison

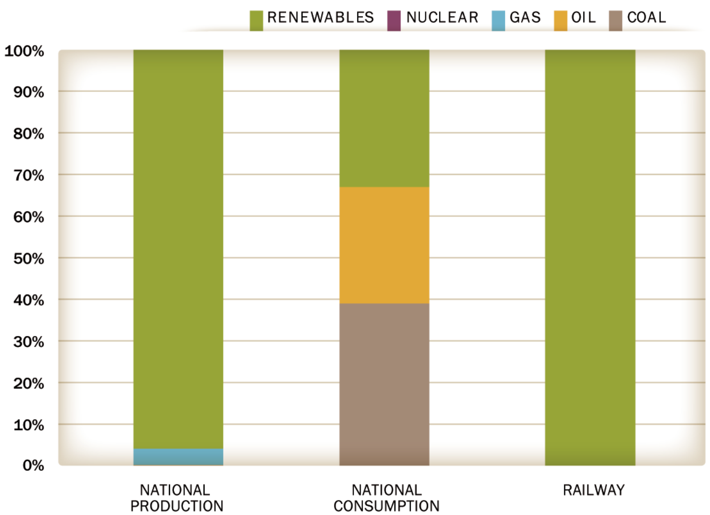
Production/Consumption/Railway electricity mix in selected countries

Norway

Table 9: **National production, national consumption and railway electricity mix in Norway**

	Year	Coal	Oil	Gas	Nuclear	Renewables
NATIONAL PRODUCTION	2010	0.1%	0.0%	3.9%	0.0%	96.0%
NATIONAL CONSUMPTION	2010	39.0%	28.0%	0.0%	0.0%	33.0%
RAILWAY	2010	0.0%	0.0%	0.0%	0.0%	100.0%

Fig. 127: **National production, national consumption and railway electricity mix in Norway**



Source: IEA (2012b), UIC (2012b) and UIC (2013b)

While Norway is a producer of renewable electricity (almost 100% from hydroelectricity), most of the electricity is being sold (through Renewable Energy Certificates – RECs – or Guarantees of Origin – GOs) to other countries. Therefore the remaining national consumption mix is much less "green", with only 33% of renewable energy.

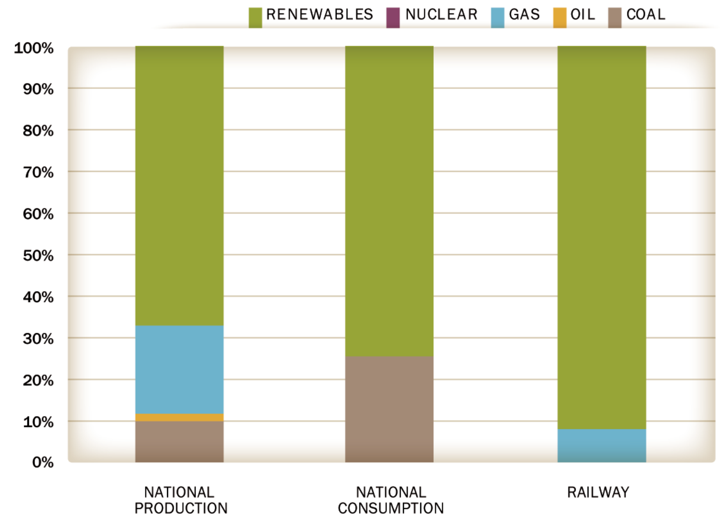
The Norwegian railways (NSB) compensate for that by buying RECs and GOs, in order to make the mix 100% renewable for the electricity that they use.

Austria

Table 10: **National production, national consumption and railway electricity mix in Austria**

	Year	Coal	Oil	Gas	Nuclear	Renewables
NATIONAL PRODUCTION	2010	9.9%	1.9%	21.1%	0.0%	67.1%
NATIONAL CONSUPMTION	2012	25.5%	0.0%	0.0%	0.0%	74.5%
RAILWAY	2012	0.0%	0.0%	8.0%	0.0%	92.0%

Fig. 128: **National production, national consumption and railway electricity mix in Austria**



Source: IEA (2012b), UIC (2012b) and UIC (2013b)

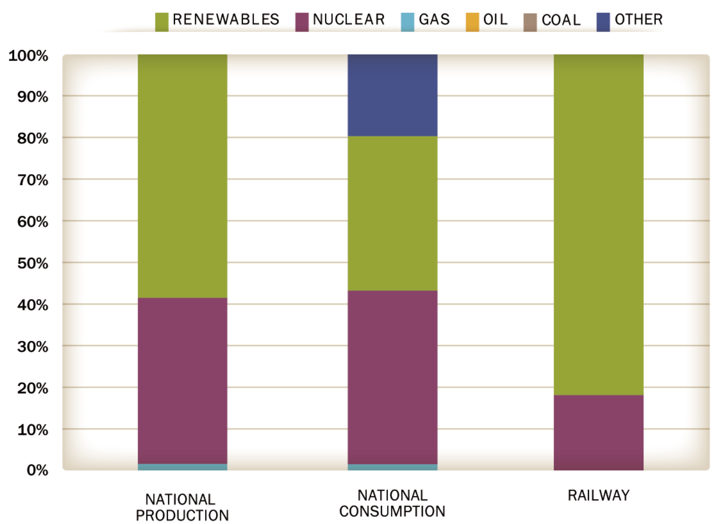
ÖBB, the main Austrian railway company, operates 8 hydroelectric plants to produce electricity for the railways. On top of that, ÖBB buys green certificates to make its mix 92% from renewable energy sources.

Switzerland

Table 11: **National production, national consumption and railway electricity mix in Switzerland**

	Year	Coal	Oil	Gas	Nuclear	Renewables	Other*
NATIONAL PRODUCTION	2010	0.0%	0.1%	1.6%	39.9%	58.4%	0.0%
NATIONAL CONSUMPTION	2009	0.1%	0.1%	1.5%	41.7%	37.1%	19.5%
RAILWAY	2010	0.0%	0.0%	0.0%	18.1%	81.9%	0.0%

Fig. 129: **National production, national consumption and railway electricity mix in Switzerland**



Source: IEA (2012b), UIC (2012b) and UIC (2013b)

* Other: partly from waste sources, partly not declared.

The difference between production and consumption mix is due to some hydroelectric power being exported.

The railway electricity mix of SBB is different from the national mix: in 2012 around 80% of the electricity came from hydroelectric power produced in SBB's hydroelectric power stations or in partner stations. To cover the residual demand for power (20%), SBB uses nuclear energy. Most electricity is produced in own power plants (hydro) or where SBB is a shareholder (nuclear). Production is generated at 16.7 Hz or transformed by the use of frequency converters and fed into the railway grid. The electricity mix is declared according to the regulation in Switzerland, as every other electricity provider does. Every railway company driving on SBB infrastructure network is supplied with the same mix.

No green certificates or RECs are being used.

SPAIN: Decarbonisation strategy

In 2012, Adif, the infrastructure manager for Spanish railways, signed a contract for electricity supply with Acciona Green Energy, a company certified as a renewable producer by the National Council of Energy. This contract includes the supply of 71% of the total electricity consumption for traction of Renfe, in terms of total energy consumption (electricity and diesel). The supply assumes 53% of energy consumption for traction use. The contract has been renewed for 2013 with 100% renewable energy including an increment of the share of Acciona Green Energy up to 94%, and 6% coming from Enérgya VM Gestión (a company also certified as green energy provider).*

The Spanish National Railways, RENFE, elaborated a target strategy in 2008 aiming for 2020 to reach a level of CO_2 emissions of 20 grams per transport unit. This target was made according to operative plans of the company and it was sent to UIC and CER (the Community of European Railways) for the signature of CER Commitment to reduce Carbon Intensity of European Railways for 2020.

* The main data of the 2012 contract can be found in the following press release:
http://www.acciona.es/noticias/adif-y-acciona-impulsan-la-utilizacion-de-energias-renovables-en-las-redes-ferroviarias-espanolas.

DIRECT RAILWAY INITIATIVES
for the greenification of energy supply: the case of Infrabel's "Green Tunnel" in Belgium

In 2011, Infrabel, the Belgian infrastructure manager, started the operation of 16 000 photovoltaic panels on top of a 3.4 km long high-speed rail tunnel, primarily designed for the protection of wildlife in a forest area and to reduce noise from the rail and highway.

The panels are installed over a 50 000 m² surface; the total installed power is nearly 4 MW and each year 3.3 GWh of electricity is generated. The energy is used to power both fixed infrastructure (e.g. railway stations, lighting, heating and signaling) and the traction of trains.

GREENING OF NATIONAL MIX:
the case of Italy

In Italy, railways use electricity provided by the grid: therefore their mix in 2012 was in fact identical to the national consumption mix, which was similar to the national production mix. No RECs or green certificates are being used. The national initiatives aimed to improve the share of renewables in the electricity mix have thus an effect on the better environmental performance of railway electric traction.

The installed power of renewable energy in Italy has grown significantly, particularly in recent years and for photovoltaic installations. This has led to an increase in the portion of renewables in the electricity production, and therefore to a decrease of the specific emissions of electric production.

Fig. 130: **Italy: Gross installed power (MW), 1996-2012 (left) and national electricity production (GWh), 1990-2012 (right)**

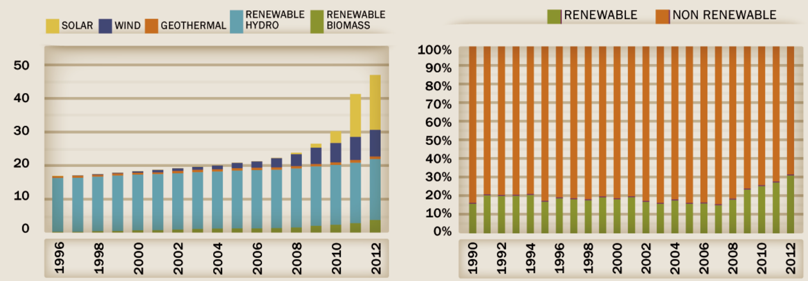
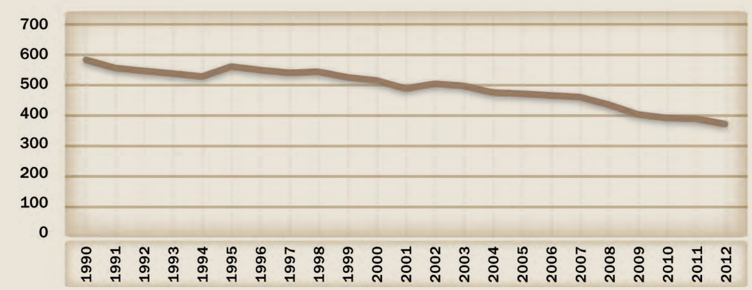


Fig. 131: **Specific emissions of electricity production in Italy (gCO2/kWh)**

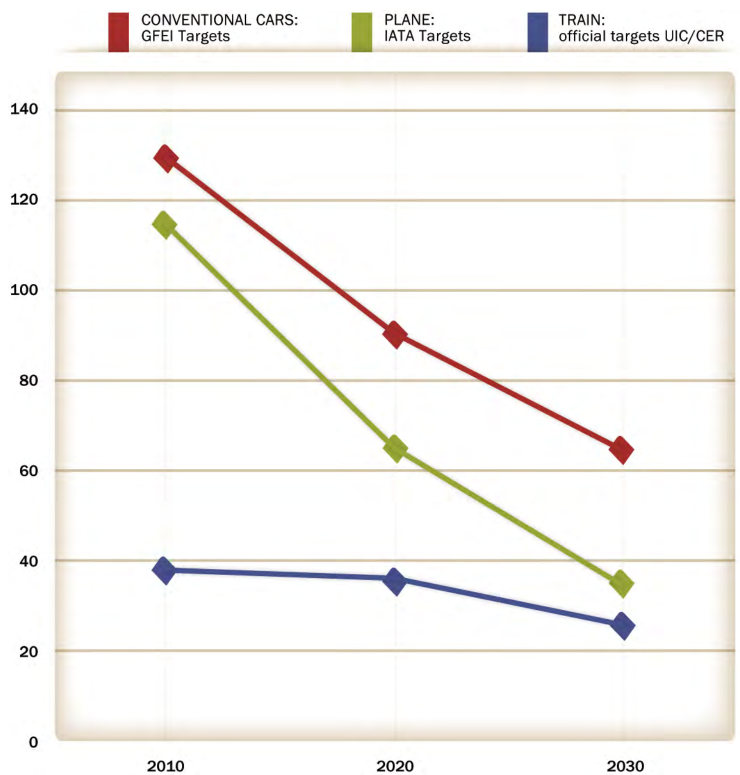


Source: Susdef elaborations based on ISPRA (2013) and Terna (2013)

Inter - modal comparison of specific emissions: baseline 2010 and sectoral targets

The graph shows a comparison between the targets for CO_2 specific emissions in 2020 and 2030 of the railway sector (UIC/CER), of the airline sector (IATA) and of the Global Fuel Economy Initiative (GFEI) for conventional cars.

Fig. 132: **Targets for specific emissions in 2020 and 2030 of railways, planes and conventional cars (gCO_2/pkm)**



Methodology used:

__UIC/CER targets:__ The 2010 value has been calculated in UIC (2012b), by using a weighted average of values collected from UIC members. The targets for 2020 and 2030 have been officially declared by UIC and CER in UIC/CER (2010): a reduction of specific emissions of 30% by 2020 and of 50% by 2030 compared to base year 1990.

__IATA targets:__ The targets for total emissions have been officially published by IATA, declaring a 50% reduction in total emissions by 2050 (IATA, 2009). The ensuing projection of total emissions has been divided by the projected 4.6% annual increase rate of pkm as expected by ICAO (2013).

__Conventional car:__ The targets have been published in GFEI (2009) and elaborated by IEA to be integrated in this graph.

It is important to note that the evolution of the REC and GO markets has not been taken into account by UIC/CER targets: these drivers may affect considerably the CO_2 values of the railway sector in the future.

Methodology Notes

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, though not 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 "CO_2 Emissions from fuel combustion by sector" figures presented in this publication (fig. 1, 29, 41, 51, 64, 74, 85, 95 and 108) 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).

Railway specific energy consumption, as shown in figures 18, 19, 47, 60, 70, 81, 91, 104 and 113, 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) allow 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.

As for China (fig. 104) there was no data concerning train-km before 1980, there was no way to allocate pkm and tkm by fuel type, so railway specific energy is drawn only from 1980.

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.).

GO
Guarantees of Origin

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)

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

REC
Renewable Energy Certificate

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

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